Dairy Australia

Australian Dairy Ingredient Reference Manual

Third edition

Thrive with Australian Dairy

Contents

Foreword

The Dairy Australia trade team is pleased to publish an updated version of the Australian Dairy Ingredient Reference Manual, a technical guide to using Australian dairy ingredients in the key Australian export markets. First published by Dairy Australia in 2005, this manual is now in its third iteration, thanks to demand from key customers in our major export destinations.

The Australian dairy industry offers premium, value added and tailored dairy products to meet the needs and demands from over one hundred countries around the world. The industry also continues to invest proactively in sustainability and innovation underpinning the dynamic and ongoing development of the industry.

Accordingly, this edition has been updated with new chapters on sustainability, frozen cream and frozen milk, along with updated material on raw milk quality control, food safety systems in Australia, applications of milk powders and cheese in food service and bakery sectors, world trends of dairy products and processing technologies and milk fat products. All the chapters have been compiled by technical dairy experts in Australia.

We hope that the information builds understanding of the quality, unique attributes, and applications of Australian dairy products. Dairy Australia encourages the Manual users to maintain discussions with their Australian ingredient suppliers on the best use of Australian dairy ingredients. Dairy Australia would also like to thank the Australian dairy industry for their support, review and inputs to the Manual. The Manual is also available in soft copy.

We look forward to receiving your comments and suggestions on the Reference Manual.

Please email any feedback to Sarah Xu, International Market Manager at sarah.xu@dairyaustralia.com.au.

We hope the Manual assists with your understanding of Australia dairy products and manufacturing processes and contributes to the building of your trust and understanding of the Australian dairy industry. Our desire is that we supply the highest quality products to suit your customer needs, and in doing so that we continue to Thrive Together.

02 Sustainability in the Australian Dairy Industry

Sustainability is defined by the United Nations as 'meeting the needs of the present without compromising the ability of future generations to meet their own needs'.[1] The Australian dairy industry has been working for many years to be more sustainable so that we can continue to uphold our promise – to provide nutritious food for a healthier world.

Australia is a trusted, agile and reliable supplier of high quality, safe and nutritious dairy products. To ensure Australia maintains this global standing, the industry works together to proactively address risks to sustainability. The Australian Dairy Sustainability Framework (the Sustainability Framework) was set up by Dairy Australia and industry partners to guide sustainable dairy production in Australia.

Our Sustainability Framework is underpinned by four commitments:

- Enhancing economic viability and livelihoods
- Improving the wellbeing of people
- Providing best care for all our animals
- Reducing environmental impact.

The Framework seeks to consider all issues across the Australian dairy industry that have the potential to affect the sustainability of our industry. The Framework is used to measure and publicly report progress to be more sustainable.

We have set goals and targets to 2030 to help us meet our sustainability commitments. These confirm our industry's commitment to continue to make changes for the better for sustainability.

Since its launch in 2012, we have reviewed our sustainability goals, targets and measures, to respond to a changing world.

Our whole-of-industry Framework is aligned with the United Nations Sustainable Development Goals. Membership of the global Dairy Sustainability Framework and of the Sustainability Agriculture Initiative (SAI) Platform's dairy working group also influences our Framework.

Overview of the Australian Dairy sustainability framework

Commitment 1
Enhancing economic viability and livelihoods

Creating a vibrant industry that rewards dairy workers and their families, dairying communities, businesses and investors.

Goal 1 – Increase the competitiveness and profitability of the Australian dairy industry

Goal 2 – Increase the resilience and prosperity of dairy communities

Goal 3 – Provide a safe work environment for all dairy workers

Goal 4 – Provide a productive and rewarding work environment for all dairy workers

Commitment 2
Improving the wellbeing of people

Providing nutritious, safe, and quality dairy food.

Goal 5 – All dairy products and ingredients sold are safe

Goal 6 – Dairy contributes to improved health outcomes for all Australians

Commitment 3
Providing best care for all our animals

Striving for health, welfare and best care for all our animals throughout their lives.

Goal 7 – Provide best care for all animals for whole of life

Commitment 4
Reducing environmental impact

Meeting the challenge of climate change and provide good stewardship of our natural resources.

Goal 8 – Improve land management

Goal 9 – Increase water use efficiency

Goal 10 – Reduce greenhouse gas emissions intensity

Goal 11 – Reduce waste.

1 United Nations. Sustainability. Available: https://www.un.org/en/academic-impact/sustainability

2.1 Internationally recognised Sustainability Framework

The Framework was informed by an extensive study that analysed the most pressing industry issues (i.e. a materiality review) as well as national consultation. This consultation involved dairy farmers and manufacturers, as well as stakeholders including government, retailers, customers, non-governmental organisations and interest groups.

This whole-of-value-chain and industry-led approach was a world-first in agriculture. Our Sustainability Framework has been recognised by global dairy customers and organisations. In 2013, Unilever recognised Australian milk production as 100% sustainable, based on meeting its Sustainable Sourcing Code and our Sustainability Framework. The Framework has received a Banksia Sustainability Award and a United Nations Australia Association award.

Robust governance

Reflecting the whole-of-value-chain approach, the Australian Dairy Industry Council, the peak national representative body of the Australian dairy industry, has overall responsibility for the Sustainability Framework. It sets its goals, targets and performance measures, and reports progress against these.

The Sustainability Framework's Steering Committee is responsible for developing and implementing the Framework. It meets quarterly and includes representatives from farmer organisations, dairy companies and Dairy Australia (i.e. the industry-owned national service body). The Steering Committee seeks endorsement from the Australian Dairy Industry Council on any major recommendations.

Dairy Australia provides support to implement the Framework.

The Consultative Forum, which includes industry and non-industry stakeholders, provides feedback on progress and facilitates two-way discussion on emerging issues both nationally and internationally.

Figure 1 Governance model for the Australian Dairy Sustainability Framework

2.2 Enhancing economic viability and livelihoods

Commitment 1
Enhancing economic viability and livelihoods

Creating a vibrant industry that rewards dairy workers and their families, dairying communities, businesses and investors.

Goal 1 – Increase the competitiveness and profitability of the Australian dairy industry

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Goal 4 – Provide a productive and rewarding work environment for all dairy workers

Australian dairy farmers and manufacturers are passionate about the industry and about providing safe, nutritious food. Efforts to shore up economic resilience and business continuity are important to ensure the Australian dairy industry is viable for the long-term and can continue supplying nutritious food to domestic and international markets.

Most Australian dairy cows graze on farms and paddocks outdoors all year round, converting good quality grass and supplementary feeds into high-quality milk. Australia has strict regulations and quality assurance programs in place to uphold its enviable reputation of supplying premium, high-quality, safe and nutritious dairy products.

The dairy industry is the third largest rural industry in Australia and is a key sector of the agricultural economy. Dairy generated $4.7 billion in farmgate value in the Australian financial year of 1 July 2019 to 30 June 2020. It is estimated approximately 37,400 people were directly employed on dairy farms and by dairy processing companies in 2020-21.

Dairy processors also made a significant contribution. According to the ***Economic and Broader Contribution of the Australian Dairy Processing Industry*** report by Deloitte Access Economics and commissioned by Australian Dairy Products Federation (ADPF) Innovation is a core aspect of dairy processing and is a fundamental pillar that supports competitiveness in domestic and export markets. Between 2017-18 and 2019-20 dairy processors invested around $36 million in research and development. These activities include developing new products, adapting existing products and adapting manufacturing activities.

Beyond its financial contribution, dairy is a pillar of the communities in which we operate. Dairy businesses create employment, services and community engagement, which in turn leads to vibrant and resilient communities.

Demonstrating how our industry's other strategic documents align with our Sustainability Framework, the ***Australian Dairy Plan***, launched in 2020, is designed to make substantial, measurable impacts on profit, business confidence and industry unity. It identifies a set of commitments aligned with our *Sustainability Framework*'s commitment to economic resilience, including:

- attracting and supporting new people and investment to build our industry
- increasing our effort in marketing and promotion to build greater levels of trust and improve the value of dairy
- intensifying the focus on farm business skills to improve profitability and better manage risk.

The ***Dairy Australia Strategic Plan 2020–25*** includes priorities to guide investment, improve profitability, strengthen sustainability, and attract and develop workers.

Stakeholders' interest in the impact of the dairy industry on human rights in the value chain remains high, and all companies with revenue greater than $100 million, including dairy companies, are required by Australian law to report on their actions to assess and address modern slavery risks in their supply chains.

Industry actions

Our industry has many actions underway to enhance economic resilience and business continuity. For example, investments to shape future success in farm performance have led to a range of innovations in critical areas such as feed base, water use, development of people, genetics and business capability. An outline of some of the highlights include:

Business skills fast tracked

Launched in 2020, *Our Farm, Our Plan* is a flagship learning program to support the rapid increase of farmers' business skills. It helps farmers to identify long-term goals, improve business performance and manage volatility. It provides one-on-one support for farmers over two years to assist them to develop their plan and put it into action. It was developed by Dairy Australia, with support from the Gardiner Dairy Foundation and DairyNZ. There continues to be a strong focus on rollout in 2022.

Other initiatives to create clear career pathways in dairy include the *Pathway for People in Dairy* program, which connects thousands of jobseekers to career resources and supports farmers to upskill new workers and to create safe, and supportive workplaces.

The industry created new avenues to dairy farm asset ownership by launching the *Dairy Farm Managers* program. Over the next five years the project is expected to support 160 people to progress their career in the dairy industry towards farm management.

Finding profit opportunities

DairyBase is an online tool enabling dairy farmers and their advisors to measure and compare farm business performance over time. Farmers can also use it to forward-budget for the coming season. By combining existing data with estimated milk price and input costs, farmers can build a more accurate picture of where opportunities for profit might be found. Running since 2015, *DairyBase* now has 2,500 users.

Monitoring performance

The *Dairy Farm Monitor Project* provides a comprehensive physical and financial analysis of 250 dairy farms across Australia. Key stakeholders across the industry including Dairy Australia and government bodies use the data to make informed decisions.

The data collected through the *Dairy Farm Monitor Project* provides high-quality comparative data in *DairyBase.* All dairy farmers can access this data through *DairyBase* to measure and compare their own farm business performance and identify areas for improvement.

Sustainable pasture-based systems

DairyFeedbase, launched in 2018, uses the latest technology and science to significantly improve on-farm profitability. The project has the potential to see returns to the industry of $100 million a year in 10 years. The project is developing easy-to-use digital tools that will provide farmers with real-time information to improve decision-making on the farm and help them strategically allocate feed. *DairyFeedbase* is a joint venture between Dairy Australia, Gardiner Dairy Foundation and Agriculture Victoria.

Tasmanian Institute of Agriculture and Dairy Australia are delivering a five-year $6.5 million program focusing on feed base research to help dairy farmers maintain efficient, profitable and sustainable pasture-based dairy systems in the future. To maximise the results of the research, mini farms will be established in Tasmania to test research theories under real farm conditions. The program, known as 'HIGH-2' for high integrity grass-fed herds, has an ambitious target to help dairy farmers grow the same amount of dry forage matter from irrigated pasture, and produce the same amount of milk solids per hectare, but halve the amount of nitrogen fertiliser.

Breeding profitable cows

DataGene is an independent and industry-owned organisation that is responsible for developing modern tools and resources to drive genetic gain and herd improvement in the Australian dairy industry, through research, development and extension activities. Formed in July 2016, DataGene brings together many 'non-competitive' herd improvement functions under the one umbrella, including genetics, herd testing, herd recording, data systems and herd test standards. DataGene aims to enable farmers and industry to maximise profit through data-driven decisions.

Thanks to DataGene, our industry has a modern genetic evaluation system, a Centralised Data Repository (CDR) that is refreshed daily, and *DataVat*, a user-friendly platform for delivering individualised results, tools and services. Recent developments include updating the Balanced Performance Index, which ranks cows according to their genetic merit for important traits that impact a farmer's costs and productivity.

Genomic testing of dairy cows and heifers doubled in Australia in 2020-21 compared to 2019-20 as farmers look to fast-track herd genetic gain and productivity.

Almost 50,000 dairy females were tested during 2020-21, a result of faster turnaround times for genomic data, favourable industry conditions and a Dairy Australia/DataGene genomic testing campaign.

Another highlight of the year was the co-development with herd test centres of a new service, *HerdPlatform*, that allows dairy farmers to interact with their data online and gain new insights into their business.

DairyBio extended

The Victorian Government invested $55 million for the second phase of *DairyBio,* the partnership to harness bioscience to address many of the issues facing dairy farmers.

The partnership with Dairy Australia and the Gardiner Dairy Foundation will support scientific research focused on genetic improvements to animals and forage species.

The long-term vision is to provide farmers with the tools and information they need to breed and feed cows that produce more milk, healthier calves and less methane under a changing climate.

Many technologies and products from *DairyBio* are already available and delivering significant value to farmers today.

Case study: Manufacturers support programs

Australia exports about a third of its milk production, and large proportion of exports are in the form of value-added products such as cheese, butter, ultra-heat treated milk and milk powders.

Innovation is important for the Australian dairy industry to remain competitive internationally, and to provide great products to customers, both domestic and overseas.

Dairy Australia's Technology Assessment (DATA) Scheme supports Australian dairy processors to determine the feasibility of new technologies or practices that show potential to significantly improve the industry's economic or environmental performance.

Co-funded by Food Innovation Australia Limited (FIAL) and administered by Dairy Australia, the DATA Scheme is designed to de-risk investment decisions and accelerate the uptake of innovative technologies.

A recent DATA project assessed energy supply options for dairy manufacturing sites to help manufacturers deal with rising energy costs. The project focused on the energy delivery options available to **Union Dairy Company's** (UDC) milk powder production site at Penola, South Australia. The project provided a framework for prioritising energy supply options. It found that generally a diverse mix of energy supply options that balance cost reduction, flexibility and longer-term price assurance could help manufacturers.

Another DATA project developed a detailed feasibility assessment for the use of anaerobic digestion (AD) as a process for both treating and deriving value from the whey and trade waste produced by a dairy manufacturer in the southern state of Victoria. The project found the business case for both the manufacturer-owned and third-party owned anaerobic digestion scenarios were extremely positive.

The volumes of whey and trade waste generated on site would allow enough biogas to be produced to offset the site's grid-supplied heat and power requirements.

2.3 Improving the wellbeing of people

Commitment 2
Improving the wellbeing of people

Providing nutritious, safe, and good quality dairy food.

Goal 5 – All dairy products and ingredients sold are safe

Goal 6 – Dairy contributes to improved health outcomes for all Australians

Dairy foods provide a unique package of more than 10 essential nutrients that are important for healthy bones, nervous and immune systems, eyesight, muscle function, healthy skin, energy levels, and growth and repair in all parts of the body.

Scientific evidence shows that consuming milk, cheese and yoghurt is linked to a reduced risk of heart disease, stroke, high blood pressure and type 2 diabetes, and is not linked to an increase in weight or risk of obesity.

Scientists and nutritionists are increasingly recognising that the effects of dairy foods go beyond the benefits of the individual nutrients they contain. The whole dairy food is greater than the sum of its parts and the unique 'dairy matrix' is responsible for its many health benefits.

Despite this, there is increasing scrutiny on the role of animal-based proteins, including dairy, in a sustainable diet. At the same time, the demand for plant-based food and beverages, such as soy and almond, is increasing.

Milk, cheese and yoghurt continue to be recognised in the official Australian Dietary Guidelines as part of a healthy diet. The Australian dairy industry continues to provide evidence to support this recognition including when the Australian Dietary Guidelines are being reviewed.

The industry also educates consumers about the benefits of dairy.

Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) published research in the ***European Journal of Nutrition*** in 2021 that shows a healthy balanced diet should include dairy foods such as milk and yoghurt; and that this diet has lower greenhouse gas (GHG) emissions compared to other less healthy options.

Researchers examined a subset of 1,732 Australian adult diets that had higher diet quality scores and lower GHG emissions. These diets are of interest because they show habits that could realistically be adopted by more Australians. The research found that 90% of these healthier and lower GHG emission diets included dairy foods, particularly milk, then cheese and yoghurt. What set these diets apart was the consumption of much less discretionary foods, including sweets, fast foods and soft drinks. The dairy industry is working to ensure dairy is seen as part of a healthy, sustainable diet.

For people to access dairy's nutritional benefits, dairy foods must be safe to consume. In Australia strict systems operate across the entire dairy supply chain to ensure that Australian dairy products meet stringent food safety requirements. Further information is available about how the Australian dairy industry's whole-of-chain food safety approach in the ***Dairy food safety: The Australian approach*** booklet.

Industry actions

Thrive together

As the world's fourth biggest dairy exporter, Australia is known for its high-quality, safe and nutritious products. Australia's diverse range of dairy farms and processors of all sizes allows us to deliver world class dairy products for our valued customers.

The milk produced in Australia supplies not only the domestic Australian market but is also processed into high quality products that are offered to key international markets.

Our mission is to foster a positive culture where everyone prospers from our farmers to our valued customers around the world, because with Australian dairy, everyone thrives together.

Dairy Australia builds strong relationships in our key markets, working together to overcome regulatory and policy issues to maintain and grow export markets.

Dairy Australia provides technical support for industry and government in policy negotiations that aim to improve Australia's access to key markets. The International Market Development program aims to develop a preference for Australian dairy by reinforcing its position as a trusted, agile and reliable supplier of high quality dairy products.

Access to markets is supported by the ***Dairy Export Assurance Program***, which aims to make it easier for Australian dairy manufacturers to export dairy products by reducing regulatory burden and streamlining audit arrangements, while maintaining the high quality for which Australian dairy is known. The program is a partnership between the Australian Government, state regulatory agencies and the dairy industry.

The industry also has campaigns to domestic Australian audiences including the ***Dairy Matters*** program.

Health resources hub

A wide selection of health fact sheets and healthy recipes featuring dairy has been collected on the **Dairy Product Health Resources** website, to make it easy for consumers and health professionals to find the information they need.

Topics covered include dietary guidelines and nutrients, health benefits (including bone and cardiovascular health), and intolerances and allergies. Information is also provided for different life stages and levels of activity.

Australian Milk Quality Awards

The Australian Milk Quality Awards recognise farms across Australia with the highest quality milk. This is defined by farms having an annual average bulk milk cell count (BMCC) in the lowest 5% of those recorded during the previous calendar year. To be eligible, dairy farms must have BMCC data supplied by their processor for a minimum of nine months. Monthly averages are then used to calculate the annual average BMCC for each farm and the winners are the top 5% of farms with the lowest BMCC.

Encouraging food safety culture

Australia's different states and territories have authorities that regulate their local dairy industry to safeguard public health. The relevant authority in Victoria has developed a new approach to food safety, which is providing consumers with greater assurance of the safety of their food.

The new approach, called ***Dairy RegTech***, focuses on improving food safety culture, recognising that it leads to better food safety outcomes. It does this by measuring behaviours related to food safety within a business and identifies areas to strengthen the food safety culture.

Dairy RegTech uses digital technology to streamline regular reporting and communication between the business and the state regulatory authority. This data helps the business and state regulatory authority work together to determine how best to improve food safety performance.

Dairy compared to plant based alternatives

Plant based beverages have experienced a slow but continuous growth in popularity in the past decade.

These products are marketed as dairy alternatives and when sufficiently fortified with calcium, are included alongside dairy foods in one of the five food groups recommended in the *Australian Dietary Guidelines*.

Compared to milk, plant based beverages contain a different package of vitamins and minerals, which are often added into the product through fortification. Only soy protein contains all the essential amino acids like animal protein, but not in the same amounts as milk. Milk contains nutrients in their natural and most bioavailable form.

Plant based beverages often have little in common with the plants they are derived from. They also cost more on a per litre basis for less nutrition and can vary widely in nutrient composition. Read more **here**.

The Australian Government held an inquiry in 2021 into food labelling laws including the use of animal protein terminology used by plant based alternatives. Individuals, businesses and representative groups were invited to make submissions to be considered by the government.

The Australian Dairy Industry Council made a submission to the inquiry. The submission argued plant based alternatives, such as “soy milk”, misuse dairy terminology and images in their marketing and labelling. Consumers can be confused by this terminology and think products either contain dairy or have equivalent nutritional value which is definitely not the case. In early 2022, the politicians involved in the inquiry released a report that recommended plant based proteins no longer be allowed to use animal descriptors like milk, cheese and meat terminologies.

Case study: Dairy reduces fractures in aged-care residents

Adding dairy foods into the daily diet of aged-care residents can reduce fractures and falls, according to a study published in the ***British Medical Journal***.

The study involved a two-year trial, led by the University of Melbourne and Austin Health, with 7,195 residents from 60 aged-care facilities in the southern Australian state of Victoria. It was the first study to test the impact of providing additional calcium and protein through dairy foods on the risk of fractures and falls in older adults.

Around one-third of all hip fractures occur in aged-care residents and around two-thirds of those in aged-care are malnourished or at risk of malnutrition.

While intake of dairy foods in this population is typically less than half the amount recommended in the *Australian Dietary Guidelines*, previous clinical trials have taken a pharmacological approach where residents had their diet supplemented with vitamin D or calcium tablets to reduce bone loss.

Principal investigator Dr Sandra Iuliano from the University of Melbourne and Austin Health added dairy foods that are naturally high in calcium and protein to the regular diets of aged-care residents.

They found this simple intervention – where dairy food intake increased from approximately two serves per day to 3.5 serves per day – led to a significant reduction in fractures and falls.

"Our cluster randomised controlled trial showed muscles of the arms and legs were maintained and falls reduced in the residents given the additional dairy foods. This is an achievable goal in any aged-care setting as these foods are widely available, palatable, low cost and can be incorporated into the daily menu," Dr Iuliano said.

The study found a 33% reduction in all fractures, a 46% reduction in hip fractures and an 11% reduction in falls, with a significant reduction apparent between three and five months after the trial began.

Dr Iuliano hopes the outcomes from the trial will be used to improve policy and good clinical practice across the aged-care sector.

The research was supported by grants from nine global dairy organisations and three philanthropic organisations, including Dairy Australia.

2.4 Providing best care for all our animals

Commitment 3
Providing best care for all our animals

Striving for health, welfare and best care for all our animals throughout their lives.

Goal 7 – Provide best care for all animals for whole life

The health and wellbeing of their animals is a top priority for the people who care for dairy cows. Providing best care for animals is fundamental to the success of every dairy business – and it is the right thing to do.

The industry is committed to adhering to the *Australian Animal Welfare Standards and Guidelines for Cattle and the Australian Animal Welfare Standards* and *Guidelines for the Land Transport of Livestock*.

The national advocacy body representing dairy farmers, Australian Dairy Farmers, has a dedicated Animal Welfare Policy Advisory Group, and a number of industry policies, also supported by dairy companies, to manage the welfare of dairy cows. Agreed whole-of-industry policies include no tail docking, providing pain relief for disbudding horns, and promoting positive stock handling practices. Industry also agreed to phase out the routine use of calving induction and this policy came into effect on 1 January 2022.

Preventative health is fundamental to the care of dairy cows. This includes installing cooling infrastructure on farms, developing strategies for lameness, animal nutrition and fertility.

Industry performance on animal care is monitored through the three yearly *Genetics and Animal Husbandry Survey*. The survey has been regularly conducted since 2005 to track on-farm practices and to provide insights into decision making on animal health, welfare, fertility and genetics over time.

Industry actions

Phasing out routine calving induction

'Routine calving induction' is a practice that was used by a minority of seasonally calving dairy farms to tighten the timeframe for calving. Animal welfare consequences include poor calf viability and increase post-parturient disease. The Australian dairy industry does not support routine calving induction and agreed in 2015 to phase it out by 1 January 2022. Industry met this deadline, with veterinary clinics no longer offering the service from 2022 onwards. Exemptions to the policy can be obtained for cows to be induced to calve for therapeutic reasons.

Promoting best practice in antibiotic stewardship

Antibiotics are a critically important tool for dairy farmers to ensure the health and welfare of their animals; however, care must be taken to use them responsibly. The dairy industry has adopted the principle of as little antibiotics as possible, as much as necessary for good animal health, and under veterinary direction. This reduces the risk of antibiotic resistance.

Dairy Australia delivers antimicrobial stewardship communications targeting farmers and veterinary doctors. They emphasise that everybody has a role to play in improving antibiotic use on farm.

To obtain information on the type and amount of antibiotics being prescribed for use by dairy farmers, Dairy Australia commissioned a review of veterinary sales during financial year 2016-17 and again for calendar year 2019. The same veterinary practices were contacted in both reviews. The figures obtained in the review were of the amount of veterinary antibiotics sold, and not directly related to dose rate. However, the results indicate the types of antibiotics being used. The 2019 review indicated that the situation had not changed markedly since 2016-17. All antibiotics used in the dairy industry must be provided via a prescription from a registered veterinarian.

The Australian Pesticide and Veterinary Medicines Authority (APVMA) regulates agricultural and veterinary chemical products in Australia, including antibiotics. It assesses and registers these chemicals as well as monitors and enforces compliance with best practice usage.

Better treatment of mastitis through new tech tool

DataGene is currently developing a tool to assist those farmers who are herd testing to generate cow lists for Selective Dry Cow therapy that will be available through *DataVat*. The tool will enable farmers to detect mastitis more easily and use antibiotics selectively to target individual cow needs rather than blanket herd treatments at dry off.

Case study: Animal health a priority in national herd improvement

The Australian dairy industry aims to continually improve the genomic data it makes available to farmers to help inform their breeding programs.

In late 2020, the industry-owned genetic gain and herd improvement organisation DataGene updated the *Australian Breeding Values* to have more emphasis on health. The increased emphasis on health ensures animals that are strong for health traits rise in both the *Balanced Performance Index* (BPI) and *Health Weighted Index* (HWI) values and rank.

The updated breeding indices follow a six month review, including an industry survey, a scientific review, and analysis of farmgate and commodity values for fat, protein, feed and labour.

Farmers who spoke in support of the updates include Janet Auchterlonie, who farms in the Gippsland region of Victoria. She said:

"As a seasonal farmer, improving my herd's health and fertility has increased the milk solids per cow. A focus on breeding for these traits has extended my cow's days in milk because they calve earlier. Knowing they will get back in calf every year, the herd has more days in milk over a lifetime. Cow efficiency underlines my business profitability. The new HWI is designed for a seasonal calving herd like mine. An index with a strong weighting towards health and fertility will help future proof my bottom line."

Tim Humphris, who farms in southwest Victoria, said:

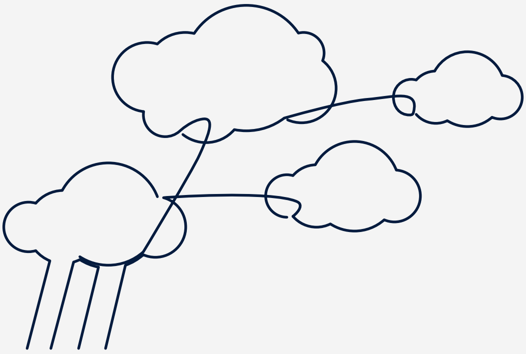
"The HWI is more positively weighted towards fertility, survivability, and mastitis resistance. From my perspective, if you are operating a pasture based seasonal calving herd, the HWI has a lot to offer."

Simone Jolliffe, who farms in Wagga Wagga, NSW, and is a former DataGene board member said:

"The indices are a breeding tool designed to help farmers and breeding advisors make the best business decisions. For those farmers who want to hone their breeding focus and make selections based on specific traits in combination with the BPI or HWI they have that capability. Equally, the BPI and HWI as standalone indices are suitable for those who want to simply select good bulls with ease and confidence."

Janet Auchterlonie

Source: GippsDairy via farmonline.com.au/story/7253399/getting-the-right-cows-for-the-system/



2.5 Reducing environmental impact

Commitment 4
Reducing environmental impact

Meeting the challenge of climate change and provide good stewardship of our natural resources.

Goal 8 – Improve land management

Goal 9 – Increase water use efficiency

Goal 10 – Reduce greenhouse gas emissions intensity

Goal 11 – Reduce waste

Like other agricultural industries, dairy depends on natural resources. Australian dairy is very mindful of our stewardship role and the need to look after water, biodiversity and soil, as well as reduce our waste and emissions of greenhouse gas (GHG).

Dairy farmers are at the frontline of dealing with the impact of climate change. Dairy Australia modelling indicates that there has been a loss of dairy farm business productivity since 2000 of the order of 0.6–0.9% per year as a direct result of climate change. Impacts are being felt through changing pasture growth patterns, reduced rainfall, heat impacts on milk production and an increase in extreme events like fire, flood and drought. Many are adapting their farm system and continue to thrive.

The Australian dairy industry has a target of reducing intensity of greenhouse gas emissions by 30% across the dairy industry by 2030. This is included in the *Sustainability Framework* and is supported by Dairy Australia's Climate Change Strategy.

Australian dairy manufacturers continue to work together pre-competitively on a number of projects to reduce their environmental impact through the Dairy Manufacturers Sustainability Council (DMSC).

Industry action

In a pleasing trend, data from dairy manufacturers indicates the sector is reducing water use and waste to landfill. The data also shows the sector continues to reduce emissions with a 23.5% decrease in intensity of emissions and decrease of 27% in absolute emissions since 2010-11.

More work needs to be done at farm level to measure emissions and address water security risk. A wide variety of initiatives by industry, both pre- and post-farmgate, support progress towards reducing environmental impact.

Understanding land, water and carbon trends

Every five years, Dairy Australia undertakes the *Land, Water and Carbon Survey* to collect information on dairy farmer practices to provide insights into attitudes, behaviour and practices relating to natural resource management.

In 2020, 500 interviews were conducted with farmers across all dairy regions. Key findings from this survey include:

- Farmers identified pest animals, noxious weeds and soil health as the top land management challenges
- Widespread confidence in understanding soil constraints, managing periods of extreme heat, prolonged drought and extreme weather events such as bushfires or floods
- 58% of dairy farms are irrigated, using an average 586 megalitres of water per year
- 55% of respondents have a water security or management plan
- 74% of farmers re-use water from the dairy shed, with 62% of shed water from all dairies re-used
- 8 in 10 farms have fenced off areas of specifically planted shelter belts (68%) and/or native and remnant vegetation (54%)
- Proportion of farms where all naturally occurring waterways are fenced continues to trend upwards, with 74% of farmers having some fencing in place
- Considerable rise in proportion of dairy farms with renewable energy saving devices installed, with 71% of farms with at least one device installed
- 1 in 10 respondents are aware of their farm's carbon footprint or GHG emissions
- lmost all farms (94%) have implemented practices that reduce GHGs, including tree planting, strategic Nitrogen application, improving energy efficiency and soil carbon
- Drums or containers recycled on the vast majority of farms.

Getting paid for protecting biodiversity

The Australian Government is seeking to establish a method to certify or verify farm biodiversity as part of the national Agriculture Stewardship Package. A certification scheme trial, which aims to see land managers, including dairy farmers, paid for the public benefits they generate from environmental stewardship, is underway. Dairy Australia is part of the trial. A pilot project started in 2021, with a policy statement expected to be released in 2022.

Defining best practice in environmental stewardship

The aim of the Sustainable Dairy Products project is to assess and improve environmental stewardship along the dairy supply chain. It is funded by the Australian Government through the National Landcare Program Smart Farming Partnership.

The project is currently analysing insights captured during farmer interviews and focus groups with industry stakeholders. The project will define best practice in environmental stewardship, set pathways to achieve environmental standards across the industry; and design a learning tool that advances the sustainability of dairy production. The program, now called *EnviroTracker*, was in 2022.

Food loss, waste and packaging

Several projects are underway to address food loss, waste and packaging.

The Australian dairy industry's target to recycle 100% of plastic silage wrap waste on farms by 2030 has been backed by a $965,400 grant from the Australian Government. Dairy Australia is using the grant to research and design a national product stewardship that is commercially viable, accessible to farmers and will provide a clean stream of material for recycling. In 2022, it launched a trial on farms in western Victoria.

In October 2021, the Australian Packaging Covenant Organisation launched the *Australian Dairy Sustainable Packaging Roadmap to 2025*. Developed in partnership with Dairy Australia and the Australian Dairy Products Federation[2], the roadmap provides a collective vision and framework for how to improve the sustainability of dairy packaging. As part of the endorsement process, heads of major dairy brands committed to working together to accelerate progress against Australia's 2025 National Packaging Targets.

With the support of the Circular Economy Business Innovation Centre, Dairy Australia is partnering with Stop Food Waste Australia and the Australian Dairy Products Federation, along with input from the Dairy Manufacturers Sustainability Council, to develop a *Dairy Sector Food Waste Action Plan*. The Action Plan will support the Australian dairy industry's commitment to halve food waste in Victoria and nationally by 2030.

Dairy Manufacturers Sustainability Council

Australian dairy manufacturers work together to reduce their environmental impact through the Dairy Manufacturers Sustainability Council (DMSC). The DMSC is a nationally recognised community of practice, comprised primarily of environmental and sustainability group managers from Australian dairy manufacturing companies. The DMSC has an industry wide focus that helps company members work together pre-competitively to improve environmental performance and the sustainability of their operations.

To support dairy manufacturers in efforts to reduce environmental impact, targets were established in the *Australian Dairy Sustainability Framework* to reduce water, emissions of GHG and waste.

The performance reported each year is based on the aggregated information provided by participating DMSC members. For 2019/20, data was contributed by Bega Cheese, Bulla Dairy Foods, Burra Foods, Chobani Australia, Lion Dairy & Drinks, Fonterra, Lactalis Australia, the Union Dairy Company and Saputo Dairy Australia. Together these companies represent up to 86% of the milk volume processed nationally.

Highlights include:

- a decrease of 5.7% in the consumptive water intensity of dairy companies in 2019-20 compared to the previous year
- a decrease of 3.3% in emissions of GHG emissions during 2019-20, which contributed to representing a 23.5% decrease since 2010-11 and a 10% decrease since 2015
- a 27% reduction in absolute emissions of GHG since 2010-11
- dairy companies diverted 93% of waste generated from landfill, compared to 76% in the previous year.

2 The Australian Dairy Products Federation (ADPF) is the national peak policy body representing commercial, post farm-gate members of the Australian dairy industry, including processors, traders and marketers of Australian dairy products.

Case study: WA dairy setting clear standards for effluent

The Western Australian dairy industry is serious about reducing the environmental impact of dairy farm effluent with its release of a revised *Code of Practice for Dairy Farm Effluent WA*.

First developed in 2012 by Western Dairy and the state government's Department of Water and Environmental Regulation (DWER), the Code provides clear standards for effluent management on dairy farms across WA.

The Code was extensively reviewed in 2020 by dairy farmers, milk processors, state and local government agencies, and dairy industry stakeholders. It now better aligns with government guidelines, current best management practices, and meets industry and community expectations.

Western Dairy chair and farmer Peter Evans said the Code would help farmers determine whether their existing or proposed effluent system met industry standards, while recognising site differences.

Mr Evans said farmers were already demonstrating their commitment to meeting the high standards and had invested heavily in effluent separation, storage and application technologies over the past four years.

A total of $1.97 million has been invested in new and upgraded dairy effluent systems through the project, with 31 farms covering a minimum of 50 per cent of costs.

"The Code also encourages farmers to use effluent to meet the nutrient needs of their pasture, which benefits not only the environment but their business bottom line," he said.

DWER DairyCare project coordinator Bree Brown said the ongoing partnership with industry had been critical to improving effluent management in WA.

"The updated Code provides dairy farmers with clear standards on the expectations of industry, government and the broader community. It also encourages innovation and a flexible approach for farmers to meet the standards," Mrs Brown said.

Jay Wynd holds a copy of the 'Code of Practice for Dairy Farm Effluent Management WA'.

Case study: Manufacturers reducing environmental impact

Australian dairy manufacturers are taking a variety of actions to reduce their impact on the environment, including upgrading equipment to save energy and investing in renewable energy production.

Recent examples include **Chobani** being named winner of the 2020 APCO Industry Sector award for the Food and Beverage sector, recognising their leadership in sustainable packaging. Chobani developed an internal Sustainable Packaging Roadmap that consciously considers Australia's *Sustainable Packaging Guidelines* and the *2025 National Packaging Targets*. Chobani has now applied the Australasian Recycling Label across all packaging and more than 75% of its total packaging is now recyclable through Australian kerbside systems. Chobani is also committed to reducing business-to-business packaging and is working with suppliers to establish reuse systems for bulk packaging.

Fonterra is partnering with Sea Forest to see if using a seaweed based feed supplement can reduce emissions from commercial dairy herds. The trial will use *Asparagopsis*, a seaweed grown naturally in Australia and New Zealand, as a feed supplement.

In laboratory testing led by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), this seaweed has shown the potential to reduce emissions from cows by more than 80%. The project is investigating to check if those results can be replicated when upscaled in larger dairy herds. The focus to date has been understanding the food safety risks and the impacts on farm operations and profitability.

Bega Cheese did a feasibility study to test whether it was possible to increase the recycled plastic content of milk bottles. Bega Cheese worked with technical experts Qenos and Nextek and was supported by co-funding from Food Innovation Australia Limited and Dairy Australia. Results of the study show a higher rate of recycled plastic can be incorporated but further evaluation is required.

Nextek recycling project: L to R: Andrew Baroutas (Bega Cheese), Peter Coates (Bega Cheese), Adriaan van Dijk (Bega Cheese), Shalini Singh (Bega Cheese).

Saputo, Dairy Australia, Bega Cheese and **Lactalis Australia** are supporting a project with the University of Technology Sydney and PEGRAS Technologies to develop a process that will improve label adhesive removal from dairy products. The project has developed a world first (patent pending) sensing method for testing residual glue levels on recycled High Density Polyethylene (HDPE) batches. Also under development is a mechanical separation technology to remove the labels and glue from the HDPE surface.

If successful, this will facilitate much more efficient recycling of these materials and result in production of higher grade recycled material.

Burra Foods uses ultrafiltration and reverse osmosis to separate water and biomass in the wastewater. This project has delivered major cost savings as Burra Foods halved the number of truck loads required to cart organic biomass waste to a recycling facility 140 kilometres from its factory in Gippsland, Victoria. The project has also resulted in reduced fuel based emissions and increased capacity of the wastewater treatment plant by enabling a higher rate of desludging of the fermentation vessels. In recent years, its team has been investigating opportunities to value add to the high nutrient biomass, such as using it as part of an agriculture product to improve soil.

2.6 Summary

- Australian dairy intends to be an integral part of the national and global effort to address the world's biggest sustainability challenges.
- Australian dairy promises to provide nutritious food for a healthier world. To do this, Australian dairy has made a number of sustainability commitments to dairy people, the wellbeing of the community, animals and the environment.
- The internationally recognised *Australian Dairy Sustainability Framework* is guiding sustainable dairy production, with goals and targets set for 2030, confirming the commitment to continue to make changes for the better.
- Australian dairy has a number of actions underway to achieve the sustainability goals.

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03 Raw Milk Quality Assurance in Australia

Content

3.1 Introduction

Definition of raw milk

Milk is defined in Standard 2.5.1 of the Australia New Zealand Food Standards Code as follows:

Milk means:

a the mammary secretion of milking animals, obtained from one or more milkings for consumption as liquid milk or for further processing but excludes colostrum; or

b Such a product with phytosterols, phytostanols and their esters added.

Skim milk means milk from which milkfat has been removed.

The Code also sets out the minimum requirements for the composition of cow's milk. It is stated in Standard 2.5.1 that packaged cow's milk for retail sale must:

a be milk from cows, or

b be milk from cows to which milk components have been added, or from which they have been withdrawn in order for the product to comply with the requirements of this Standard,

c be milk from cows that has the same whey protein to casein ratio as the original milk and,

d contain no less than 32g/kg of milkfat, and

e contain no less than 30g/kg of protein measured as crude protein.

Note. *The Food Standards Code is published by Food Standards Australia New Zealand and can be viewed on their website* ***http://www.foodstandards.gov.au/code.***

The official definition of milk that has been adopted in Australia differs slightly from that adopted by the Codex Alimentarius Commission (1999), which reads as follows:

'Milk is the normal mammary secretion of milking animals obtained from one or more milkings without either addition to it or extraction from it, intended for consumption as liquid milk or for further processing.'

Raw milk is defined by the Codex Alimentarius Commission (2004) as milk that has not been heated beyond 40°C, which is the upper limit of the body temperature range for a healthy cow or undergone any treatment that has an equivalent effect on the milk. The normal core body temperature of a healthy resting cow is 38.6°C, however, a cow's body temperature can range from 37.8°C to 40.0°C.

The discussion on raw milk quality for the purposes of this chapter is confined to cows' milk. It covers the period from milking of the cow and concludes with pasteurisation or an equivalent treatment of the raw milk. During this period, the raw milk is filtered, cooled, stored, agitated, pumped, and transported on one or more occasions, pasteurised but not heat treated in any other way.

Overview of hygienic milk production systems in Australia

Raw milk quality issues are discussed in this chapter from the perspective of the Australian dairy industry. Some key points about the Australian dairy industry relevant to this discussion are:

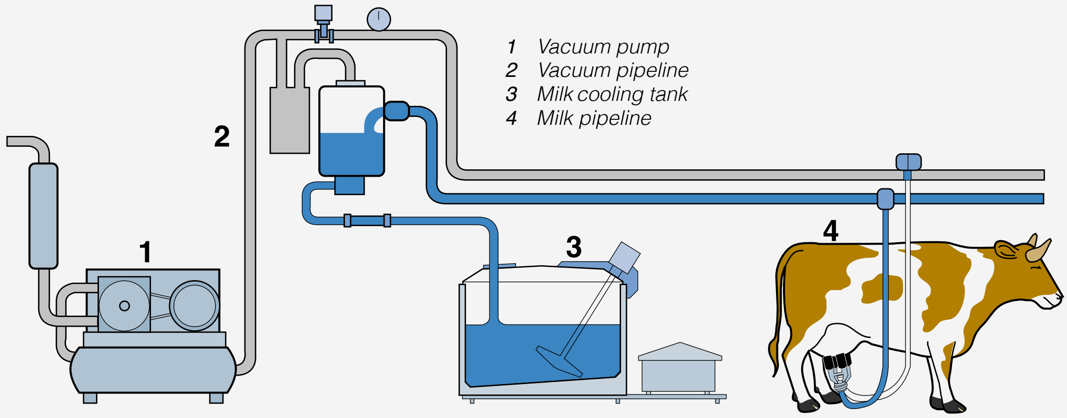
- Owner-operated farms dominate the Australian dairy industry, i.e. the owner of the farm also operates the farm, sometimes with the help of hired labour.
- The dominant breed of dairy cattle in Australia is the Holstein Friesian, which accounts for almost 80% of all dairy cattle. Other important breeds are the Jersey (10%) and cross breeds of Holstein and Jersey. Other breeds include the Illawarra or Australian Red, Guernsey, Brown Swiss, and Ayrshire.
- Australia's climate and natural resources are favourable to dairying and allow the industry to be pasture based, with approximately 60-65% of the cattle feed requirements coming from grazing. The balance of the feed intake is in the form of grains, hay and silage, which are fed to improve milk yield and composition. Seasonality is most evident in south-eastern Australia, in the state of Victoria, where milk production peaks around October and tapers off in the cooler months of May and June. However, the seasonality of milk production in Queensland, New South Wales and Western Australia is much less pronounced, due to a greater focus on drinking milk and fresh products in the product mix of these states.

On most farms, cows are machine milked twice each day in a central milking shed on the farm, widely known as a 'dairy'. The cows are herded into the milking sheds of the dairy farms from the paddocks for pasture grazing or feeding areas for milking and return to the paddocks or feeding areas as soon as they are milked. The milk is cooled to 4°C or lower, typically 2-3°C in an insulated stainless bulk milk tank or silo on the farm ready for pick up by bulk milk tanker from the factory.

Depending on the capacity of the storage tank or silo and the policy of the milk processing company, the milk is collected from the farm every day and transported to the processing factory in an insulated stainless steel road tanker. At the processing factory, the milk is pumped into an insulated storage silo where it is held, usually less than 24 hours, prior to pasteurisation and further processing as required to convert the milk into products such as liquid drinking milk, cheese and milk powders.

Australian dairy cows grazing pastures, the main source of feed in Australia

Figure 1 General design features of a dairy with a pipeline milking machine and cooling of milk to <4°C by direct expansion coils in the wall of the milk storage tank



Source: Tetra Pak Dairy Processing Handbook, Third Edition, 2015.

3.2 Milk composition and flavour

Female mammals secrete milk to provide their offspring with their complete nutritional requirements. However, milk also has several physiological functions for the young including passive immunity by immunoglobulins and other antibacterial agents, digestive aids by enzymes, enzyme inhibitors, binding, or carrier proteins, growth factors and hormones.

Because the nutritional and physiological requirements of each species of mammal differ, the composition of milk shows marked inter-species differences (Fox, 2003). The gross composition of the main commercial dairy species is shown in the table below, as a comparison to human milk.

Typical composition (%) of milk from mammals (Fox, 2003)

Species	Total solids%	Fat%	Protein%	Lactose%	Ash%
Cow	12.7	3.7	3.4	4.8	0.7
Buffalo	16.8	7.4	3.8	4.8	0.8
Goat	12.3	4.5	2.9	4.1	0.8
Sheep	19.3	7.4	4.5	4.8	1.0
Human	12.2	3.8	1.0	7.0	0.2

The gross composition of milk belies its great complexity. For example, milk fat contains up to 400 fatty acids, resulting in several thousand triglycerides and complex lipids. In addition to the eight main proteins, α_{s1}-, α_{s2}-, β- and κ-caseins, β-lactoglobulin, α-albumin, blood serum albumin and immunoglobulins), milk contains at least 80 minor proteins, including approximately 60 enzymes.
The ash fraction of milk contains at least 30 elements, which are important for milk stability and nutrition. Milk contains all known vitamins, some at quite high concentrations compared to other foods (Fox, 2003).

Milk is a highly variable biological fluid. The composition of cows' milk will vary with the individual animal, the breed of cattle, health of the animal, nutritional profile of the feed supply, stage of lactation, age of the cow and interval between milkings. Variability in milk composition due to these factors is evened out by mixing of milk from many farms at the processing factory, but some variability persists and may be quite large depending on season and availability of feeds. In addition, the actual structure of some of the constituents also varies with cow's feed. For example, the fatty acid profile of the milk fat is strongly influenced by the cow's diet. The variations in the composition of milk influence the processing properties of milk and the resulting products. Some of the variability can be minimised by animal husbandry practices or processing technology, but some differences may persist (Fox, 2003).

From a physicochemical viewpoint, milk is a very complex fluid, the constituents of which occur in three phases. Quantitatively, about 40% of the dry matter of milk is a true solution of lactose, organic and inorganic salts, vitamins and other small molecules in water. In this aqueous solution are dispersed proteins, soluble whey proteins, caseins as large colloidal aggregates or micelles ranging in diameter from 50 to 600 nanometres (nm), and lipids which exist in an emulsified state as globules ranging in diameter from 0.1 to 20 microns (μm) and stabilised by a lipoprotein membrane, known as the milk fat globule membrane (Fox, 2003).

Milk has a slightly sweetish taste due to the lactose, which has a one-sixth the level of sweetness as sucrose. The pleasant mouthfeel of milk is due to its colloidal constituents, as well as the fat. The white colour of milk is caused by the scattering of light by the colloidal particles, especially the casein micelles. Other physical properties of milk, such as freezing point and pH, are determined by the low molecular mass compounds in true solution (Fox, 2003).

Fresh milk is slightly acidic, with pH of 6.6 - 6.7. The acidity of normal milk varies between 0.15 and 0.18% expressed as lactic acid (Webb *et al*., 1974).

The osmotic pressure of milk and its freezing point is equal to that of the blood of the mammal secreting it. Hence the percentage of lactose and ash found in milk varies within narrow limits and is constant for milk from a single species. Any increase or decrease in lactose content is compensated by a decrease or increase in other soluble components (Webb *et al*., 1974).

Milk was intended to be consumed directly from the mammary gland and to be expressed from the gland at regular intervals. However, in dairying operations, raw milk is stored for various periods ranging from a few hours to several days, during which it is cooled and agitated. These treatments cause some physical changes and lead to some enzymatic and microbiological modifications which may adversely impact the quality of the milk. Raw milk is therefore a highly perishable product. However, this perishability can be managed by a well organised and efficient dairy industry (Fox, 2003).

Dairy products are susceptible to a wide range of quality defects. Some of these can originate from the feed of cow, or from microbial, chemical, or physical contamination of the raw milk during production, transport, or storage. Testing of milk for all possible defects, including unpleasant odour, and off-flavour using laboratory equipment can be challenging and time consuming. For example, the compounds responsible for many off flavours are present in concentrations below the detection limits for a lot of laboratory testing equipment. In contrast, however, applications of sensory evaluation for quality control and quality judging in the dairy industry by experienced quality assessors have been successfully practiced for more than 50 years (Delahunty, 2003).

Sensory evaluation of milk quality by trained operators is a key acceptance test for raw milk before it is collected from the farm, transported to and accepted at the processing factory. This process is termed 'milk grading'. However, sensory evaluation of raw milk is now usually restricted to an assessment of the suitability of the milk based on its odour and appearance as the industry considers that tasting of the milk represents an unacceptable health risk to the taster.

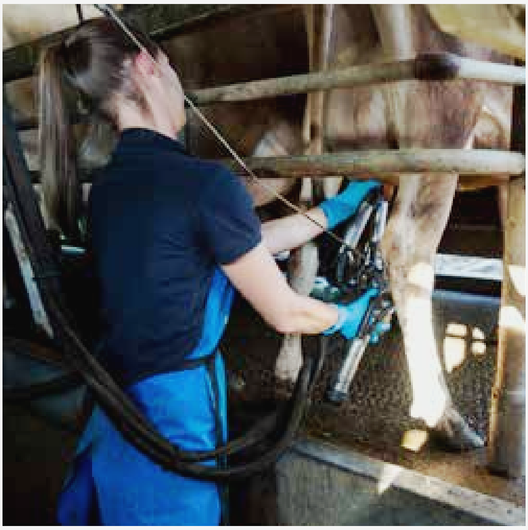
3.3 Contaminants of raw milk

Milk must have a desirable chemical composition and be of a satisfactory hygienic quality. It must be wholesome and safe for humans to consume after an appropriate heat treatment. This is essential for public health and for the quality of products. Contaminants in milk from a well fed and healthy cow, enter the milk before, during or after milking. Any changes that occur in the milk due to this contamination are detrimental to milk quality and safety. The various types of milk contaminants, their sources, and their effects are discussed below.

Microbial contaminants

The milk in a healthy udder is free of microorganisms; however, it is subject to contamination with microorganisms from several sources as soon as the milking process commences. These sources include: the teat canal and the exterior surface of the teat during milking, the environment such as water, soil and dust, milking equipment and milk pipelines, farm bulk milk storage tanks, the milk collection tanker, milk pipelines, pumps and storage silos at the processing plant. Cows with mastitis can shed high numbers of the particular bacterium causing the udder infection in the milk (Frank and Hassan, 2003; Slaghuis *et al*., 2003; White, 2003).

Some microorganisms move up the teat canal causing aseptically drawn milk to be contaminated; these organisms are known as udder commensals and are part of the normal udder microflora. The udder commensals usually contribute low levels of contamination, typically 100-1000 colony-forming units (cfu) per mL. Contamination from this source is unavoidable. The normal microflora of the udder is dominated by streptococci, staphylococci, and micrococci (Frank and Hassan, 2003; Heeschen, 1996; White, 2003).



Teat cups – a component of machine milking equipment – applied to the teats of a cow

Further microbial contamination of the milk may occur during the milking process. However, provided hygienic milking practices and equipment are used, the total bacterial count of the milk in the farm storage vat should not exceed 10,000 cfu per mL. To achieve this, immediate cooling of the milk to <4°C is required to minimise growth of the contaminant bacteria. Under appropriate conditions of storage for <2 days, the total bacterial count of the milk can be expected to be 1000 - 50000[4] cfu per mL. Spoilage of cold stored milk due to microbial activity can be first detected by sensory methods if the total bacterial count of the milk is 1×10^6 to 1×10^7 cfu per mL; however, an exact count at which this occurs cannot be specified because the spoilage threshold will vary with the composition of the microflora and the storage history of the milk (Heeschen, 1996).

Streptococcus agalactiae and Staphylococcus aureus are the bacterial species implicated in the infection of the mammary gland known as mastitis. However, there are other causative agents, including *Streptococcus dysagalactiae, Streptococcus uberis* and *Escherichia coli* (Bramley and McKinnon, 1990).

Milk from quarters of the udder infected with *S. aureus* usually has a total bacterial count of 1 x 10^4 cfu per mL; however, milk from quarters infected with *Str. agalactiae* can have bacterial counts >1 x 10^6 cfu per mL (Heeschen, 1996).

The microflora of raw milk are generally from the following broad groups:

- **Lactic acid bacteria**. This group includes the lactococci, lactobacilli and enterococci. Milk is the original source of commercial lactic cultures used in the manufacture of fermented products such as cheese and yoghurt. If milk is not cooled immediately, these organisms can multiply quickly in the milk and produce lactic acid, resulting in a sour taste, drop in pH and eventually coagulation of the milk. These defects can be evident within a few hours under favourable conditions for bacterial growth. Cooling of milk to <4°C inhibits the growth of lactic acid bacteria.
- **Thermoduric bacteria**. This group typically consists of Gram-positive organisms and includes the vegetative cells of the genera *Microbacterium* and *Micrococcus* and spores of the genus *Bacillus*. Thermoduric bacteria can survive pasteurisation. These organisms have relatively little impact on the quality of raw milk provided it is cooled to below 4°C. Some of them will contribute to the bacterial count of pasteurised milk and other products, and the spores of *Bacillus* can germinate in heat-treated milk and cause quality defects in products such as pasteurised milk, cream and UHT milk.

  A thermoduric count on farm milk is regarded as a good indicator of the standard of hygiene of the milking equipment, and some dairy companies routinely test their farm milk supplies for this purpose. A count of less than 2 x 10^3 cfu per mL is indicative of a high standard of hygiene in the dairy.

  Thermophilic bacteria are a sub-group of the thermoduric bacteria that can cause quality problems in dairy products processed at high temperatures and with long production runs, such as milk powder and evaporated milk. These are usually aerobic spore-forming bacteria (*Bacillus* spp.), from raw milk. They can survive pasteurisation and form biofilms on the equipment surfaces in the hot section of the plant, where they can grow quickly and contaminate the product (Craven *et al*., 2001).
- **Psychrotrophic bacteria**. This group of bacteria can grow in milk at refrigeration temperatures, albeit slowly. They are mostly Gram-negative rods, with *Pseudomonas* the most common genus and *Ps. fluorescens* the most common species. *Ps. fluorescens* has a doubling time of about 10 hours at 4°C. If the initial psychrotrophic count in the milk is 1 x 104 cfu per mL, it can increase to above 1 x 106 per mL in four days.

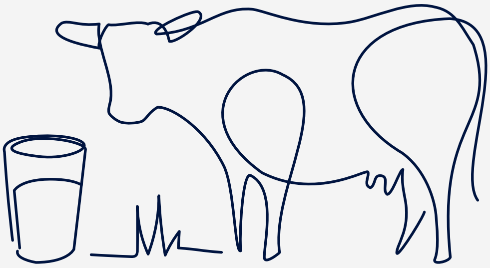
  The psychrotrophic bacteria can be very detrimental to milk quality, especially because proteases and lipases produced by many of these bacteria are very heat stable. Thus, not only might the quality of the raw milk be affected adversely by these organisms, but the heat-stable proteases in particular will remain active in the processed product and can affect the quality of products such as cheese and UHT milk.

  To avoid the adverse effects of psychrotrophic bacteria on the quality of milk and other dairy products, it is essential that the milk is produced, stored and handled using hygienic equipment and methods, stored below 4°C and pasteurised as soon as possible but within 3-4 days. The psychrotrophic bacteria will eventually become the dominant type of the microflora in raw milk during extended periods of cold storage.
- **Coliforms.** Coliforms including E. coli can occur in raw milk. While their presence in pasteurised products is indicative of poor plant hygiene and improper processing practices, no particular significance is usually attached to their presence in raw milk provided the milk is stored below 4°C and not consumed as raw milk.

- **Pathogens.** There are many pathogenic microorganisms in raw milk. The more common among these include *Salmonella* spp., *Listeria monocytogenes, Campylobacter jejuni, Staphylococcus aureus, E. coli, Yersinia enterocolitica, Bacillus cereus* and *Streptococcus pyogenes*. All of these organisms are destroyed by pasteurisation. Consumption of unpasteurised milk should be avoided.

  Raw milk can be a vehicle for transmission of the zoonotic bacterial agents *Mycobacterium bovis* and *Brucella abortus*. However both of these organisms have been eliminated from the Australian dairy herd (Bramley and McKinnon, 1990; Frank and Hassan, 2003; Heeschen, 1996; White, 2003).

Cows being milked in a rotary dairy



Somatic cells

Mastitis is an inflammation of the mammary gland, caused by an intra-mammary microbial infection which results in altered composition of milk. The two main methods used by industry for the detection of mastitis are: (i) visual examination of the raw milk for clinical signs such as clots and flakes, and (ii) the determination of the somatic cell count (SCC) of the milk. Somatic cell counts are white blood cells called leucocytes and their count in the milk increases during inflammation. When clinical signs are observed in milk from a quarter of the udder, the milk by definition is abnormal.

There is no single SCC that can be said to be the dividing line between normal and abnormal milk. Nevertheless, the SCC of normal, healthy quarters of first lactation heifers without any previous history of udder infection should be less than 100,000 cells per mL of milk. If SCC is greater than 200,000 cells per mL it indicates the presence of infection and inflammation, at least in young cows. However, older cows with a previous history of mastitis infection can produce milk with much higher cell counts, such as 200,000 – 400,000 cells per mL, without any evidence of clinical mastitis. In Australia, the maximum SCC count acceptable is 400,000. In cases of severe infection of a quarter, the SCC of the milk from that quarter can exceed 10 million cells per mL (Anon., 2005; Smith, 2002). Sub-clinical mastitis occurs when the level of the infection of the mammary gland is sufficient to cause elevated cell count, but not clinical signs of infection such as clots.

In general, the higher the SCC of milk, the lower is its quality, particularly its manufacturing properties. High cell counts are also indicative of poor practices on the farm especially relevant to the milking process and animal health.

Residues of antimicrobial products used to treat infections in the cow

Antimicrobial drugs are widely administered to individual farm animals for the treatment of bacterial infections or prophylactically to prevent the spread of disease, to augment growth of the animals and increase yield of products. In the case of dairy cows, the most commonly used antimicrobials are the antibiotics used to treat mastitis. Other diseases of dairy cows that can be treated with antimicrobials include laminitis, respiratory diseases, and metritis.

Numerous antimicrobial products are available for the therapeutic treatment of clinical mastitis during the cow's lactation period, and also for prophylactic use for all cows at drying off at the end of lactation; this latter use of antimicrobials is known as 'dry cow therapy'. Both types of these antibiotic preparations are usually administered as intra-mammary infusions, though the former can be administered systemically in severe cases.

However, regardless of method of administration to the animal, all antimicrobial drugs used for the treatment or prevention of mastitis or other diseases can enter the milk to a certain degree.

The presence of residues of antimicrobial drugs in milk is important for two main reasons:

1. **Technological impacts**. Antimicrobial residues lead to partial or complete inhibition of acid production by lactic starter cultures during production of fermented milk products such as cheese and yoghurt. They can also cause inadequate ripening of cheese and defects in the flavour and texture of products.
2. **Health impacts**. Some consumers may exhibit allergic reactions to residues of antibiotics and their metabolites present in the food that they consume, such as the β-lactam antibiotics. Of the various types of antimicrobials used to treat mastitis, the β-lactam antibiotics penicillin and penicillin derivatives are the most widely used for lactating cows, either alone or in combination with other antimicrobial substances.

   Other antimicrobial groups in common use are the aminoglycosides, macrolides and the sulpha drugs.

   A general concern with the widespread use of antimicrobials in both the animal industries and human medicine is the potential development of antibiotic resistant pathogens. Bacteria can develop resistance to antibiotics and the presence of antibiotic residues in milk provides another avenue for this to occur. Furthermore, antibiotic resistant bacteria and resistance genes can be transmitted from animals to humans via the food chain (Fischer *et al*., 2002a; Honkanen-Buzalski and Suhren, 1999).

Management of residues of antimicrobials in milk requires an integrated approach by Government agencies, the dairy companies and the dairy farmers.

In Australia, all agricultural or veterinary chemical products including antimicrobials for administration to dairy cows must be registered with the Australian Pesticides and Veterinary Medicines Authority (APVMA) before they can be supplied, distributed, or sold anywhere in Australia. Registration ensures that the product is safe to use and works when used according to the label. As part of the registration process, a withholding period is set for each product. Maximum residue limits (MRLs) for the chemical in milk may also be set if appropriate.

Antimicrobials with MRLs for milk include Benzyl G Penicillin (0.0015 mg/kg), Streptomycin (0.2 mg/kg), various Sulphonamides, e.g. Sulfadiazine (0.1 mg/kg) and Tetracycline (0.1 mg/kg). In each of these cases, the MRL is set at about the limit of determination. The Australia New Zealand Food Standards Code does not specify MRLs for some registered antimicrobials as mentioned in Standard 1.4.2 – Maximum Residue Limits, Australia only, June 2015). Thus, it is illegal to sell milk in Australia containing any detectable antimicrobial residues.

Dairy companies receiving milk from producers must continually monitor their milk supplies for the presence of antibiotics residues.

Managing the administration of antimicrobials to dairy cows for mastitis treatment or for any other purpose is an important task for all milk producers.

Chemical residues

Chemical residues in milk can be grouped into several broad categories, depending upon their source:

1 **Agricultural pesticides**. This group of chemicals includes insecticides, herbicides and fungicides used in the production of crops and pastures fed to dairy cattle. The chemicals enter the milk via the cow's body, which yields secretory residues of the pesticides that can pass through the blood-milk barrier into the milk.

However, with most of the modern pesticides now in use, usually no more than 5% of the quantity ingested in the feed reaches the milk. The remainder of the chemical is metabolised in the cow's body or excreted in the cow's urine or faeces. With adoption of Good Agricultural Practice, residues of pesticide chemicals should not be present in milk, or if they are, they are at levels well below the prescribed MRL (Bluthgen and Tuinstra, 1997).

Good Agricultural Practice includes using only registered agricultural chemicals in accordance with the directions on the label and observing the Withholding Period for Grazing. Depending on the product and the crop, the Withholding Period for Grazing can range from 0 to 28 days. In Australia, a system of Vendor Declarations requires vendors of stock feed to declare if the feed has been treated with an agricultural chemical and, if it has, to provide the name of the chemical used and date of last application.

Several decades ago, organochlorine insecticides such as DDT, dieldrin and chlordane, did create residue problems in dairy products. There are two reasons for this: (i) they were persistent in the environment and (ii) they are lipophilic, which enabled them to accumulate in the milk fat. However, the use of this class of chemical has now been banned. Any farms with patches of soil containing high residual levels of these chemicals have now been identified and the use of these areas is under Government supervision to ensure that the residues do not enter the human food chain.

2 **Parasiticides**. Parasiticides are chemical agents that are administered to cattle to control either endoparasites such as helminths and liver fluke, or ectoparasites such as ticks and biting flies. With a few exceptions, most chemicals for the treatment of endoparasites cannot be used on lactating cows in Australia. Chemicals for the treatment of ectoparasites used strictly according to the instructions on the product label should not cause any residue problems in the milk.

3 **Dairy detergents and sanitisers**. Residues of detergents and sanitisers used to clean milking machines and milk storage equipment on the farm can enter the milk, particularly if the cleaning, sanitising, draining, or pre-milking rinsing procedures are improperly conducted. Sanitisers in common use include iodophors which are organic compounds containing iodine in a micellar form, chlorine containing compounds such as hypochlorite, surface active agents such as quaternary ammonium compounds and peroxy compounds such as peracetic acid.

If used according to good hygienic practice, significant levels of residues of detergents and sanitisers should not be present in milk and should not cause any health concerns for consumers.

However, it must be noted that overuse or careless use of iodophors for sanitising farm equipment can result in an elevated iodine content in the milk, which can interfere with thyroid function in certain consumers, especially if the level exceeds 500 µg/L (Fischer *et al.*, 2002a). Use of iodophors in the Australian dairy industry for sanitising of farm equipment has declined in recent years.

Use of iodine based post-milking teat dips for mastitis control can also lead to slight elevation of the iodine levels in milk.

4 **Industrial chemicals**. Accidental contamination of stock feeds with industrial chemicals that have a potent effect on human health, such as dioxins and polychlorinated biphenyls (PCBs), have occurred in some countries. Such contamination has resulted in residues in milk. However, the Australian dairy industry has a good record in relation to such incidents.

Radioactive isotopes

As a result of accidents in nuclear power plants, radioactive isotopes have contaminated the environment and entered the food chain, including milk. The accidents that have attracted most publicity are those of Chernobyl (April 1986, Soviet Union) and Fukushima (March 2011, Japan). There are no nuclear power plants in Australia.

The radioactive isotopes are unstable and emit radiation while undergoing decay.

After a nuclear explosion, most of the radioactivity is 'injected' into the troposphere. The removal of particulate radioactivity from troposphere is fairly rapid, usually within a month. Troposphere is the lowest portion of the earth's atmosphere, varying in height from almost 8 km at both poles to about 20 km at the equator. There is only a very limited mixing of air between hemispheres in the troposphere layer, near the equator, but there is no mixing of airflows in the stratosphere between hemispheres (Kathren, 1984).

The radioisotopes of the greatest concern for the dairy industry are Caesium-137, Strontium-90, and Iodine-131. While Iodine-131 has a short physical half-life of less than nine days, Caesium-137, and Strontium-90 have very long physical half-lives of 29.1 and 30 years respectively, so they will persist in the environment for a long time.

Because of the airflow patterns over the hemispheres, Australia's food chain has not been affected by the nuclear accidents in the northern hemisphere. Consequently, the levels of human made radioactive isotope residues in milk and dairy products made in Australia are extremely low compared to most areas of the northern hemisphere.

Physical matter

Sediment, such as dirt, animal manure, feed dust, and foreign matter, such as hair, insects and plant material, can enter milk and have a detrimental effect on the quality of milk. They can be a source of bacterial contamination and off-flavours. If milk is heavily contaminated with sediment, some of it may settle at the bottom of the milk storage tank and be noticeable when the milk is pumped out.

Milk is usually filtered on the farm and clarified when it reaches the processing factory to remove any sediment and foreign matter present.

Farm milks can be tested at the receiving factory for the presence of foreign physical matter by the sediment test; in this test, 100 mL of milk is passed through a standard filter disc and the sample assigned a score by comparing the amount of foreign matter on the disc with a set of reference standards.

Chemical taints

Milk absorbs taints and odours from the surrounds very readily. Some of these may be harmless, but some others adversely affect the organoleptic quality of the milk and products. Some taints may indicate the accidental contamination of milk with dangerous substances. Any milk in a farm vat that exhibits an unacceptable or unusual odour should be rejected by the tanker driver at collection.

Phenolic substances are a particular hazard and should not be used or stored in or near the dairy. If the phenolic substances enter milk, they can react with residues of chlorine sanitisers to form chlorophenols, which have a potent odour even at very low levels of concentration.

Weed and feed flavours

Substances capable of causing taints or off-flavours in milk can be transmitted directly from the cow's feed into the milk via the cow's digestive tract and blood supply. The presence of these substances in milk at detectable threshold levels is regarded as a defect. The defects can impact odour or taste and can range in intensity from mild to severe.

Some of these taints originate from common pasture plants and also weeds that cattle eat. For example, the dimethyl sulphide content of milk increases when cows are fed on a lucerne based diet. Low concentrations of dimethyl sulphide contribute to the characteristic flavour of raw milk, but higher concentrations can give a 'cowy' or 'malty' flavour.

Taints from pasture species and weeds are more apparent during the spring season, when they usually exhibit a flush growth. The occurrence and intensity of the taints from these sources can be minimised by selection of pasture species, control of weeds and grazing management.

Supplementary feeds can also be a source of taints. For example, cheese made from milk sourced from cows that have been fed on citrus pulp can develop taints during maturation. Also, milk from cows fed supplementary feeds with a high oil content can develop oxidised flavours.

In some cases, the taints can be removed or reduced by a vacuum deodorisation step if they are volatile. However, some taints caused by consumption of weeds such as Bitter Cress, are very difficult to remove by processing.

The best way to detect taints or off-flavours is by sensory evaluation of the milk. This evaluation should include tasting only if the milk has been pasteurised or made safe for human consumption.

Toxins of fungal and plant origin

Some fungi and plants can produce toxins that have an adverse effect on human health. Of these, the mycotoxins, secondary metabolites of fungi, are the most important for milk.

Aflatoxin M^1 is a mycotoxin that appears in milk due to the intake of aflatoxin B1 contaminated feed by dairy cows. Aflatoxin B^1 can be produced in stock feed by the fungi *Aspergillus flavus, A. parasiticus* and *A. nominus* under warm and humid conditions. The feed materials at greatest risk are peanut hay, maize, oilseeds and the residue called press meal, remaining after extraction of the oil from oilseeds. The aflatoxins are produced pre-harvest but their production in stored grain also can be very high if the grains are not kept dry. Bakery waste can also be a major source of aflatoxin if it is not kept dry. Around 0.3 - 6.3% of aflatoxin B1 in the feed intake is transformed by the cow into aflatoxin M^1 in milk.

Aflatoxins are acutely toxic to humans when they are consumed in relatively large quantities and may cause liver cancer if they are consumed in smaller doses over a long time. Hence the feeding of mouldy feeds and press meal of oilseeds to milking cows must be avoided.

The Australia New Zealand Food Standards Code does not set a maximum limit for aflatoxins in milk or dairy products. Hence their presence in milk at levels exceeding the limit of detection, about 5 µg per kg is not permitted. Aflatoxin M1 is included in the ongoing AMRA survey conducted by the Australian dairy industry. Commercial test kits enable dairy companies to carry out their own screening of milk if required.

Carryover of other mycotoxins, such as ochratoxin A, into milk is not significant and hence they are not regarded as a health issue in milk (Heggum C, 2004; Fischer *et al.*, 2002b; van Egmond *et al.*, 1997).

Plants can also produce toxins that affect the health of the consuming animal, such as pyrrolizidine alkaloids produced by the pasture weeds Paterson's curse, heliotrope, ragwort, and ptaquiloside produced by several species of bracken fern (Fischer *et al.*, 2002b). These weeds are managed by Good Agricultural Practice and there is no evidence to indicate that plant toxins are an issue in Australian milk supplies.

3.4 Milk spoilage caused by natural milk constituents

Raw milk contains a number of indigenous enzymes, including lipases, esterases, plasmin which is a proteinase, phosphatase, lactoperoxidase and xanthine oxidase. Of these, lipoprotein lipase (LPL) is the most important for quality of milk.

LPL accounts for most of the lipolytic activity of raw milk. The total amount of LPL in raw milk is sufficient to cause rapid hydrolysis of a large proportion of the milk fat. Fortunately, this does not happen if milk is handled well, because the LPL is unable to access the fat since it is protected by the milk fat globule membrane. However, physical damage to the milk fat globule membrane in raw milk or, in some cases, simply cooling certain individual milks soon after secretion, can initiate lipolysis. Lipolysis in milk and milk products releases free fatty acids and partial triglycerides, resulting in rancid off flavours causing technological challenges. Therefore, lipolysis in raw milk is a constant challenge for the dairy industry.

The lipolysis in milk caused by LPL can be broadly categorised into two types: spontaneous and induced. Spontaneous lipolysis is initiated by the simple act of cooling raw milk to 10°C soon after it is taken from the cow. It only occurs at the farm and is associated with predisposing factors such as late lactation, poor quality feed and mastitis. In contrast, induced lipolysis is initiated by physical damage to the milk fat globule membrane, which allows the lipase access to the milk fat triglycerides. It can occur on the farm, during transport and in the factory. Physical actions causing induced lipolysis include agitation and pumping, especially with air incorporation or high shear, homogenisation, mixing of raw and homogenised milk, freezing and thawing. For example, if the pipeline connection on the suction side of the centrifugal pump is loose, air is sucked into the pump with the milk during pumping causing damage to the fat globule membrane and resulting in lipolysis.

Both spontaneous and induced lipolysis progress during subsequent storage of the raw milk, with most of it usually occurring during the first 24 hours of refrigerated storage after milking (Deeth, 2006).

3.5 Storage and transport of raw milk via cold chain

Maintenance of the cold chain for raw milk from production on the farm through to pasteurisation in the processing factory, is essential to prevent spoilage of the milk. Also, the milk should be pasteurised and converted into products as soon as possible.

All milk in Australia is stored in stainless steel bulk milk tanks on the farm. These tanks must comply with Australian Standard 1187-1996: Farm milk cooling and storage systems (https://www.saiglobal.com/PDFTemp/Previews/OSH/As/as1000/1100/1187.pdf). This Standard requires that the milk be cooled to <4°C within 3.5 hours of the commencement of milking and maintained at that temperature during storage. The milk passes from the cow via the milking machine either directly into the tank where it is fully cooled by a direct expansion 'cold-wall' system (see figure 1) or more commonly through a plate cooler where the milk is pre-cooled to 18-25°C before it enters the storage tank, where final cooling also takes place via a cold-wall system (see figure 2). The refrigeration equipment attached to each milk tank is fitted with thermostatic controls to ensure that the temperature of the milk remains below 4°C but above freezing during storage.

The milk is collected from the farm at regular intervals in an insulated stainless steel road tanker designed especially for the collection of milk from farms. It is then transported to a processing factory, where it is pumped – with further cooling if necessary – into an insulated stainless steel silo for storage until it is pasteurised.

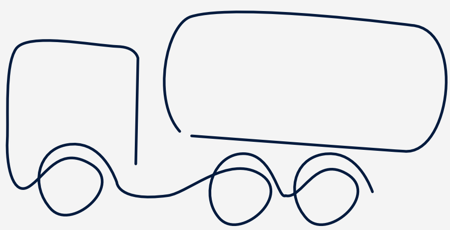
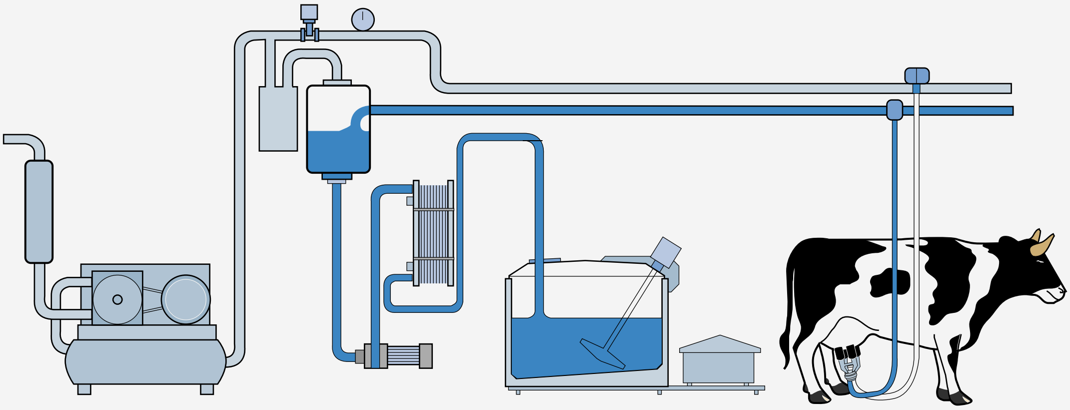


Figure 2 General design features of a farm dairy with a pipeline milking machine and a plate heat exchanger (1) to pre-cool the milk from 37°C to 18-25°C before it enters the storage tank, where final cooling to <4°C occurs



Source: Tetra Pak Dairy Processing Handbook, Second Edition, 2003.

Bulk milk collection at a farm dairy: Milk being pumped from a farm storage tank into a collection tanker:

A profile of the typical cold chain for raw milk in the Australian dairy industry is summarised below. There may be minor variations to this profile depending on company policy and the regulations of the State food safety regulatory agencies.

Step	Milk temperature and storage period	Comments
1. Milk taken from cow and stored in farm tank	Milk must be cooled to 5°C or less within 3.5 hours from the start of milking as stated in the Food Standards Australia New Zealand (FSANZ) Standard 4.3.4	Cooling rate and temperature profile will vary, depending on the capacity and configuration of the cooling system.
2. On-farm storage	Temperature of the milk maintained at less than 4°C during storage. A daily pickup from the farm is most common, though pickup can be on every second day in those periods of the year when milk production on the farm is lower.	Sometimes the practicalities of collecting milk from the farm soon after completion of the last milking in the pickup period, when the temperature of the milk might have yet fallen below 5°C is difficult. In some states, milk that is collected within 3.5 hours from the start of milking and is above 5°C will be subject to a risk assessment by the milk processor. Milk that fails this assessment cannot be used for human consumption. The calculations behind the risk assessment are based on research from the University of Tasmania and are endorsed by industry.
3. Transport to processing factory	Temperature of milk during transport will be the average temperature of the mixed milk. Transport is mostly for 4-8 hours but can be 2 hours or occasionally longer up to 12 hours.	The period of time required to complete a milk collection run depends on the number of farms, the proximity of the farms to each other and distance to the processing factory.
4. Receival at processing factory	Milk cooled on receival to less than 5°C if it is above 5°C and the milk is not to be processed that day or is to be trans-shipped to another factory.	If milk is above 4°C and the milk is to be processed that day, it may or may not be cooled to less than 4°C on receival, depending on company policy and assessments of risk to quality.
5. Storage at processing factory pending pasteurisation	Milk is held at the processing factory for 12-24 hours before it is pasteurised, sometimes even for a shorter period; maximum period is 48 hours.	Period of storage at the factory will depend on product mix, processing cycles, volume of milk intake and availability of equipment for product manufacture.

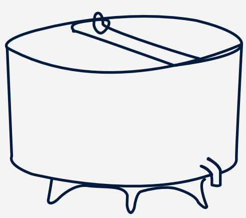
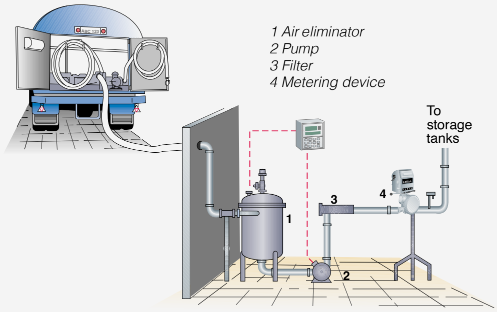
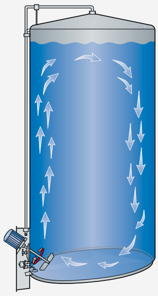


Figure 3 Receiving raw milk from farm collection tanker at dairy factory



Source: Tetra Pak Dairy Processing Handbook, Third Edition, 2015.

Figure 4 Silo for storage of raw milk at a processing factory, with mechanical agitation of the milk



Source: Tetra Pak Dairy Processing Handbook, Third Edition, 2015.

Silos for storage of raw milk at a processing factory

3.6 Testing of raw milk: standards, testing methods and interpretation of results

All dairy companies carry out a series of quality checks on raw milk supplies for acceptance and payment purposes. There is a set of basic quality tests that all companies conduct, and some additional checks that only some companies carry out to help them meet their particular quality objectives. An outline of a typical testing program, which commences with a sensory assessment of the milk at the farm storage tank by the tanker driver collecting milk before it is pumped into the tanker, is shown below:

Examining culture plates in a dairy company's microbiology laboratory

Step	Basic quality checks and procedures	Comments
On-farm quality checks	• At every pickup, milk is checked by the tanker driver for visual appearance and smell (odour) to ensure it is of acceptable quality before it is pumped into the tanker. • At every pickup, temperature of milk in farm storage tank is checked and recorded on both farm records and tanker collection log.	• Most companies do not permit their tanker drivers to taste the milk, as it represents an unacceptable health risk to them. For example, in some regions, drivers can contract the infectious disease Q Fever by tasting the milk. • In most cases temperature is also recorded automatically by a data logger on the tanker as the milk is pumped into the tanker.
On-farm sampling	• At every pickup, a sample of the milk in the farm storage tank is taken for laboratory analysis using a drip sampler attached to the milk tanker. • An additional sample for microbiological analysis is taken as required direct from the storage tank by the tanker driver using a sanitised stainless steel dipper.	• The drip sample is usually used to determine milk composition for payment purposes, Bulk Milk Cell Count, presence of antibiotic residues and in some cases also Total Bacterial Count by Bactoscan. • Some companies only use the drip sample for determining the Total Bacterial Count (or other microbiological tests if done), while others use the dip sample to confirm a high count detected by the Bactoscan. • Samples are stored at 0-4°C pending testing at the laboratory.
Acceptance/ screening of milk in farm collection tankers on arrival at receival factory	• Every consignment of farm milk is checked for the presence of antimicrobial residues especially β-lactams using a 'Broad Spectrum' commercial test kit. In some cases, the milk is screened using a 'Rapid' test kit before it is pumped out, followed by a confirmatory test using a 'Broad Spectrum' test kit. • Some companies routinely check acidity of tanker milk before pumping it out. • Some companies check tanker milk temperature; if it exceeds 5°C, acidity is then checked.	• Other quality tests carried out by some dairy companies on farm tanker milk include: – Milk composition (fat, protein, lactose). – Freezing point (to detect adulteration with water). – Total Bacterial Count of tanker milk by either the Standard Plate Count or the Bactoscan; if the count exceeds 50,000 cfu/ml, samples from individual farms are checked; and/or – Resazurin dye reduction test (a quick test to detect excessive microbial activity).

Step	Basic quality checks and procedures	Comments
Quality checks carried out on samples of individual farm milks in the dairy company laboratory	• Total Bacterial Count: Determined by Bactoscan once every 10 days; recognised standard is <50,000 cfu/ml.	• Most dairy companies have a milk payment scheme that provides for a scale of adjustments to the base payment rate that reflects the Total Bacterial Count, e.g. a bonus payment if count <20,000 cfu/ml and a deduction (penalty) if count >50,000 cfu/ml. • Some dairy companies also test farm milks for count of thermoduric bacteria as an index of farm hygiene; a count <2,000 cfu/ml is regarded as very good and a count >10,000 cfu/ml as poor.
	• Bulk Milk Cell Count: Determined by Fossomatic or similar instrument on every pickup; recognised standard is <400,000 cells/ml.	• Most milk payment schemes also provide for a scale of adjustments to the base payment rate that reflects the Bulk Milk Cell Count, e.g. a bonus payment if count <200,000 cells/mL; penalty if count >400,000 cells/mL; suspension from supply if >600,000 cells/mL.
	• Antimicrobial residues: Farm milks are checked once per month using a 'Broad Spectrum' commercial test kit; recognised standard is 'Not Detectable.'	• Some companies test individual farm milks once per month in addition to every farm tanker, whereas other companies rely on the testing of every farm tanker with trace back to individual farms if positive.
	• Milk composition: The fat and protein content of a sample taken from the farm storage tank at every pickup is determined by a Foss Milkoscan or similar instrument.	• Most payment systems in Australia are based on the mass of milk protein and milk fat in the milk. • In Australia, the protein content of farm milks for payment purposes is measured as true protein. Also, the composition of farm milks for payment purposes is expressed on a mass/volume basis. • The standards adopted by the Australian dairy industry for the composition of farm milks are a minimum of 32 g/L for milk fat and 30 g/L for protein.
Pasteuriser balance tank	• Some companies test milk from every silo every day for Total Bacterial Count; recognised standard is <150,000 cfu/ml.	• Determination of Total Bacterial Count of the raw milk at the balance tank provides a check on the plant hygiene and temperature at all points in the milk handling chain.

Samples of farm tanker milks are also taken monthly for analysis under the Australian Milk Residue Analysis (AMRA) survey for a range of chemical residues.

3.7 Restrictions on the sale of raw milk and products made from raw milk

In Australia, the sale of raw unpasteurised cow's milk for human consumption, is not permitted. This is because of the risk of transmitting foodborne illness through raw milk. The Food Standards Code under section 4.2.4 allows for the production and sale of selected cheeses made from unpasteurised milk. The standard requires strict supply chain control over the production, transport and processing of raw milk to ensure the final product is safe for consumers. The manufacture of raw milk cheeses for human consumption must be approved by the relevant state authority,

3.8 Regulation of raw milk quality

The food safety aspects of raw milk quality are regulated via Standard 4.2.4, *Primary Production and Processing Standards for Dairy Products*, of the Australia New Zealand Food Standards Code. This Standard states, in part, that a dairy farm production business must control the potential food safety hazards in the milk it produces by implementing a documented food safety program. In most states, the food safety program must be based on HACCP, Hazard Analysis Critical Control Points. The food safety programs are subject to audit at regular intervals, usually every 12 months, by auditors employed by or contracted to the relevant state food safety agency.

The implementation of Standard 4.2.4 and other relevant sections of the Food Standards Code in relation to raw milk is the responsibility of state food safety agencies:

- Victoria – Dairy Food Safety Victoria, **www.dairysafe.vic.gov.au**
- NSW – New South Wales Food Authority, **www.foodauthority.nsw.gov.au**
- Queensland – Safe Food Queensland, **www.safefood.qld.gov.au**
- Tasmania – Tasmanian Dairy Industry Authority, **www.dpipwe.tas.gov.au/biosecurity/product-integrity/food-safety/dairy**
- South Australia – Dairysafe (Dairy Authority of South Australia), **http://dairy-safe.com.au**
- Western Australia – Health Department of Western Australia, **http://ww2.health.wa.gov.au/Health-for/Industry-trade-and-business/Food**

Aspects of raw milk quality that do not fall within the scope of food safety are managed by the dairy companies through their quality assurance programs.

3.9 Dairy company programs for the management of raw milk quality

The dairy companies have documented programs for the management of raw milk quality as a component of their company quality assurance programs. Some of the companies have also developed their own generic on-farm quality assurance and food safety manuals in conjunction with the State dairy food safety agencies. These manuals, which are designed to ensure that the company's quality needs are met, are made available to each of the company's milk producers and form the basis of the on-farm quality assurance programs. Company field staff assist the farmers with the implementation of the programs.

3.10 Recent developments in testing methodologies

The basic elements of testing programs for assessment and management of raw milk quality have changed slightly in recent decades. The main changes that have occurred are:

- The introduction of automated laboratory equipment – with varying levels of automation and software support for sample identification and reporting, depending on brand and model – for the determination of fat, protein and lactose content. For example, Foss Milkoscan range, Bentley MIR range and Delta Instruments Lactoscope range, somatic cell count by Foss Fossomatic range, Bentley Somacount range and Delta Instruments Somascope range and total bacterial count by Foss BactoScan).

These instruments can be used separately or, in the case of the Foss MilkoScan and Fossomatic, combined into an integrated unit, the CombiFoss. Integrated units are also available from other equipment manufacturers, e.g. the Bentley Combi series and the Delta Instruments Combiscope range.

This equipment allows a test result to be obtained quickly and with a high throughput of samples, e.g. the Foss BactoScan FC can provide a bacterial count in less than nine minutes, with a throughput of 150 samples per hour, while some models of the Milkoscan and Fossomatic can handle 500 samples per hour.

Foss CombiFoss company's automatic sampling device showing progression of milk samples.

Source: Foss, Denmark, **www.fossanalytics.com**

For more information on Foss milk testing instruments, refer to website: **www.fossanalytics.com**

For more information on Bentley milk testing equipment, refer to website: **Bentley Instruments Inc**

For more information on Delta Instruments milk testing equipment, refer to website: **deltainstruments.com**

- There is a trend towards centralised laboratories, either within the company or operated by an external contractor largely driven by the need to maximise the throughput of samples through expensive laboratory equipment and cost considerations. In some cases, the use of a centralised laboratory may require transport of samples over long distances by road or air.
- ELISA test kits are now available from commercial suppliers for the detection of antimicrobial substances in milk, e.g. antibiotics used to treat mastitis. Kits are also available for the detection of other contaminants such as aflatoxins. These kits allow testing to be done rapidly, within 30 minutes. In the case of antibiotic residues, they can also provide a greater level of specificity for the type of residue present compared with the longer 'Broad Spectrum' kit or standard disc assay methods.
- Same day reporting of test results to the farmer is now widely used by the dairy companies. This has been facilitated by the use of laboratory equipment and test kits that allow more rapid testing, a capacity to test samples from every tanker pick-up and the transmission of the results to the farmer by fax or email. The farmer is thus in a better position to take prompt corrective action on any quality issues. Some companies phone test results through to the farmer if there is a serious quality problem. Paper copies of test results are also delivered to the farmer by the tanker driver at the next milk pick-up.

3.11 Conclusions

Raw milk quality is a complex topic, with many facets, components, variables and indices. To ensure that raw milk is always of the highest quality when it is processed, an integrated and informed approach is required by the dairy farmer, the dairy processor and the regulatory authorities.

The milk production system must result in raw milk that meets the following criteria:

- It is safe to consume after it has been pasteurised, i.e. it must be free of harmful chemical residues and toxins;
- It is free of adulterants, for example added water;
- It is free of unpleasant flavours, taints or odours and is of normal appearance;
- It meets the nutritional needs of the consumers; and
- It can be processed into high quality dairy products, such as cheese and yoghurt, with high yield of product.

Good quality dairy products can only be made from good quality raw milk.

3.12 Frequently asked questions (FAQ)

A Composition of milk

1. Does breed of cattle influence the composition of milk?

Breed of cattle has a marked effect on the composition of milk, particularly on the fat and protein content.

This is illustrated by the typical milk compositions in the table below. Breed can thus impact several processing parameters such as product yield and processing characteristics of the milk. Note, however, that breed is just one of many factors that influence the composition of milk.

Effect of breed of cattle on the average composition of herd milks (after Webb et al., 1974).

Breed	Water (%)	Fat (%)	Protein (%)	Lactose (%)	Ash (%)	Non-fat Solids (%)	Total Solids (%)
Guernsey	85.35	5.05	3.90	4.96	0.74	9.60	14.65
Jersey	85.47	5.05	3.78	5.00	0.70	9.48	14.53
Brown Swiss	86.87	3.85	3.48	5.08	0.72	9.28	13.13
Holstein	87.72	3.41	3.32	4.87	0.68	8.87	12.28

2. Does composition of milk change during the lactation period of the cow?

The main changes in the composition of milk during the lactation period occur within the first few days after birth of the calf. The transition in the composition of colostrum to that of normal milk is illustrated in the table below.

Typical changes in the gross composition of cow's milk after calving: the transition from colostrum to normal milk (after Marnila and Korhonen, 2003).

Days after calving	Total protein (%)	Fat (%)	Lactose (%)	Ash (%)
0.5	14.6	5.3	2.6	1.16
1	9.4	5.4	3.6	1.03
1.5	5.5	4.4.	4.3	0.92
2	4.5	4.5	4.6	0.87
3	4.2	4.5	4.8	0.85
4	4.1	4.8	4.9	0.85
8	3.6	4.8	4.9	0.81
14	3.3	4.6	5.1	0.78

The proportion of whey proteins in colostrum is higher than in normal milk. The main protein fractions present in colostrum are the immunoglobulins. The transition from colostrum to normal milk is complete within 4-5 days after birth of the calf, though slight changes in composition continue for some time.

The amount of solids-not-fat in the milk will usually drop to a lactation low at 2-3 months, increase slowly to six months and then increase rapidly towards the end of lactation which is approximately ten months from birth of calf. Lactose percentage drops slightly towards the end of lactation. Fat content of the milk can vary widely during the lactation period.

Other important factors influencing the composition of milk are cow nutrition and mastitis type udder diseases.

3. For how many days should colostrum be excluded from the milk supply?

Colostrum has a strong odour, a bitter taste, a slight reddish-yellow colour and contains a large percentage of immunoglobulins. Inclusion of colostrum in the milk supply can have a disastrous effect on the quality of the milk and can cause problems during processing. It should be excluded from the milk supply for at least four days after calving.

4. What is a MilkoScan?

A MilkoScan is a laboratory instrument manufactured by Foss company for the determination of milk composition. There are various models, but all utilise the principle of absorption of different wavelengths of infrared light by the components of milk. MilkoScan instruments based on mid-infrared technology allow the fat, protein, lactose, total solids and solids-non-fat content of milk and in some cases also the freezing point depression to be determined.

Advanced models of the MilkoScan that use the FTIR (Fourier Transform InfraRed) Technology allow other parameters of milk quality to be measured, including casein, free fatty acids (FFA) and pH.

MilkoScans are widely used in the Australian dairy industry for testing farm milks for payment and quality purposes.

Similar instruments available from other equipment manufacturers are the Bentley mid-infrared range, widely used in herd improvement laboratories in Australia and the Delta Instruments Lactoscope range incorporating both mid-infrared and FTIR models.

5. How can the adulteration of milk with water be detected?

The freezing point of pure water is 0°C. If solutes like salts, are added to water, its freezing point is lowered below 0°C; the greater the amount of salts added, the lower the freezing point of the solution. The solutes in milk, principally lactose and dissolved mineral salts, depress its freezing point to about -0.5°C

The osmotic pressure of cow's blood remains fairly constant. The cow's biological system has to balance the osmotic pressure of the milk in the udder with that of the blood circulating through the udder. Hence the freezing point of milk is also maintained at a fairly constant level.

The freezing point of genuine milk from individual cows varies with the breed of cow, feed, season, time of lactation and the climate. However, as milk is pooled in a farm storage tank, then into tankers and factory silos, these variations are averaged out.

In the United States, the Association of Official Analytical Chemists recommends that milk with a freezing point below -0.525°C may be presumed to be free of added water. Thus, for each 1% addition of water, the freezing point between -0.525°C and 0°C will rise by 1%. However, the presence of added water needs to be confirmed by tests on authentic milk samples from a similar source.

In Australia, there is currently no specified legal standard for the freezing point of milk. However, a freezing point of -0.517°C is regarded as the upper limit for genuine milk. Some of the dairy companies use higher levels for quality control purposes, e.g. -0.512°C for tanker milk and -0.500°C for farm milk. This provides for a margin of error and for natural variation, especially in periods of drought when cattle might be under nutritional stress. Thus, operational standards for freezing point need to be set locally, based on the local industry conditions and circumstances.

The freezing point test has been used for estimation of water in milk for almost 100 years. The early reference test, Hortvet method, has now been replaced by the thermistor cryoscope, which is now the internationally recognised standard method [ISO 5764:2002. *Milk. Determination of freezing point. Thermistor cryoscope method (Reference method)]*. Some models of the Foss MilkoScan and similar instruments made by other manufacturers allow the freezing of point of milk samples to be determined in-line together with the composition of milk.

6. What is the difference between the crude protein and true protein content of milk?

Crude protein, sometimes called total protein, is estimated by measuring the total nitrogen content of milk and multiplying it by a standard empirical factor to express the results on a protein equivalent basis. The total amount of nitrogen in milk, however, comes from both protein and non-protein sources. True protein reflects only the nitrogen associated with protein and does not include the nitrogen from non-protein sources.

Non-protein nitrogen is a normal component of milk. The non-protein nitrogen (NPN) fraction is composed of urea and other low molecular weight nitrogen-containing compounds such as creatine and creatinine. About 50% of the NPN in milk is urea, and variation in NPN is attributed primarily to variation in urea content. Non-protein nitrogen has little nutritional value and does not contribute to cheese yield. The amount of NPN in milk varies naturally, just like any other milk component. On average, NPN accounts for about 0.19% of the protein content of milk when it is expressed it is as a crude protein value but may range from 0.12% to 0.25%.

Kjeldahl nitrogen analysis forms the basis for the reference tests for both crude and true protein. In both cases, total nitrogen is multiplied by empirical factor 6.38 for dairy protein to express the results on a protein equivalent basis. This factor is constant and unique for dairy protein and is different for other food proteins such as egg protein and wheat protein.

The modern infrared milk analysers detect a signal generated from the protein molecules but cannot detect the NPN substances. Thus, while the infrared analysers can be calibrated to take account of the NPN component, errors in protein measurement due to variation in the NPN content of milk can occur. Measurement of true protein eliminates these errors (Barbano and Lynch, 2007).

7. How does the composition of milk expressed on a mass/mass basis differ from that expressed on a mass/volume basis?

Milk has a specific gravity of 1.032; thus 1 L of milk weighs 1.032 kg. Assume, for example, that 1 L of milk contains 33 g of milk fat: the fat content of this milk can be expressed as either 33 g/L (or 3.3% m/v, where m/v = mass/volume), or 32 g/kg (or 3.2% m/m, where m/m = mass/mass). Thus, one method of expressing milk composition can be converted to the other simply by applying 1.032 as a conversion factor.

In Australia, where farm milk production is measured in litres, the composition of farm milks for payment purposes is usually expressed on a mass/volume basis. However, the composition of processed products is usually expressed on a mass/mass basis.

B Microbial contaminants of milk

1. What is the Total Bacterial Count of milk and how is it determined

The Total Bacterial Count is a measure of the numbers of the bacteria in milk that are able to form colonies on a suitable growth medium (Plate Count Agar) when incubated aerobically at 30°C for 72 hours. Usually, 1 mL of serial dilution of the milk, e.g. 1/100 or 1/1000, or a small aliquot of milk dispensed with a micropipette, e.g. 10 µL (1/100), is mixed with 12-15 mL of the molten agar medium and incubated for a set time to allow bacterial colonies to grow. Thereafter, colonies are counted and multiplied by the dilution factor for the sample. Since colonies and not bacteria are counted, the count is correctly expressed as 'colony-forming units' (cfu) per mL; in some cases, a colony will be derived from a single bacterial cell, while in other cases a colony might be derived from a clump of cells.

The Total Bacterial Count, also known as the Standard or Total Plate Count is recognised worldwide as the best overall indicator of the microbiological status of milk in terms of its hygienic production and storage history.

The Australian Standard Method for the standard plate count on milk and other foods has been published by SAI-Global (2004). The plate count method has been discussed by Brazis (1991). Faster and less costly variations of the standard plate count method that were widely used by the Australian dairy industry for routine determinations of the total bacterial count of farms milks before the introduction of automated bacteria counting equipment (see FAQ on 'Bactoscan' below) are the plate loop method (Hill, 1991) and the roll tube method (Slaghuis, 1991); both of these continue to be valid techniques for routine use.

2. How is the Thermoduric Count of milk determined?

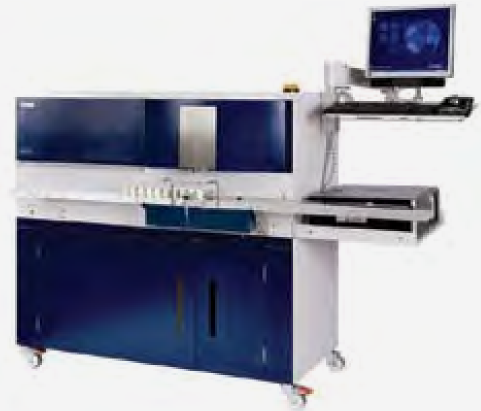
A sample of the milk is pasteurised in the laboratory by placing it in a glass tube or bottle and heating it in a water bath at 63°C for 30 minutes, then cooling. The heated sample is then plated out using the standard plate count method as described above. The Bactoscan or similar instruments cannot be used in this case, as they will give an erroneous result.

3. How is the Psychrotrophic Count of milk determined?

Psychrotrophic count of milk is measured by plating out using the standard plate count method as described above and the plates are incubated at 7°C for 10 days.

4. What is a BactoScan?

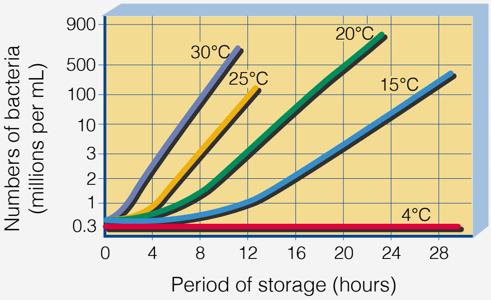
A BactoScan is a laboratory instrument manufactured by Foss for the counting of bacteria in milk. The analytical method is based on flow-cytometry principles and specifically counts single bacteria. It is widely used by Australian dairy companies for determining the total bacterial count of raw milk for quality control and payment purposes. For more information on the BactoScan equipment, refer to the Foss website: **www.fossanalytics.com**



Foss BactoScan

Source: Foss, Denmark, **www.fossanalytics.com**

Figure 5 Simple representation of the effect of storage temperature on the growth rate of bacterial contaminants in raw milk



Note. The numbers of bacteria in raw milk stored at 4°C will also increase with further storage, due to growth of psychrotrophic bacteria (see table below).

Source: Modified from the Tetra Pak Dairy Processing Handbook, Third Edition, 2015

5. What factors influence the multiplication of bacteria in milk during storage?

The temperature and duration of storage, the number and type of bacteria in the milk and, to a lesser extent, the natural inhibitory systems in the milk, all influence the increase in bacterial numbers in stored milk. Because of the wide variation in the initial microflora, and also in the conditions under which the milk is stored, only generalisations can be made about the changes that occur in the microflora during storage and transport.

The temperature of storage is the most important factor (refer to chart below). If, for some reason such as loss of refrigeration due to failure of electricity supply, the milk is stored at 25-30°C, the spoilage organisms that would be most active are the streptococci and the coliforms. Consequently, acid production would occur and the milk could show evidence of souring and spoilage within a few hours. The effects of storage at 15-25°C would be similar, but the spoilage will take slightly longer. Below 15°C, the psychrotrophic Gram-negative rods predominate and the nature of the spoilage is different from that at higher temperatures and takes longer to become evident (Bramley and McKinnon, 1990). Acidity becomes progressively less evident as the temperature is reduced and the spoilage is increasingly due to the heat-stable extracellular proteases and lipases that are produced by the psychrotrophs. Spoilage is characterised by unclean, bitter and rancid flavours, protein degradation and protein instability.

The variability in the rate of increase in bacterial numbers that can occur during cold storage of raw milk is illustrated in the table below. The samples A-G were taken from the bulk vats on different farms after two milkings with storage at less than 4°C, then stored for a further four days at 5°C and the total bacterial count determined daily. The data illustrated that the initial total bacterial count was not always a good guide for the increases in bacterial numbers that occur during storage. It is the numbers of psychrotrophic bacteria initially present in the milk that is important.

Total bacterial counts of individual farm bulk milks stored at 5°C (after Bramley and McKinnon, 1990)

Farm	Total bacterial counts per mL during storage at 5°C after collection of samples from the farm bulk milk tank			
	0 days	**2 days**	**3 days**	**4 days**
A	5,800	3,300	7,900	14,000
B	14,000	10,000	11,000	70,000
C	14,000	10,000	710,000	15,000,000
D	28,000	83,000	2,800,000	18,000,000
E	62,000	400,000	9,500,000	41,000,000
F	170,000	110,000	110,000	130,000
G	240,000	1,800,000	8,900,000	17,000,000

C Mastitis and somatic cell count of milk

1. What effect does mastitis have on the quality of milk?

The inflammation of the udder caused by the mastitis infection affects the circulation of blood through the udder and, as a consequence, volume of milk produced is reduced and the composition of the milk changes as summarised below:

- decreased production of lactose;
- increased influx of salts;
- decreased production of casein;
- increased influx of blood and therefore increased somatic cell count;
- increased influx of enzymes, especially plasmin, which is a heat stable proteolytic enzyme;
- increased influx of immunoglobulins;
- changes in quality of fat; and
- decreased quality of the milk fat globule membrane.

The reduction in milk quality associated with elevated somatic cell count can lead to inefficient processing and undesirable quality of products. Some of the quality defects progressively become more pronounced as the somatic cell count of the milk increases. These include:

- deterioration in milk flavour including development of a rancid taste;
- decreased yield of cheese due to changes in protein and fat;
- longer renneting time in manufacture of cheese;
- increased cheese moisture, resulting in weak and pasty body and defects in flavour;
- longer whipping time for cream; and
- reduced shelf life of manufactured dairy products (Anon., 2005; Auldist, 2003).

2. How is the somatic cell count of milk measured?

The oldest method for enumerating the somatic cells in milk is the direct microscopic count, often combined with methylene blue staining. While this method is slow and labour intensive, it is still widely used as a reference method for calibration of the modern analytical instruments.

Instrumental systems, such as Foss Fossomatic cell counters, are now generally used. The Fossomatic system utilises the principles of flow cytometry. The nuclei of the somatic cells are stained using ethidium bromide and then counted as they pass in a thin film under a high energy light source (Kelly, 2003).

Instrumental cell counters broadly similar to the Fossomatic include the Bentley Somacount range and Delta Instruments Somascope range.

For more information on the Fossomatic, Somacount and Somascope instruments, refer to Section 10 above.

3. What are the recognised standards for somatic cell count?

There are no legal standards set for somatic cell count in milk in Australia but a level of less than 400,000 is acceptable in Australia. The European Union has set an acceptance standard of less than 400,000 somatic cells per mL for herd milk, calculated as the geometric average over two months with at least two tests per month or over three months with at least one test per month, effective from 1 January 1998 (Council Directive 92/246/EEC of 16 June 1992).This standard is used as the benchmark by the Australian dairy industry.

Most dairy companies in Australia include a graduated scale for somatic cell count in their milk payment systems, with counts less than 200,000 or 250,000 per mL attracting the highest payment.

The Australian dairy industry launched a national mastitis and cell count control program, titled 'Countdown Downunder' in 1998. One of the goals of this program was to work towards having all milk supply below 400,000 cells per mL, and 90% of all milk supply below 250,000 cells per mL. During 2000-2004 the percentage of the milk supply with a cell count below 400,000 per mL increased from 90.7% to 94.6%, and the percentage below 250,000 per mL increased from 64.2% to 70.8% (refer to website **https://www.dairyaustralia.com.au/Countdown**).

D Residues of antimicrobial products

1. What steps are necessary on the farm to ensure that milk is not contaminated with residues of antimicrobial products?

- Identify the correct cow to be treated;
- If treating a case of clinical mastitis, identify the correct quarter of the udder to be treated;
- Select a suitable antimicrobial or antibiotic and ensure that it is registered for that use;
- Clearly mark the treated cow and quarter;
- Accurately record the treatment date, cow number, quarter treated, product used and withholding period (WHP);
- Ensure that the milk from treated cows does not enter the milk supply;
- Ensure that milking of cows under treatment is done last;
- Ensure that withholding periods for cows under treatment are strictly observed; and
- Ensure that milk from treated cows is held separately and discarded.

2. What are typical withholding periods (WHPs) for antimicrobial products registered for the treatment of mastitis by intramammary infusion?

WHPs are product specific and the label must be checked. For antimicrobial products registered for use during lactation, the WHP is commonly 3 or 4 days which is 6 or 8 milkings, but for some products it is 7 days or 14 milkings. It is important that instructions on the product label are followed.

For antimicrobial products registered for use as dry cow therapy, the WHP is commonly 30 days, but is 35 days for some products. If the cow calves before the WHP has expired, the milk must be withheld from supply for human consumption for a period specified on the product label and this period can be as long as 10 days.

3. What are some common causes of contamination of milk in the bulk milk tank on the farm by antimicrobial residues?

The common causes are:

- Treated cows not clearly marked or identified;
- Treatment details of the cow not recorded;
- WHP not observed;
- Treated cows accidentally milked along with other cows not under treatment and their milk added to the bulk milk;
- Products not used as per label or in combination with other veterinary medicines;
- Treated cows not milked last or equipment not cleaned after milking a treated cow;
- Milk from treated cows not clearly segregated from the main milk supply; and
- Cows purchased and new owner not aware of their treatment history.

4. How are residues of antimicrobial products detected in milk?

The standard reference method for detection of residues of antimicrobial chemicals, also widely referred to in Australia as inhibitory substances or antibiotics in milk is a biological disk assay using *Bacillus stearothermophilus var. calidolactis* as the indicator organism. This organism is particularly sensitive to penicillins, β-lactam compounds, which can be detected at levels exceeding 0.0015 μg/mL. However, the method is also reasonably sensitive to the cephalosporins, also β-lactam compounds, and the sulphonamides. The presence of β-lactam compounds, penicillins and cephalosporins can be confirmed by addition of penicillinase (β-lactamase) to the sample. The method can be made semi-quantitative for β-lactam compounds by constructing a standard reference curve using a series of dilutions of penicillin G in milk known to be free of inhibitory substances [refer to Australian Standard AS 1766.3.11-1991, Food microbiology - Examination of specific products - Dairy products - Test for penicillin, or method 2.1.1.1, International Dairy Federation, 1991a]. This test is not used by industry for daily screening of milk supplies.

Several 'Broad Spectrum' milk residue test kits based on the standard reference method with *B. stearothermophilus* var. *calidolactis* as the indicator organism have been developed by commercial companies, and these are widely used by Australian dairy companies to screen both milk tankers and individual farm supplies for the presence of antimicrobial residues. Brands of these tests include Delvo SP-NT, Copan, AIM BRT MRL, Charm II and Eclipse. These tests, which are qualitative and designed to indicate whether or not an antimicrobial substance is present in milk at levels exceeding the MRL, take about 2.75 hours to complete.

Several more rapid tests, based on the Enzyme-Linked Immunosorbent Assay (ELISA) technique, have been also developed. These have excellent sensitivity, specificity, and can be completed in 10 minutes. Brands of these tests include SNAP, Charm ROSA, Beta-Star, Delvo SP-NT, Copan, AIM BRT MRL, Charm II, and Eclipse. Some Australian dairy companies use these tests to do an initial check on the milk from farms arriving at the factory in tankers. This is followed up with one of the 'Broad Spectrum' test kits that use *B. stearothermophilus* var. *calidolactis* as the indicator organism, as described earlier.

An overview and listing of the antimicrobial screening test kits available in Australia has been prepared by Dairy Food Safety Victoria - Technical Information Note – Antibiotic Screening dated July 2016.

An overview of the 'higher level' chemical-physical confirmation tests for the detection of antimicrobial residues in milk has been prepared by Pedersen and Suhren (2000). These tests, many of which utilise high pressure liquid chromatography (HPLC), can only be carried out in well-equipped analytical laboratories and hence are not routinely used by industry for screening purposes.

5. What is the incidence of antimicrobial residues in Australian dairy products?

Australian dairy companies test each tanker load of farm milk on receival at their factories for the presence of antimicrobial residues, using one or more of the test kit methods referred to earlier. Any milk containing residues is rejected for human consumption and traced back to identify the farm which supplied the milk.

No inhibitory substances, specifically the antimicrobial chemicals penicillin G, streptomycin and oxytetracycline, were detected in Australian dairy products such as whole milk, chocolate milk, Cheddar cheese and infant formula) during the 20th Australian Total Diet Survey conducted by Food Standards Australia New Zealand in 2003 (refer to website: **foodstandards.gov.au/publications/Pages/20thaustraliantotaldietsurveyjanuary2003/20thaustraliantotaldietsurveyfullreport**).

E Foreign physical matter in milk

1. How can the contamination of milk during milking with sediment and foreign matter be minimised?

- Apply teat cups only to clean and dry teats.
- Wash and dry dirty teats before applying the teat cups.
- Avoid washing udders.
- Dry the wet teats with clean and disposable paper towels only.
- Ensure hands of milkers on the farm are clean.
- Keep lanes and gateways free of mud.
- Clip or singe udder hair.
- Trim cows' tails.
- Use a milk filter that can handle the maximum milk flow rate.
- Change filter socks at each milking, and
- Wash and sterilise reusable filter socks before reuse.

F Weed and feed flavours in milk

1. What are some common stock feeds and weeds that produce taints or off-flavours in milk?

Feed	Cause	Off-flavour
Beet byproducts	Trimethylamine	Fishy
Common rye and wheat	Trimethylamine	Fishy
Onion pulp	Rumen action	Onion
Gramineae (grasses)		Off-flavour
Legumes or legume hay		Bitterness
Cruciferae	Mustard oil	Sharp radish-like flavour
Residues from processing of fruit and vegetable		Off-flavour
Dry feed	Lack of a-tocopherol	Oxidised
Poor quality silage		Silage flavour
Land Cress		Burnt, unclean, sharp pungent, herb-like

G Aflatoxins

1. How can the incidence of aflatoxin in milk be avoided?

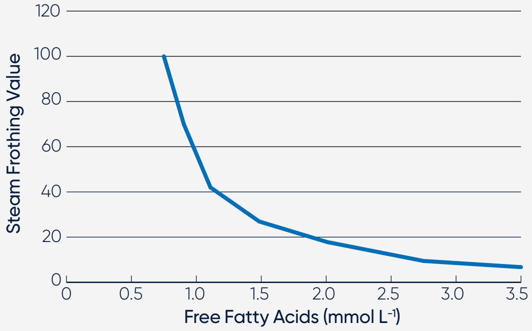
Because aflatoxins are not produced in pasture, grass hays and silage, the pasture based dairy production systems that are widely used in Australia present a low risk for the incidence of aflatoxin in milk. The aflatoxin risk is confined to feeding of grain based concentrates, peanut by-products, bakery waste and material containing fruit and vegetable by-products, particularly if they have not been properly dried or allowed to get wet. Dairies purchasing grain and mixed feed should obtain a written assurance from their supplier that it meets local stock food standards for aflatoxin; in Queensland, for example, an upper limit of 0.02 mg aflatoxin B1/kg in stock food for dairy cattle is specified in the Agricultural Standards Regulations 1997 (Blaney *et al.*, 2006).

H Defects in milk and impact on uses for the milk.

1. What is the cause of lack of frothing in cappuccino coffee?

A major functionality effect of lipolysis in milk is depression of its frothing and foaming ability when injected with steam. This causes difficulty in producing acceptable froth when making cappuccino coffee. It is due to the partial glycerides produced during lipolysis, which are surface active and displace the froth stabilising proteins at the air–water interface of the foam bubbles. A typical plot of the relationship between the frothing capacity shown by Steam Frothing Value and lipolysis measured by Free Fatty Acid level of milks is shown below. This plot demonstrates that as the free fatty acid (FFA) level increases due to lipolysis, the volume of froth produced by injecting steam into the milk becomes progressively smaller. In this case, the Steam Frothing Value (SFV) of the milk before the onset of lipolysis was 100, corresponding to a FFA level of 0.75 mmol/litre. However, a modest increase in the FFA level to 1.0 mmol/L resulted in a decline in the SFV to 58, while a further increase in the FFA level to 3.0 mmol/L resulted in a decline in the SFV to just 8 (Deeth, 2006).

Relationship between the steam frothing value (SFV) and free fatty acid (FFA) level of milks. (SFV = the volume of froth on the milk after steam injection x 100/original volume of milk.)



Source: Deeth (2006), based on data originally published by Deeth and Smith (1983).

In practice, milks with an FFA level greater than 1.5 mmol/litre are likely to have impaired frothing properties, while the frothing capacity of milks with an FFA level greater than 2.0 mmol/litre is markedly reduced. An FFA >1.5 is a reasonable threshold value for factory screening of milk from farm storage tanks or farm collection tankers (Deeth and Smith, 1983).

***Note**. The terms mmol/litre and meq/litre are numerically identical for monovalent acids such as fatty acids.*

2. What are the main differences between milk lipoprotein lipase (LPL) and the bacterial lipases produced by the psychrotrophs growing in refrigerated raw milk?

Milk lipoprotein lipase is naturally present in milk. In contrast, the bacterial lipases are not originally present in milk but are produced by the psychrotrophic bacteria that enter the milk from various sources such as contaminated equipment. These psychrotrophs are able to grow slowly in the refrigerated raw milk and can produce extracellular lipases if their counts are allowed to reach high levels, such as >one million per mL. The main differences between the two types of lipases are summarised in the following table, adapted from Deeth (2006).

Milk lipoprotein lipase (LPL)	Lipases produced by psychrotrophic bacteria
Destroyed by high temperature-short time (HTST) pasteurisation	Stable to HTST and even to ultra-high temperature (UHT) treatment
Milk fat globule membrane (MFGM) acts a barrier to lipid substrate	MFGM presents no barrier
Activated by serum lipoproteins	Most not activated by serum lipoproteins
Effect mostly associated with fresh milk and cream	Effect mostly associated with stored products—UHT milk, cheese, butter, milk powders
Effect in cheese and butter obvious at manufacture and does not change during storage	Effect in cheese and butter obvious only after storage and gets progressively worse during storage
High levels in raw milk	Trace levels only in good quality raw milk

3. How can hydrolytic rancidity caused by milk lipoprotein lipase be prevented?

- Avoid large numbers of cows in late lactation, especially under poor feed conditions;
- Provide a constant balanced diet for the cows;
- Exclude milk from cows with clinical mastitis and discard such milk;
- Correctly design, install and maintain milking equipment;
- Avoid excessive air intake at teat cups;
- Minimise centrifugal pumping, especially of warm milk and with air incorporation from the suction side of the pump;
- Avoid vigorous agitation of raw milk, particularly using air and at higher temperatures;
- Avoid fluctuation in storage temperature of milk;
- Never mix raw and homogenised pasteurised milk; and
- If milk is homogenised during the pasteurisation process, use a processing system that provides for heat treatment of the milk immediately after the homogenisation step (Deeth and Fitzgerald, 2006; International Dairy Federation (1991b)).

3.13 Glossary

Bulk milk cell count (BMCC).

The number of somatic cells in a consignment of bulk milk from a farm, expressed as cells per mL. Dairy companies usually determine the BMCC on a sample of milk taken from the farm storage tank at every pickup and the results are widely used as a guide for the milk payment scheme.

Colostrum

The secretion from the mammary gland or udder of the cow for the first few days of the lactation. It differs in composition from the later secretion, known as normal milk.

HACCP

Hazard Analysis and Critical Control Points, a system for managing food safety.

Lipolysis

The hydrolysis of triglycerides or triacylglycerols, the major lipid components of milk fat, catalysed by lipase enzymes. The products of the reaction are free non-esterified fatty acids, partial glycerides such as mono- and di-glycerides and, in some cases, glycerol. A distinguishing feature of lipases is their ability to act at the lipid–water interface of emulsions of long chain, insoluble triglycerides.

Organoleptic

Tests relevant to the organs of sense such as taste and smell. An organoleptic assessment of quality includes sight for visual appearance, smell for odour, taste, if safe to do so and feel, if relevant.

Mastitis

An inflammation of the mammary gland or udder, caused by an intra-mammary microbial infection. Composition of the milk changes and quality of the milk is impaired.

Maximum Residue Limit (MRL)

The MRL is the maximum limit of an agricultural or veterinary chemical that is permitted to be present in a food, usually expressed in milligrams of the chemical per kilogram of the food (mg/kg). MRLs are published in the Australia New Zealand Food Standards Code. If an MRL is not published in the Code for a chemical in a particular food, there must be no detectable residues of that chemical in that food.

Mesophile

A microorganism that grows best in the temperature range 25-40°C, but cannot grow at 4°C.

Psychrotrophs

A microorganism that is capable of growth at 4°C also at 20°C and above with optimum growth temperature often in the range 25-28°C.

Thermoduric

A microorganism that can survive the heat treatment applied to milk when it is pasteurised at 72°C for 15 seconds or 63°C for 30 minutes or equivalent.

Thermophile

A microorganism with an optimum growth temperature around 50-60°C.

Somatic cell count

The number of somatic cells in milk, expressed as cells per mL. The count is an indicator of udder health.

Somatic cells

The cells present in milk that originate in the mammary gland. They are mostly white blood cells, with a small percentage of epithelial cells also present. The number of cells in the milk can increase dramatically during periods of inflammation of the mammary gland.

Withholding Period (WHP)

In the case of milk, the withholding period is the minimum number of days that must elapse between the last administration or application of a registered veterinary chemical product to a cow. For example, treatment of mastitis with an antibiotic or the feeding of treated stock food, and the collection of milk from that cow for human consumption. In Australia, the WHP, if applicable, must be stated on the label of every registered veterinary chemical product.

Withholding Period for grazing

In the case of milk, the withholding period for grazing is the minimum period that must elapse between the last treatment of a crop or pasture with a registered agricultural chemical with a stated withholding period for milking cows and the collection of milk from those cows for human consumption.

3.14 References and further reading

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04 Milk Powders Manufacture, Functionality and Applications

Content

Abbreviations used in this chapter

ADMI	American Dried Milk Institute (Now the ADPI - American Dairy Products Institute)
AIC	Australian Ingredient Centre (Now DIGA Dairy Ingredients Group of Australia)
AMF	anhydrous milk fat
aw	water activity
BD	bulk density
BMP	butter milk powder
CSIRO	Commonwealth Scientific & Industrial Research Organisation
EPT	extrusion porosification technology
FCMP	full cream milk powder
FF	free fat
GDL	glucono-delta-lactone
HTST	high temperature short time
IDF	International Dairy Federation
PV	peroxide value
PSD	particle size distribution
REM	recombined evaporated milk
RSCM	recombined sweetened condensed milk
SMP	skim milk powder
SEF	solvent extractable fat
UDWPN	un-denatured whey protein nitrogen
UHT	ultra-high temperature
USDEC	United States Dairy Export Council
WPNI	whey protein nitrogen index
WFN	white fleck number

4.1 Introduction

Milk powders are used by consumers and food manufacturers as a substitute for fresh milk and fresh milk products and as ingredients for the manufacturing of many processed products. Examples include traditional dairy products such as yoghurt and ice cream to confectionery and, bakery products, health drinks and nutraceuticals. The quality and functionality of milk powders determines the effectiveness of their use and thus the acceptability of the end products to consumers.

All milk powders are manufactured to certain specifications which define their composition and physical, chemical, and microbiological quality. Equally important are specifications relating to the functionality of the powders with respect to their ability to perform functions as required by the end users in specific applications. That is, powders can have the same composition, physical and microbiological attributes, but they can perform very differently if they have different functionality. A good example is low heat, medium heat and high heat skim milk powders which have similar compositions but vastly different functionality and applications. The functional attributes are not always set out in the standards, specifications or agreements but they are very important for the end user.

There is a very broad range of 'milk powders' available today. This chapter concentrates on:

- Full cream milk powder (FCMP); also known as whole milk powder (often abbreviated to WMP): typically produced by the removal of water from fresh whole milk, resulting in a dried product with a maximum of 4.5% moisture (more typically 2.5%) and a minimum of 26% milk fat, with all other constituents, lactose, minerals and proteins, in approximately the same ratio as the milk from which it was manufactured.
- Skim milk powder (SMP) which is non-fat dried milk (sometimes abbreviated to NFDM): typically produced by the removal of water and fat from milk, resulting in a dried product with a maximum of 4% moisture (more typically 3.5%) and a maximum of 1.5% milk fat (typically less than 0.5%), with all other constituents, lactose, minerals and proteins, in approximately the same ratio as the milk from which it was manufactured, and
- Buttermilk powder (BMP): typically, the product resulting from the removal of water from buttermilk, the liquid by-product of butter manufacture, resulting in a dried product with a maximum of 4% moisture (range 3.0 to 4.0%), a minimum of 4.5% milk fat and approximately 30% protein.

This chapter considers the manufacture, specifications, functionality, applications and nutritional aspects of these powders and then explores relevant frequently asked questions.

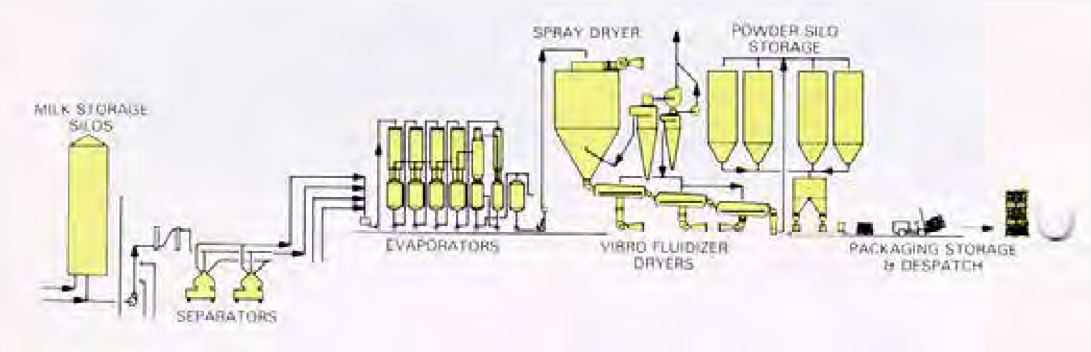
4.2 Overview of manufacturing principles

The basic aim in the manufacture of milk powders is to convert liquid milk to powder, thus extending shelf life and reducing transport and handling costs. The process must be such that there is minimal loss of nutritive value and functional properties. The powder must be easy to handle, especially during use and any deterioration during storage must be kept to a minimum. It must be easily reconstituted or repacked for a range of applications and must be able to display all the functional attributes of the original milk and in many cases demonstrate enhanced functionality.

The manufacture of conventional milk powders, SMP, FCMP and BMP utilise some common unit processes such as evaporation and spray drying. Additional processes may be required specific to the product such as extent of heat treatment for low heat, medium heat, and high heat SMP.

Figure 1 shows a typical flow diagram for milk powder manufacture by evaporation and spray drying. The raw material for SMP and FCMP is fresh milk whereas, for BMP it is the fresh buttermilk, by-product of butter manufacture. Each of the following unit processes plays a significant role in the manufacture of a stable, and functional milk powder with consistent good quality.

Figure 1 Typical flow diagram for the manufacture of milk powder



Starting material

For SMP and FCMP the starting material is standardised milk to ensure it meets the desired final powder composition. This entails the separation of whole milk to produce a skim milk stream, which typically contains less than 0.1% fat for SMP manufacture and a cream stream. For FCMP the skim and cream streams are remixed at a specific ratio to give the desired fat to solids non-fat ratio, this may also require addition of cream or skim to the full cream milk stream.

Preheating

The standardised milks are then subject to a preheat treatment. A range of time / temperature regimes are applied typically with a minimum of pasteurisation at 72°C / 15 sec. For SMP, different heat treatments are applied to the milk for low, medium and high heat powders to impart or improve specific functional properties, such as flavour. Heat treatment denatures whey proteins, with the percentage of whey protein denaturation increasing with heat treatment. The degree of denaturation is normally expressed as Whey Protein Nitrogen Index (WPNI) as milligrams of undenatured whey protein (udwp) per gram of powder. This classifies SMP either low, medium or high heat (see also FAQ).

Table 1 Categories of spray dried skim milk powder

Category	Temp/time	WPNI mg/ u.w-p
Extra low-heat	>70°C	*
Low-heat (LH) powder	70°C/15s	>6.0
Medium-heat (MH) powder	85°C/20s	5–6.0
"	90°C/30s	4–5.0
"	95°C/30s	3–4.0
Medium high-heat (HH)	124°C/15s	1.5–2.0
High-heat (HH)	appr. 135°C/30s	<1.4
High-heat high stable (HHHS) (from selected milk)	appr. 135°C/30s	<1.4

*Not measurable

Table by Sanderson N.Z, J. Dairy Technology, 2, 35 (1967)

Concentration

The milk is then concentrated to around 50% solids by the removal of water in a thermal evaporator. The configuration of this is usually of multiple effects with a host of vertical tubes bundled together with product flowing down the tube inner and heat being applied on the outer. These units operate under a vacuum to decrease the temperature of evaporation and are thus very economical, removing up to 30 kg of water for every 1 kg of steam used. This efficiency is obtained by reusing the heat of the removed vapour, and by the use of mechanical or thermal recompression to boost the temperature of the vapour. Low temperatures are used (~45 - 68°C) to enable milk to 'boil' at low temperature under vacuum. There is virtually no thermal damage to the milk solids as the concentration of milk is lifted to 50-55% solids.

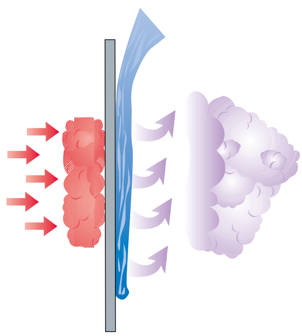
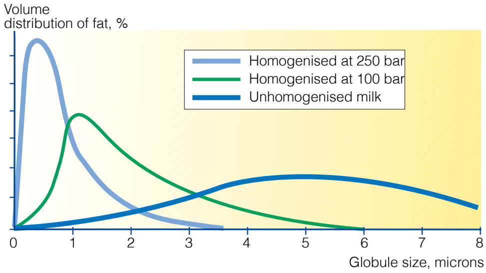


Fig. 6.5.1 *General principle of evaporation. A partition is heated by hot steam and vapour evaporates from the liquid on the other side.*

Homogenisation

Following evaporation, the concentrate for SMP is introduced to the spray dryer. However, for FCMP and BMP the concentrate is homogenised (at 50 to 75°C at total pressures up to 90 bar usually with two stage configuration) prior to spray drying to create a stable emulsion of much smaller fat globules protected by encasing them in a thin film of milk protein.



From Tetra Pak Dairy Processing Handbook

Atomisation

The concentrate is then introduced into the main chamber as a thin mist using atomisation – either centrifugal or nozzle atomisation. There is a vast range of configurations and designs of spray dryers. These incorporate different shaped main chambers, alternate atomisation technologies, single and multi-stage layouts, different air exit points, internal and external fluid beds, and different agglomeration systems. Each design is often product specific but many are multi-functional. After the initial drying the powder is often instantised by the application of lecithin to fat containing powders or returning the fines to the main chamber for SMP to enhance dispersibility. Secondary drying is completed in fluid bed dryers operating at low temperatures and the powder is generally packed in 25 kg multiwall bags.

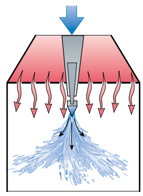


Fig. 17.5 *Stationary nozzles for atomising the milk in a spray drying chamber.*

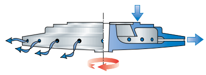


Fig. 17.6 *Rotating disc for atomising milk in the spray drying chamber.*

From Tetra Pak Dairy Processing Handbook

Roller Drying: An older technology called roller drying which is utilised for the manufacture of FCMP specifically for use in chocolate manufacture because the powder has high free fat content which is desired functionality in chocolate manufacture. (see FAQ). There are also some new drying systems showing promise such as extrusion porosification technology (EPT) developed by French company Clextral. The patented EPT process involves the spray drying of products and ingredients with a high amount of solids, which delivers a unique porosified powder structure. The EPT operates at a lower temperature than regular spray drying which not only saves large amounts of energy but causes significantly less damage to a food's flavour and nutrients.

4.3 Functionality

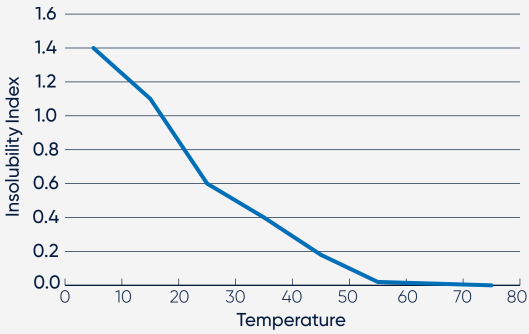
Milk powders contribute three distinct types of functionality – physical, nutritional, and physiological. Physical properties refer to the structural and chemical attributes that the powder brings to its use as an ingredient in a food system. Examples include the ability to bind and form a gel or a stable foam. These are largely determined after reconstitution and can also impact the sensory properties of resulting products. Nutritional functionality refers to the ability of a powder to be a source of nutrients. Based on its composition, physiological functionality refers to the ability of milk powders to facilitate a bio modulating response because it contains bioactive substances that the body uses for improved physiological function such as improved gut function. This can be due to the milk's natural composition (e.g. colostrum or milk peptides) or because the powder can be used as a carrier of additional functional health substances such as probiotics or prebiotics added during manufacture.

Physical functionality

Solubility

Solubility is the most important functionality as it is a prerequisite for most other physical functionalities. If a powder does not solubilise completely as a homogeneous system, it will be difficult to use it properly. The insoluble material is usually denatured proteins or combinations of casein, whey proteins and lactose. Whole milk powder often exhibits more insolubility than skim milk powder. The solubility of powders can deteriorate during storage depending on conditions such as temperature and humidity.

Figure 2 Insolubility index of reconstituted powder at high solids as a function of the temperature (Unpublished information)



Factors which influence the solubility of powders include seasonal variations in composition and quality of milk, preheating of milk during manufacture (the higher the temperature the more susceptible to insolubility), the type of dryer used (roller drying being particularly detrimental to solubility), the atomisation system (nozzle vs centrifugal disc), the configuration of the spray dryer (single versus multi stage dryers), the degree of homogenisation (FCMP) and the conditions of manufacture. The temperature of reconstitution also plays a key role in determining the degree of insolubility of powders particularly at high solids as shown in Figure 2. showing how the insolubility index of the premix for recombined sweetened condensed milk (RSCM) can rise dramatically if the reconstitution water temperature is decreased. Milk powder reconstituted at single strength total solids demonstrates similar behaviour but usually not to the same extent as at high solids.

Instant properties

This refers to the ability of powder to instantly reconstitute and is an essential attribute for many applications. The process of redissolving the powder in water is influenced by many factors such as temperature of water, which at times are counter-productive to other functionalities.

The instant properties of powders are influenced by several related attributes:

- **Flowability**

Flowability is important for transport, weight measurement, packaging, storage, and handling, both as a powder and in subsequent applications. It is influenced by particle morphology (size, shape, and structure) and overall distribution of the powder particle sizes. Good flowability is usually obtained from larger particles, or agglomerates with a minimal number of smaller particles. However, this particle size distribution may have an adverse effect on bulk density (BD). Lower BD improves flowability but the relationship is not as strong with tapped BD. Uniformity of particle size also improves flowability but impacts BD.

The fat content significantly influences the flowability of powders, in particular proportion of 'free' fat on the surface of particles. Any increase in free fat will reduce flowability. The addition of free flowing agents to improve free flow (e.g. silicates) and/or the application of an instantising operation can be used to improve the flowability of powders.

- **Wettability**

Wettability refers to the ability of a powder to be wetted and in particular for water to penetrate the surface of the powder at a given temperature. If a powder fails to wet properly lumps may form. The degree of agglomeration, homogenisation, the amount of wettable surface and its nature (the presence of free fat is an inhibitor) and the amount of interstitial air influence wettability. Another relevant factor is the structure of the powder particle surface. If the surface has been hardened ("case-hardening") during drying, the ability of water to readily penetrate the particle is diminished.

- **Sinkability**

After powder has wetted, it becomes heavier and generally sinks to just below the surface of the water. This is influenced by particle density, composition of powder, and proportion of occluded air.

- **Dispersibility**

Once the powder has wetted and 'sunk' below the surface, the powder should display dispersibility which refers to the ability to disperse particles without forming dry lumps and with instantaneous disintegration of agglomerates into single particles. The key factor influencing dispersibility is agglomeration. For good dispersibility, agglomeration should be optimised to produce few agglomerates >250 micron, few compact agglomerates and very few or no fine particles which are detrimental to dispersibility.

Emulsion and foaming capacity

Milk powders can be used in applications where foaming and emulsifying properties are required, e.g. ice cream, mousse, and baked products. These properties are performed by the milk fat having a variety of physical interactions at the surface of air bubbles and by clumping of the fat globules. The hydrophilic and hydrophobic groups of milk proteins contribute through their surface-active properties, stabilising the air/water interface of air bubbles and the oil/water interface of fat globules. The factors that influence the foaming capacity of milk include pH, mineral balance, the status of the fat, temperature, the degree of denaturation of whey proteins (the greater the denaturation the lower the foaming capacity) and the presence of low molecular weight surfactants. The foaming capacity can be enhanced by having higher content of occluded air which is released upon reconstitution. Injecting air into the concentrate during atomisation further improves foaming capacity.

Heat stability

Heat stability is the ability of reconstituted milk, either single strength or concentrated, alone or in combination with other ingredients, to be heat processed and stored without unduly thickening, coagulating or precipitating. Concentrated milks are more susceptible to heat instability than single strength milks. The whey proteins are denatured when temperature above 65°C is applied, whereas casein, is stable up to temperatures of 140°C. Milk proteins are destabilised by heat-induced changes including a decrease in pH, denaturation of whey proteins and the shift of calcium and phosphate from the serum into the colloidal phase. Once the whey proteins have been denatured their state cannot be reversed whereas the effect on minerals, particularly calcium and phosphates, can be reversed when relatively low heat treatments are used. The inherent heat stability of milk can vary during the dairy season in pasture based countries such as Australia and is related to shifts in mineral balance and pH. This mineral balance phenomena is used to adjust the heat stability of milk and produce powders suitable for particular applications

Water binding capacity

The proteins and to a smaller extent lactose in milk powders can bind water and this is called water binding capacity. Casein can bind approximately 3.3 g of water per gram of protein. Undenatured whey proteins can bind ~0.4 g/g whereas denatured whey proteins can hold up to 2.5 g/g of water which is more than 6 times the level for undenatured whey proteins. Water binding capacity is important in in dairy, confectionery, bakery and meat application. In yoghurt for example, denatured whey protein from WPC can be used to overcome defect of water leakage.

Viscosity development

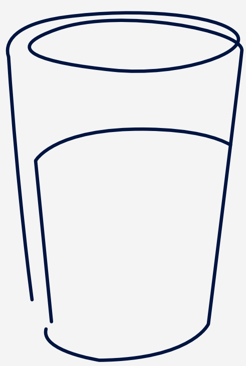
The proteins in milk powders can be used to modify rheological properties such as viscosity in several applications. This ability is influenced by the concentration of solids, temperature, and the dispersion and degree of denaturation of the whey proteins. This property predominantly occurs because of protein-protein interactions similar to those for gelation. Viscosity development is particularly important in yoghurt and recombined sweetened condensed milk (RSCM).

Hydration

Hydration refers to dissolving of milk powder on reconstitution to establish the original milk protein and mineral equilibria balance. The majority of this occurs rapidly in 10 – 20 minutes at temperatures above 25°C. Therefore, ideally hydration times for powders need not exceed 15-20 min at normal processing temperature of 40 - 55°C with a longer time only being implemented for higher solids solutions such as MPCs. For powders with low hydration ability, the hydration time required may be longer.

Colour

The ability of milk powders to influence colour is often overlooked. The powders themselves must meet colour specifications. The ability of powders to enhance colour through heating resulting in browning due to the Maillard reaction is an advantage in applications such as bakery and confectionery.



Gelation

Gelation refers to the ability of the proteins in dairy powders to form gels, hold water and fat, assist in structure development, and aid in texture and mouthfeel. The whey proteins can form heat induced gels and the caseins together with the whey proteins can form gel networks by rennet action (cheese manufacture) or by acidification, as in some dairy desserts.

Flavour

All milk powders must be free from any foreign flavours or taints. Flavour development due to proteins and fat during heat processing results in a range of different flavours. Fat also can act as a carrier of flavours that are fat soluble. Flavours developed through high heat such as caramelised flavour are helpful in selected applications such as confectionery.

Nutritional and physiological functionality

Milk and milk powders are a rich source of a range of essential nutrients, necessary for good health in humans. Therefore, the incorporation of dairy products into a well-balanced diet is highly recommended. From data presented by Miller (2000) it can be seen that the total amount of energy provided by milk in a typical USA diet at 9.3% is low. However, milk is a nutrient dense food which can supply a significant percentage of the recommended daily intake (RDI) of several micronutrients e.g. calcium at 73%. This can be further enhanced by the fortification of dairy powders during manufacture, (e.g. iron).

Milk powders contain proteins, carbohydrates, fat, vitamins, and minerals important for human health.

- **Proteins:** Casein represents approximately 80% and whey proteins 20% of total milk proteins. Milk proteins provide several essential amino acids including lysine. Milk proteins provide several functions beneficial to humans including reducing blood pressure, preventing dental caries, assisting in the prevention of some cancers, assisting the immune system and helping to develop bone strength. Both predominant proteins in milk, casein, and whey, have high protein efficiency ratios which supports human growth.
- **Carbohydrates:** the main carbohydrate in milk is lactose, others include glucose, galactose, and some oligosaccharides. Some people are lactose intolerant but lactose can be hydrolysed into glucose and galactose, by enzymatic action using lactase. Lactose has nutritional benefits because of its slow digestion rate, often with some reaching the colon intact enabling it to act as a nutrient for the natural gut flora.
- **Vitamins and minerals:** Milk is a good source of all the vitamins required for human health. These include the fat soluble vitamins A, D, E and K as well as others including B_1, B_2 and B_{12}. SMP lacks the fat soluble vitamins A,D,E,K but can be fortified with these if needed. Milk is also a good source of minerals, particularly calcium which is essential for cell membrane functions, hormonal regulation and bone health. Other minerals including magnesium, potassium, phosphorus, sodium, zinc and iron also play important roles.
- **Fat:** Milk fat has more than 400 different fatty acids. Milk fat also delivers fat-soluble vitamins. Other important milk fat components are conjugated linoleic acid, butyric acid, and sphingomyelin.

Milk is now known to assist with the following disorders:

- Cancer – Increased calcium and vitamin D reduces cancer promoting effects particularly in Western style diets. Calcium, vitamin D, bacterial cultures, conjugated linoleic acid and sphingolipids protect against colon cancer.
- Hypertension – There is increasing medical evidence suggesting that calcium, magnesium and potassium from milk can lower blood pressure and reduce hypertension risk in humans.
- Osteoporosis – Prevention of osteoporosis is influenced by bone mass at maturity around 30 years age. This is influenced by the intake of calcium and vitamin D in the young growth stages and post skeletal maturity. This is particularly of interest to post-menopausal women and to both men and women in their later life.

Measurement of functionality and physical characteristics of powders

There are a vast number of methods undertaken for the measurement of functional properties and physical characteristics of powders. Many of these are accepted worldwide as standard methods (e.g. AS 2300, IDF, ADPI Bulletin 916), others are proprietary or are used by individuals as a guide for purchase or for assessing the usefulness of particular powders for specific applications.

Bulk density (BD)

100g powder is transferred to a 250ml measuring cylinder. The surface is levelled and the volume measured (poured BD), the cylinder is then tapped one hundred times (loose BD), the volume recorded and then tapped a further 525 times for a total of 625 times (BD) and the final volume recorded. The volume measured after each of these operations is termed the poured, tapped, and bulk density. There are several variations of this method (e.g. up to 1250 taps and the use of specialised equipment such as the Stampf volumeter) and the method used must be quoted when a result is being given. Factors that can influence the BD include the interstitial air, the occluded air, the particle density, and the PSD.

Table 2 Typical analysis: loose BD

FCMP, non-agglomerated	0.56 – 0.66 g/ml
FCMP, agglomerated	0.45 – 0.52 g/ml
FCMP, instant	0.45 – 0.52 g/ml
Regular SMP	0.58 – 0.68 g/ml

(References: ISO 8156:2005, IDF 129A, ADPI Bulletin 916)

Colour

Colour can be measured against a set of standard colour discs. Another more defined method of measuring the colour or whiteness of milk powder is using a Chroma meter such as the Minolta colour meter which measures three colour parameters by tristimulus colorimetry: "a" value measures the redness, "b" value measures yellowness and the "L" value measures the lightness. An even spread of powder on a Petri dish is measured using the L, a, b scale at an illuminate of D65.

Table 3 Typical results

	L	a	b	Whiteness
SMP	101.33	-5.52	16.49	****
FCMP agglomerated	98.22	-6.05	28.01	***
FCMP instant	100.34	-5.86	22.67	****
FCMP non agglomerated	100.72	-6.12	22.39	****
BMP	98.58	-6.83	22.35	***

(Reference: AIC Powder Functionality Manual)

Viscosity

The inherent viscosity of milk powders can be measured in several ways depending on its intended application. Powder is dissolved at a set total solids and viscosity is measured at a specified temperature by a viscometer to yield a base viscosity for many applications. However, specific measurement techniques are required to test suitability for some applications such as reconstituted sweetened condensed milk (RSCM). For this application, the viscosity contribution of specific milk powders can be measured in two ways:

- using a laboratory assessment method such as Kieseker (1965) or Weerstra (1988)
- undertaking pilot scale manufacture of RSCM and measuring viscosity.

Heat stability

The heat stability of milk and milk powders is very important because heat treatment is applied in most powder applications. The test result must be relevant for that specific application.

One simple method involves heating a sample of milk or reconstituted milk in a sealed tube to a certain temperature (typically 120°C to 140°C) in a bath and measuring the time taken for the sample to coagulate. The longer the coagulation time, the more heat stable the milk or milk powder. This method does not measure thickening which can be an indicator of heat instability. Other methods using time coagulation criteria include mixtures of reconstituted milk with various amounts of ethanol (the ethanol stability test – Horne 1980).

However, these types of tests can only give consistent results on milk samples alone i.e. they can predict the heat stability of the milk itself under the conditions of the test, but they do not accurately predict the behaviour of milk powders in applications. This is particularly the case with concentrated milk applications such as recombined evaporated milk (REM). One option is to undertake pilot scale manufacture of the product and thus identify the ability of the powder to meet the heat stability requirements. Obviously, this method is rather costly and time consuming.

The Australian dairy industry has access to an improved method to that of Kieseker (1988) developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in which a laboratory scale analysis (See Figure 3) of a recombined powder and milk fat are subjected to a regime equivalent to that of the commercial manufacture of recombined evaporated milk (REM). A range of stabilising salts such as phosphates are added in a prescribed way to assist in identifying the maximum heat stability point. This test can also be carried out during the manufacture of the powder to enable pre-phosphating of the powder at the point of manufacture.

Figure 3 Equipment used in the CSIRO heat stability test. (Kieseker & Aitken 1988)

Emulsion capacity and stability

Emulsion capacity and stability measurements include volume index, capacity, activity index and stability. The results of these tests only indicative and interpreted accordingly.

The *emulsion capacity* of a milk powder solution can be determined by pumping oil into a protein solution with homogenisation while monitoring the electrical resistance of the solution. When the capacity of the powder solution to emulsify oil is exceeded, the solution changes from continuous water (oil in water) to continuous oil (water in oil) phase. At this point a rapid increase in electrical resistance occurs. A typical example of this approach is the method of Vuillemarde *et al* (1990) which has been adopted and modified by many researchers e.g. Williams (Personal communication, 2005).

For the measurement of the *emulsion volume index*, a model emulsion is prepared and allowed to age overnight at 4°C and then its emulsion stability is determined using a haematocrit centrifuge. A typical example of this method is that of DeCastro-Morel and Harper (2002) and McDermott *et al* (1981). Again, there are modifications of these methods (Personal communications, Williams, 2005).

Because of the lack of comparability of most methods for emulsion capacity and stability, attempts have been made to try to standardise the reporting of the results. An example of this is the work of Bennett *et al*. (Internal communication, 2005).

A simple method is to add milk powder (in 0.1 g increments) to a mixture of water and oil (1.0g oil to 99.0g water). The oil droplets on the surface will appear as large droplets prior to powder addition. High speed mixing is applied and the powder is added. The oil is satisfactorily emulsified when the droplet sizes on the surface reduce to <0.5mm in diameter.

When this droplet size is reached, the amount of powder added is recorded. Higher quantities of powder required indicates lower emulsifying capacity.

FCMP, non-agglomerated	0.9g
FCMP, agglomerated	1.7g
FCMP, instant	1.3g
Regular SMP	1.0 to 2.0g
BMP	1.7g

Foaming and whipping capacity and stability

Figure 4 Apparatus used in determining foam stability and over run (Ward *et al* 1997)

The foaming and whipping of milk powders are important in many applications such as ice cream manufacture. There are many methods for determining foaming and whipping capacity.

Researchers in Australia have modified the method of Phillips *et al* (1987) and adopted another method (Ward *et al* 1997) for working on enhancing the foaming capacity of milk powders. This method enables an initial visual comparison (see Figure 4) between two powders with subsequent measurement of over run or foam expansion as calculated by the following formula:

$$\% \text{ Overrun} = \frac{(\text{Weight of unwhipped solution}) - (\text{Weight of same volume of foam})}{\text{Weight of same volume of foam}} \times 100$$

$$\% \text{ Stability} = \frac{(\text{Weight of 100ml foam}) - (\text{Weight of liquid drained})}{\text{Weight of 100ml foam}} \times 100$$

A simple method to estimate foaming capacity and foam stability is to make up a 10% (w/w) powder solution in water (at 20°C), foam with a suitable domestic mixer (e.g. ultra turrax), and then to pour the foam into a cylinder and measure the volume for foam capacity. The volume is then measured again after a further 15 min standing. The reduction in foam is recorded as the foam stability.

Table 4 Typical results (for this simple test)

	Foaming	Foam stability
FCMP, non-agglomerated	102ml	2 ml
FCMP, agglomerated	106 ml	6 ml
FCMP, instant	100 ml (no foam)	N/A
Regular SMP	130–170 ml	37–60 ml

(Reference: AIC Powder Functionality Manual)

Wettability

Wettability is measured by systematically placing a weighed amount of powder (typically 10g) onto the surface of a set amount of water (250 ml at 25°C) and noting the time for all the powder to become wetted i.e. fall below the water line.

(References: IDF 87, Pisecky (1997))

Dispersibility

Dispersibility is measured by placing a weighed amount of powder (typically 10g) onto the surface of a standard amount of water (typically 250 ml at 25°C), stirring the solution for a set time with a rotational pattern, and then sieving the contents. After drying, weighing the residue, and reporting the dispersibility in terms of the mass of the test portion and the values for water content and total solids.

(References: IDF 87, Pisecky, 1997)

Flowability

There are several sophisticated analytical instruments to measure flowability. (e.g. Hosokawa micron powder tester, Aeroflow powder flowability analyser – see Figures 5 & 6). The Hosokawa instrument can measure several other characteristics including BD, compressibility, angle of repose, angle of spatula, angle of fall, cohesion and dispersibility.

Figures 5 and 6 The Aeroflow and Hosowaka Powder analysers

A simple way is to measure flowability by passing through a funnel or the measure of the amount of powder flowing down an incline. For example, 6g of powder is placed at the top of an inclined plane (50mm long at 45°C) and all the powder that flows to the bottom is collected and weighed and expressed as a % of the 6g original sample.

Table 5 Typical analysis (using simple method as above)

FCMP, non-agglomerated	35–95%
FCMP, agglomerated	92–93%
FCMP, instant	90–97%

(Reference AIC, Powder Functionality Manual)

Other methods developed include the use of a specially designed stainless steel rotating drum operating at a set rpm (usually 30) into which a weighed sample of powder is introduced and the time taken for all the powder to be spun out of the drum is recorded.

Table 6 Typical analysis

FCMP, non-agglomerated	200–300 s
FCMP, agglomerated	50–100 s
FCMP, instant	40–60 s
Regular SMP	50 s
Agglomerated skim	10–20 s

(Reference, Pisecky, 1997)

Particle size distribution (PSD)

PSD affects functional properties including flavour release, flowability, dispersibility, solubility and emulsion stability. PSD of milk powders and liquids can be measured by three methods: a) putting powder through a sieve rack of different sizes b) using a microscope for visual analysis, and c) sophisticated counting techniques using laser diffraction.

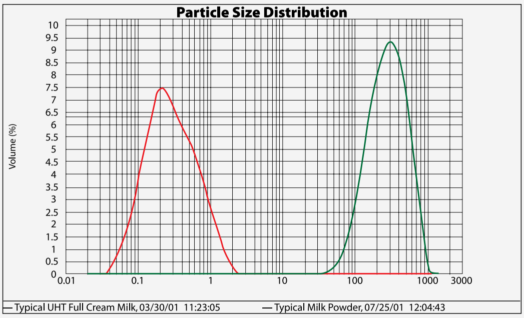
Sieving methods can only be used as a guide given that the mechanical movement can cause changes to the powder morphology e.g. break down of agglomerates. The capacity of powders to flow freely is a prerequisite for best results and often requires the addition of a free flowing agent.

Microscopic examination is time consuming and operator dependent in many instances. It has the obvious advantage of being able to visually examine the powders for other structural features while undertaking the counting and sizing.

A popular method to measure PSD is Malvern Mastersizer (Figures 7 & 8) which measures PSD under either wet or dry conditions by maintaining the particles in a stream of air or suspended in a solution of isobutanol or similar medium. This method works well for particles in the 50nm to 2mm range.

Figure 7 Malvern Mastersizer 2000 particle size analysis system

Figure 8 Typical PSD for UHT milk and FCMP



Coffee Stability or Coffee Test

The coffee test is a measure of the resistance of proteins to instability in the coffee environment.

There are several variations of the coffee test, but essentially 1% coffee solution is heated to 75 - 85°C, a weighed amount of powder is added and stirred in a standard manner. The amount of undissolved material on the surface, called feathering and the amount of sediment are visually noted and quantitatively measured. Care must be taken with coffee selection to ensure pH around ~4.9 but not much lower as this pH is close to the isoelectric point of the proteins. Any further lowering of pH will significantly impact the results. Acceptable quality of powder should show feathering 0.2 - 0.3 ml whereas > 1.0 ml is unacceptable quality. Powders with a whey protein nitrogen index (WPNI) < 3 tend to give better results.

Sludge test

The sludge test is similar to the coffee test. 2g of powder is dissolved in water (at 25°C for the cold sludge for instant powder, 45°C for the cold sludge for agglomerated powder and 85°C for hot sludge for both instant and agglomerated), mixed, poured through a filter and the sediment is collected, dried and weighed. The result reported as the weight of dried sludge.

Table 7 Typical analysis

FCMP, non-agglomerated	0.3g
FCMP, agglomerated	0.1g
FCMP, instant	0.0g
Regular SMP	0.0 – 1.3g
BMP	0.1g

(Reference, Pisecky, 1997)

Solubility

The test for solubility of powders is called the insolubility index because it measures the amount of insoluble powder under standard conditions. A typical test requires adding 13g of FCMP or 10g of SMP or BMP to 100ml of water at 24°C or 50°C, mixed in a specially designed apparatus, decanted into special centrifuge tubes, centrifuged and the sediment is measured in ml.

Care must be taken to maintain the temperature as it is the single most determinant factor for insolubility.

Table 8 Typical analysis

FCMP, non-agglomerated	Max 1.0 typically 0.5 ml
FCMP, agglomerated	Max 1.0 typically 0.5 ml
FCMP, instant	Max 1.0 typically 0.5 ml
Regular SMP	Max 1.25 typically 0.5 ml
BMP	Max 1.25 typically 0.5 ml

(References: AS 2300.4.4-1994, ISO 8156:2005, IDF 129A:2005, ADPI Bulletin 916)

Gelation

The ability of milk powders to form gels is significantly influenced by the environment of the food application. The test to provide an indication of gel strength requires reconstituting 50% w/w in water, heating the solution to 80°C with stirring. Next the solution is refrigerated for 10 to 12 hrs and gel strength measured using a suitable instrument such as Instron or TA.XT2).

Browning

The test involves placing 25g of powder on a cookie or muffin tray and baking in an oven at ~200°C for 10 – 15 minutes. Thereafter, the powder is slowly cooled to room temperature. The colour is measured with a chromometer such as Minolta colour meter for L, and b colour values at D65 illumination. A suitable instrument for this is a Minolta colour meter.

Table 9 Typical analysis

	L	a	B	Browning
SMP	81.27	2.36	39.30	**
FCMP agglomerated	58.77	12.08	40.77	****
FCMP instant	56.19	15.48	39.30	****
FCMP non agglomerated	82.58	0.17	37.10	**

(Reference: AIC, Powder Functionality Manual)

White flecks

White flecks are undissolved particles, which can be seen when a thin layer of milk solution is observed. White flecks clog filters because of their soft physical nature and their abundance. This phenomenon is more commonly observed when solutions of high total solids are prepared.

As in the dispersibility test, 10g of powder is placed onto the surface of 250 ml water at 25°C, the solution is stirred in a rotational pattern for a set time. Thereafter, 100 ml of water is added and the stirring process is repeated. This mixture is poured through a sieve and the volume of liquid that passes through in 15 seconds is recorded. The result is reported as the white fleck number (WFN). A simpler method is to reconstitute 50g of powder in 300ml of water at 20°C or 80°C by mixing with a teaspoon for six complete clockwise and six anticlockwise motions. Then allow the mix to stand for 5 min, dip a clean teaspoon into the mix, slowly withdraw, and then count the number of white flecks deposited on the back of the spoon. Typical results are shown below:

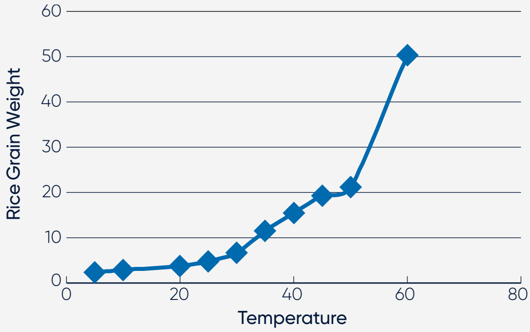
Table 10 Typical results

	20°C	80°C
FCMP, non-agglomerated	clumps	10–12
FCMP, agglomerated	clumps	0–2
FCMP, instant	0–3	0–2
Regular SMP	clumps	0–2

(Reference: AIC, Powder Functionality Manual).

When making up solutions with high total solids such as RSCM the appearance of the white fleck phenomena is a function of the mixing temperature, with the amount of white fleck material produced increasing as the mixing temperature rises, as shown in Figure 9 where the white flecks are referred to as "rice grain".

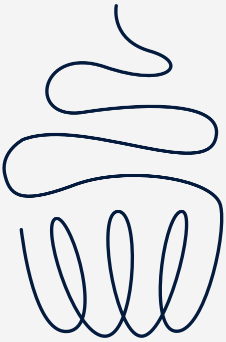
Figure 9 Effect of temperature on rice grain formation at high solids (Personal observations)



Scorched particles

Scorched particles are usually measured according to the method set out in American Dry Milk Institute (ADMI). 25g of SMP or BMP or 32.5g FCMP are mixed at 18 – 27°C for 50 sec in 250 ml of water with antifoam added. The solution is then filtered through standard discs which are then gently dried and compared to a standard photographic scale.

(Reference: ADPI Bulletin 916)



4.4 Applications

Dairy product applications

The manufacture of dairy products from several milk ingredients is called recombining. Figure 10 shows layout of a recombination plant. Reconstitution, unlike recombining, refers to mixing one ingredient with water. For example, mixing FCMP in water is reconstitution whereas mixing SMP in water followed by addition of AMF and homogenisation of the mix would be termed recombining as it uses two ingredients rather than one.

Recombining and reconstitution are popular in countries which have little or no supply of local fresh milk. Milk powders can be tailor made for specific end use and applications. Techniques to tailor functionality of powder for specific uses include preheating the milk and the use of additives such as minerals. For example, varying the preheating temperature and time of skim milk prior to evaporation and spray drying yields three (and more) types of SMP such as low heat, medium heat, and high heat SMP. Each of these types has specific functionality and applications which cannot be interchanged with other types. For example, low heat SMP is best used for recombined milk while high heat is better suited for bakery applications. Skim and full cream milk powders and AMF are the predominant ingredients used in recombining and reconstitution. Buttermilk powder is also used as a substitute for these products at levels of up to 20% for various enhancements.

Figure 10 Typical layout for a recombining plant for liquid milk

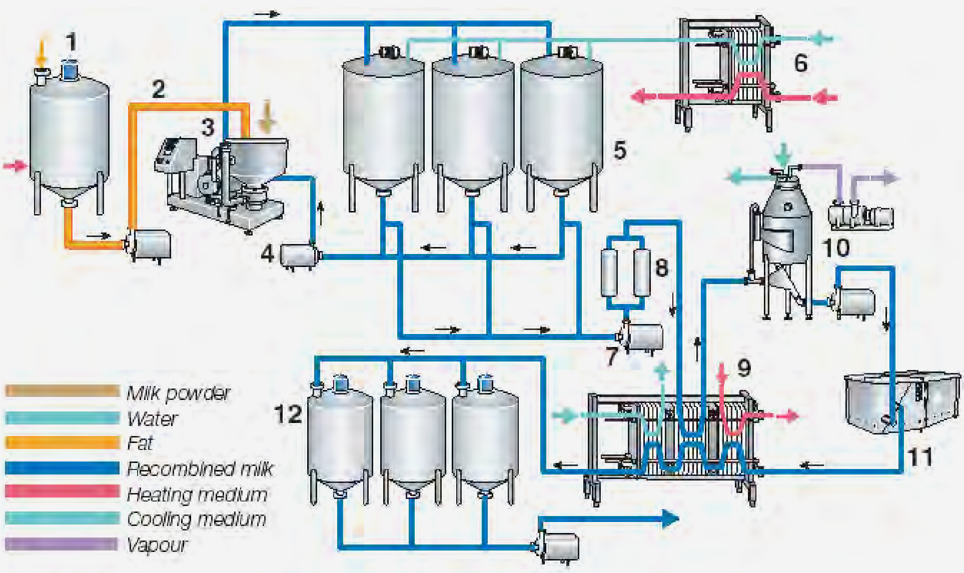


Fig.18.5 *Recombination plant with fat supply to mixing vessel.*

1 Tank for fat
2 Insulated pipe for fat
3 Mixer with high-shear mixing unit
4 Circulation pump
5 Mixing tanks
6 Water heater
7 Discharge pump
8 Filters
9 Plate heat exchanger
10 Vacuum deaerator
11 Homogeniser
12 Storage tanks

From Tetra Pak Dairy Processing Handbook

Sweetened condensed milk

Medium heat powder is generally used for the manufacture of sweetened condensed milk. The most important functionality required is for the powder to induce a viscosity in the final product within a specific range. The viscosity optimum at manufacture is 25- 40 poise which increases to 60 - 100 poise when stored for approximately 6 months. This range will change from manufacturer to manufacturer according to plant configuration and the ability to manipulate viscosity with unit processes especially heat treatment and homogenisation.

Single strength milk

Single strength liquid milk can be manufactured using several technologies. The three main methods are pasteurised, UHT and sterilised or retorted. Pasteurised milk is heated to 72°C for 15 – 30 sec and has a shelf life of 14 days, while UHT requires heating to 135 -140°C for 3 – 5 sec and shows shelf life of 3 – 9 months. Sterilisation or retorting requires heating to 118 - 125°C for 10 to 13 min and shelf life is around 12 months.

It is recommended that low or medium heat milk powders are used in the manufacture of UHT recombined single strength milk whether plain or flavoured. The use of high heat powder, particularly manufactured by HTST preheat treatment, is not recommended as it often imparts a cooked flavour to the final product. High heat powder manufactured by UHT preheat treatment is preferred if high heat powder is to be used. One important aspect of milk powders for UHT applications is that they must not contain enzymes that are resistant to heat. These enzymes, usually heat resistant lipases and proteases, have a detrimental effect on the storage stability of UHT milk as they are responsible for thickening, sedimentation and coagulation. A guide for selection of powders for UHT milks is that the powders should contain no more than 9 mg/100g of pyruvate (a metabolite of a psychotropic bacteria) that develops during cold storage of milk.

Evaporated milk

Powders used for the manufacture of evaporated milk must be high heat and must be heat stable as they need to withstand high retort heat treatment without excessive thickening or coagulation. Buttermilk powder is often used because of its high level of milk fat globule membrane which is known for enhancing emulsification and heat stability properties as well as imparting rich flavour. Further improvement of the heat stability during sterilisation can be accomplished by addition of mineral salts such as citrates, carbonates, or polyphosphates. Orthophosphates are generally avoided as they promote age gelation in the sterilised concentrated product.

Cheese

The primary consideration in selecting milk powder for use in recombined milk for cheesemaking is that it must be low to extra low heat. If medium heat or high heat powders are used, the resultant reconstituted milk will yield a soft curd on rennet addition which is undesirable. Low to extra low heat powders will give the best results for cheese making where the whey protein is largely in the undenatured state and the milk is close to fresh milk quality. Adjustments to manufacturing conditions compared to conventional cheese making may need to be made, and these include salt addition and pH change.

Yoghurt

Both high and low heat milk powders can be used for yoghurt. Heat treatment of reconstituted milk during yoghurt manufacture helps set the functionality from either type of powder. The heat treatment of reconstituted milk should be sufficient to denature the whey proteins as this assists with yoghurt quality with a firm texture and good resistance to syneresis. Both HTLT (e.g. 85°C /30 min) and UHT treatment are used for this purpose. Water holding capacity is also enhanced which helps improve yoghurt quality.

Ice cream

The ability to form stable foams by the incorporation and holding of air is one of the main attributes sought in milk powders for ice cream manufacture. The proteins in the powder act at the oil and water interface to stabilise emulsions. Low and medium heat powders are used as they enable the flavour of the ice cream to be enhanced and developed without interference as low and medium heat milk powders have a very bland flavour, and possess good emulsification, water binding and texture development properties.

Cream

The manufacture of recombined cream from milk powders is possible with the incorporation of another dairy fat source or with the use of high fat containing powders specifically manufactured to deliver substantial amounts of fat in a powdered form. Powders containing up to 65% fat are commercially available.

General food applications

A broad range of milk based powders such as SMP, FCMP and BMP are used in a variety of non-dairy applications. These traditional powders are used for bakery, confectionery, meat products, prepared mixes, as well as sauces, soups, spreads, meat, fish, and desserts. High heat SMP or BMP is generally preferred in bakery applications especially for good loaf volume). Low heat SMP is preferred in beverages for good sensory and flavour. SMPs are also used extensively in animal milk replacers as a minor or major component. FCMPs are used as an economical source of dairy solids, including milk fat, a convenient form of nutritious milk that is easily reconstituted and does not require refrigeration and also an easily and readily transportable dairy ingredient (USDEC, 2007b).

All these milk powders have functional properties that are valuable in formulated and processed food applications. These properties include solubility, emulsification, gelation, water-binding, whipping, foaming, viscosity, heat stability browning, colour, and flavour aroma attributes. All these attributes are present in the powders and can be further enhanced during application by appropriate processing.

Confectionery

Milk powders are a key ingredient in the formulation of candy, nougats, frosting and creams, and provide flavour and functionality to these products. The proteins in milk powders can act at oil and water interfaces to form and stabilise emulsions. Together with lecithin (the natural emulsifier present in the milk fat globule membrane) they prevent oiling off and creaming. Undenatured milk proteins can form rigid, heat-induced, irreversible gels that hold water and fat and provide structural support to confections. The firm, chewy texture of some confections is related to the binding of water by casein. Milk powders are also important in the formation of foams which is important in confections such as nougat, frosting and various creams, and in contributing a pleasant dairy flavour note and aroma to confections (USDEC, 2007a).

SMP is used in confectionery manufacture and contributes to browning and caramelised flavour by Maillard reaction products produced when heat is applied. SMP also contributes to structure by water binding, reducing fat globule mobility, gelation and creating firmness and chewiness in the final products. FCMP and BMP, which are not used as often in this application, assist in emulsification and the creation and maintenance of uniform foams. BMP is used for flavour enhancement and because of its high lecithin content assists in emulsification.

SMP has also been shown to result in enhanced toffee flavour while other applications include uses in fudge to produce dairy flavours and in hard-candy filling and marshmallows for improved flavour and browning characteristics (Campbell and Pavlasek, 1987).

Table 11 Usage of milk powders in confectionery

Dairy powder	Typical usage level (% w/w)
SMP	Caramel candy (4.2), chocolate candy coating (15), fudge icing (2.2), reduced fat icing (4.0), chocolate frosting (0.2), compound coating (8 – 10), fudge (8.5), toffee (2.5)
FCMP	Milk chocolate (~20),

(Reference Chandan and USDEC 2007a)

Chocolate

Traditionally, FCMP, BMP and SMP have been used in the manufacture of chocolate. For example, FCMP in chocolate applications is used to reduce plastic viscosity, decrease refining time and change chocolate hardness, solid-fat content and surface colour (Walshe, 1994).

The physical characteristics of milk powders can have a significant impact on the processing conditions as well as the physical and sensory properties of the finished product. Aspects of chocolate manufacture and storage such as tempering conditions, melt rheology, hardness and bloom stability are dependent on the level of free fat in the milk powder. However, powder particle characteristics of the milk powder also influence the physical and sensory properties of the final products (Liang and Hartel, 2004).

Adjustment of lactose content by ultrafiltration and diafiltration of milk in FCMP manufacture affects the microstructure of spray-dried FCMP. Milk powder particles with ~0% lactose have a more porous matrix with deep dents and wrinkles, lower true and apparent particle densities and larger median diameter, vacuole volume, surface area and free fat content. Higher lactose concentrations produce spherical particles with a less porous matrix, higher true and apparent particle densities, and smaller median diameter, vacuole volume, surface area and free fat content. FCMP with modified lactose content may have potential in the manufacture of milk chocolate (Aguilar and Ziegler, 1994).

Increasing the concentration of amorphous lactose from spray-dried powders in chocolate decreases viscosity, increases particle size of refined chocolate mass and lowers the concentration of surface-active agents. Increasing the concentration of crystalline lactose for milk powders in chocolate increases viscosity, decreases particle size and increases the concentration of surface-active agents. Conditions which affect lactose crystallinity in milk powders, such as improper storage and handling prior to use in chocolate production, could be responsible for variations in chocolate viscosity noted sometimes by processors (Aguilar and Ziegler, 1995).

When used in chocolate processing, spray-dried milk powders together with an alternate independent fat source, have been shown to produce lower viscosities, compared with those obtained by using roller-dried milk powder (Attaie *et al.* 2003).

Milk ingredients influence consumer liking of milk chocolate through the quality driving parameters of particle size, sandiness, viscosity, melting mouthfeel and milk flavour. Chocolates made from milk products that contain considerable amounts of free fat, e.g. SMP plus anhydrous milk fat (AMF), score better than those using bound fat, e.g. FCMP. Milk fat status has more influence than differences between spray and roller-dried powders.

High free fat cream powders have been shown to be the most suitable for cream chocolates (Bolenz *et al*. 2003).

A high solvent-extractable fat (SEF) or free fat (FF) content is a desirable attribute for FCMP intended for chocolate manufacture. FCMP produced by conventional powder manufacturing processes have low SEF contents (<40 g free fat per kg total fat in powder). Full-cream milk powders with high levels of SEF (up to approximately 400 g/kg total fat in powder) can be obtained by separating full-cream milk into cream and skim milk fractions, pasteurising the cream fraction, then, either cooling the cream and recombining it with a skim milk concentrate or homogenising it at high temperature and pressure prior to blending it with a skim milk concentrate. Full-cream milk concentrates produced by either process can then be spray dried without homogenisation.

In addition to the use of altered processing steps for manufacture of milk powders, the level of SEF in milk powder is also influenced by the total solids of the cream and the milk concentrates used in the production of the milk powders (Clarke and Augustin, 2005).

The favourable flow property of milk chocolate when roller-dried milk powder is used is attributed to the high free fat content. The liberation of fat during the various stages of chocolate manufacture has been investigated in milk powders differing in free fat content. Refining of the chocolate mass discloses a major part of enclosed milk fat. Nevertheless, the flow properties differ depending on the type of powder used. Normal spray-dried whole milk has insufficient flow properties for chocolate manufacture. However, replacing roller-dried FCMP by spray-dried SMP combined with anhydrous milk fat (AMF) is a better option for improved flow properties (Dewettinck *et al*. 1996).

It is possible to alter important properties of chocolates using milk powders of varying fat contents, free-fat contents and particle sizes (Keogh *et al*. 2003). Shear cell techniques have been used to measure milk powder flow properties for chocolate manufacture. Fat content, free-fat content, particle size, moisture level, lactose content, amorphous lactose content and storage conditions have been evaluated for their effect on flowability of the milk powders. Increased fat content reduces powder flowability especially when comparing 1% (SMP) and 26% (FCMP) fat powders. Varying free-fat content has no effect on flowability. Particle size has a major influence on flowability, as increasing the particle size significantly improves the flowability of SMP and FCMP. The concentration of amorphous lactose increases the susceptibility of powders for absorbing moisture, resulting in reduced flowability and increased caking on storage (Fitzpatrick *et al*. 2005).

Exposing spray-dried FCMP to high shear and elevated temperature in a twin-screw continuous mixer increases the free fat content. Exposure to elevated temperatures and high shear has been shown to: (a) increase the free fat to > 80%, (b) crystallise the lactose, (c) reduce the average volume-based particle size, and (d) broaden the particle size distribution. Processing generally enhances the functional properties of spray-dried FCMP for milk chocolate manufacture (Koc *et al*. 2003).

Spray-dried milk powders have a median particle size of 30-80 µm. Roller-dried powder particles, with larger ~ 150 µm particle size are preferred for chocolate making. New processes have been developed resulting in spray-dried powders with median particle size of 132-162 µm. These particle sizes in the chocolates were correlated with higher free-fat and lower vacuole volumes in the powders (Keogh *et al*. 2004).

The free-fat content and the median particle size of high-fat milk powders has been shown to be affected by the protein content and solid-fat content of the milk but not significantly affected by the lactose content or the protein: lactose ratio. It is possible to predict the free-fat content of high-fat milk powders, from the protein and solid-fat content of the milk (Twomey *et al*. 2000).

Spray-dried high-fat milk powders with different properties can be used to make chocolates with a range of viscosities and yield values for different end uses, such as moulding or enrobing (Twomey *et al*. 2002).

Flavour variability in SMP can carry through into chocolate manufacture and ingredient applications such as hot cocoa mix, chocolate bars and ice cream and yoghurt which can negatively affect consumer acceptability (Caudle *et al*. 2005).

New research on the role of spray drying, along with other processes in the development of dairy ingredients for applications in chocolate and the preparation of microencapsulated powders has been reviewed (Kelly, 2006).

Table 12 Usage of milk powders in chocolate

Dairy Powder	Typical Usage level (% w/w)
FCMP	Milk chocolate (20),
SMP	Milk chocolate (15), compound coatings (8-10),

(Reference Chandan and USDEC 2007a)

Bakery

In bakery applications such as biscuits, breads, donuts, and pancakes, both SMP and FCMP are extensively used. These enhance browning by Maillard reaction and impart natural flavour, as does BMP when used as the fat component. They also enhance texture and structure, particularly in crepes, croissants, and muffins, by forming dense foams with finer more uniform bubbles due to their emulsification attributes and water binding abilities. Milk powder also increases the water binding capacity of bread dough in direct proportion to the amount added which has a positive effect on texture, flavour and product shelf life (USDEC, 2007c).

Milk powders add to colour and flavour by Maillard reactions where the amine group of the protein reacts with lactose and other carbohydrates. Lactose is not fermented by baker's yeast in yeast-leavened bakery products and remains available for colour development in the crust. SMP is also used in baking applications to enhance the level of milk solids, contribute to milk flavour and to stabilise cake batter emulsions.

Table 13 Usage of Milk Powders in Bakery

Dairy powder	Typical usage level (% w/w)	Functionality
SMP	Biscuits (4.1), yellow layer cake (2.22), croissants (3.41), donuts (2.00), muffins (2.35), choco chip cookie (1.25), cheese scone (2.05), cookies (2.5), bread dough (1.0 - 4.1), white cake (2.1)	In bread & biscuits – flavour, colour, crust, water absorption and texture In cakes – browning, water binding, emulsification & texture
FCMP	White bread (0.5), cookies (3.05), crackers (1.6 - 2.52),	Flavour and texture
BMP	Pancakes (4.85)	Flavour and emulsification

(Reference Chandan and USDEC 2007g)

Meat and fish

SMP is used in prepared meat and fish products where its water binding and emulsification properties are used for structure and texture, especially in comminuted meat products.

The proteins in milk powders can act as oil-water interfaces to form and stabilise emulsions. The lecithin present in milkfat also helps in stabilising emulsions. Undenatured milk proteins in the powders can form rigid, heat-induced gels that hold water and fat and help to provide structural support to meat products. Milkfat present in some powders can act as a carrier for fat-soluble ingredients, spices, and herbs. The low melting point of milkfat also ensures complete flavour release (USDEC, 2007d).

SMP has been used to emulsify fish oil prior to microencapsulation and spray drying into fish-oil containing powders (Augustin *et al*. 2006). Milk powders have also been used to enhance the textural properties of meat batters (Barbut, 2006), while SMP has been shown to affect the yield and sensory quality of cooked sausages (Ellekjaer *et al*. 1996). SMP has also been shown to improve the yield, emulsion stability, appearance, colour, flavour, texture and overall acceptability of chicken patties (Girish *et al*. 2004) and cooked turkey breast meat (Haines, 2004).

Table 14 Usage of Milk Powders in Meat and Fish Products

Dairy Powder	Typical Usage level (% w/w)
SMP	Bologna (4.2), corned beef (12.1), salami (4.5), meat loaf (5.0), roast beef loaf (9.4)

(Reference Chandan and USDEC 2007d)

Sauces and soups

Milk powders contribute to the viscosity of soups and sauces and SMP, FCMP and BMP all contribute to quality of soups and sauces by enhancing emulsification, water binding and flavour development. Structure and formation can be enhanced by the gelation capacity of SMP and FCMP.

SMP is often used in sauces to modify viscosity and texture. This increase in viscosity and improvement in texture can be enhanced by increasing the amount of powder in the soup formulation or by using powder with a higher protein content. (Muir *et al*. 1991a).

SMP has also been shown to be suitable for incorporation into cream of tomato soup. In this application, however, the effect of changing powder protein content and heat classification appears to have no effect on the texture and viscosity of cream of tomato soup (Muir *et al*. 1991b). SMP is also used in soup formulations for the elderly for its nutritional properties (Arhontaki *et al*. 1991).

Table 15 Usage of Milk Powders in Soups and Sauces

Dairy powder	Typical usage level (% w/w)
SMP	Soups (5.5 – 8.0),
FCMP	Sauces (7.6 – 10.0)

(Reference Chandan and USDEC 2007f)

Desserts

Milk powders are useful for their foaming properties in frozen desserts, whipped toppings, meringues, and mousses.

SMP improves the foam structure and texture in cakes (USDEC, 2007c), while the foaming and emulsification capacity of FCMP and BMP are also used to advantage in desserts. The flavour of SMP enables the natural flavour of products to come through, and Maillard browning products add flavour to custards, puddings, and crème caramels.

The acidification of milk is an integral step in the manufacture of products such as yoghurts, acidified dairy desserts and sour creams. As pH is reduced, the milk develops viscosity. Acidification under quiescent conditions yields a set gel. A range of textures in milk products may be obtained depending on the nature of the acidifying agent, the final pH and the milk ingredients used. The acidifying agent is added to the milk during the manufacture of the dairy product. However, there are opportunities to provide food manufacturers with acidified powders. An example of this is yoghurt powders, where cultured milk is dried. The use of a chemical acidulant, glucono-delta-lactone (GDL), for the production of acidified skim milk powders (which thicken or gel upon reconstitution depending upon the amount of heat applied) and the effect on functional properties has been reported (Clarke and Augustin, 2000). Milk powder also contributes to the gel strength of desserts (Verbeken *et al*. 2006). The addition rate of milk powders in the formulation of desserts varies greatly and can be around 1 - 10%.

Beverages

Milk powders are used in beverages where they enhance mouthfeel by affecting texture and viscosity. Milk powders are also used in a variety of beverages to enhance nutritional attributes as they provide high quality protein and contain essential amino acids. Milk powders are also high in calcium and vitamins and can therefore be used to fortify beverages.

Milk powders can form foams in beverages such as nutritional shakes. As dairy protein concentration increases, foams become denser with more uniform air bubbles and a finer texture. Specialised SMP with enhanced foaming and steam frothing properties have also been reported (Augustin and Clarke, 2008). Examples of beverages that contain milk powders include, meal-replacement type beverages, chocolate drinks and infant formula mixes (USDEC, 2007e). SMP and FCMP are typically used at 5 – 10% of the formulation in these applications.

The use of nano technology is now being used to manufacture milk based ingredients that can be added to clear beverages. These ingredients enhance the nutritional value of the beverage without adversely impacting clarity.

Infant formula

In general, human milk compared with cow milk, contains lower level of minerals, protein, but higher levels of carbohydrate and fat.

See Table 16

Table 16 Comparison of Nutrient Composition of Cow and Human Milk

Nutrient	Cow	Human
Water, g	87.99	87.50
Food energy, kcal	61	70
Protein, g	3.29	1.03
Fat, g	3.34	4.38
Carbohydrate, g	4.66	6.89
Ash, g	0.72	0.20
Minerals, mg		
Calcium	119	32
Magnesium	13	3
Phosphorus	93	14
Potassium	152	51
Sodium	49	17
Vitamins, mg		
Ascorbic acid	0.94	5.00
Riboflavin	0.162	0.036
Niacin	0.084	0.177
Vitamin B_{12}	0.357	0.045

(Reference: Miller, Handbook of Dairy Foods and Nutrition, 2006)

Milk powders provide a sound nutritional base for infant formulas, with good supply of mineral nutritional elements such as Ca, Cu, Fe, K, Mg, Mn, Na, P and Zn. In general, the bioavailability of these nutritional elements in milk powders and infant formulas is high. FCMP also contains several water-soluble vitamins (e.g. thiamine, riboflavin, niacinamide, pyridoxal, ascorbic acid, choline. inositol, biotin, pantothenate, folate and vitamin B12) as well as fat-soluble vitamins (e.g. A, D, E and K).

Milk powder future developments

Innovative technologies are always evolving to produce better, more efficient, and functional products. Milk powders are no exception and with developments in advanced process control, especially for large drying plants, fractionation of milk into greater functional products that can be dried for added stability and microencapsulated powders to deliver functional stable ingredients.

Conclusion

The traditional milk powders SMP, FCMP and BMP continue to be used in a range of food applications despite the emergence of an ever increasing range of specialised dairy based and non-dairy based ingredients. These traditional powders have a strong appeal and are often preferred because of their traditional and accepted usage in food. The use of SMP, FCMP and BMP and the specific type of each of these is usually dictated by the functionality that is required to perform in the formulation and application. The functionalities exhibited include water binding, flavour, nutritional enhancement, emulsification, browning and texture modification. Examples of the applications and functionality include bakery (water binding, emulsifying, foaming, whipping, and gelling); confectionery (water binding, foaming, viscosity, colour, and emulsification); and meat products (gelation, water binding and emulsifying). These functionalities are induced and enhanced during the manufacture of the powders and are tailored to the end use. With the ability to tailor make and further refine the attributes of these products it is envisaged that SMP, FCMP and BMP will continue to be a favoured ingredient in food applications well into the future.

4.5 Product development

Method

In developing new ingredients or powders with enhanced functional properties for specific end-uses, the Australian dairy industry together with various research groups adopt the following approach.

They firstly identify the target functionality required and consider the major factors that can affect this target functionality. The use of compositional change, manufacturing techniques, addition of other ingredients are then considered and used to produce the desired effect. The effectiveness of the developed ingredient is then evaluated by the application of functional screening tests which are used to examine the inherent performance. The powder is then finally evaluated in the specific application for which it was designed. Many factors, especially the local product composition, can dramatically affect the ability of an ingredient to perform its task. All this requires knowledge and understanding of the fundamental aspects of milk components, and their interactions in various food systems, the effects of variation in milk composition and effects of processing and how the various processes, both conventional and innovative can be used to manipulate and control the properties of ingredients and finally the key functional attributes required in target formulations where the dairy ingredients are used.

The process of developing and producing a successful dairy powder ingredient requires the knowledge and understanding of:

- the fundamental aspects of milk components
- ingredient interactions in various food systems
- the effects of variation in milk composition
- the effects of processing on the ingredient properties
- how to manipulate process controls to vary ingredient properties
- key functional attributes required in target formulations

Other powders

Cream powder

As most high fat powders manufactured today contain a mix of many ingredients (special proteins and emulsifiers) to maintain stability, the challenge is to convert a high fat emulsion into a powder with a low level of surface fat to minimise oxidation and to achieve good flowability, all without the need for additives. Technologies are available to manufacture simplified formulations of powders containing 60 to 70% fat without the need for these expensive additives. This gives a powder that is easy to use, has good shelf life and is heat stable.

Yoghurt base powder

This milk based milk ingredient has been developed specifically for the manufacture of recombined yoghurt. It can contain fat if required. It enables the manufacture of yoghurt with reduced milk solids requirements, thus reducing raw material costs while maintaining or enhancing the physical characteristics of yoghurts such as gel strength or viscosity and minimising defect of water leakage.

Blends

The economic advantages of using cheaper milk based ingredients in formulations have led to the emergence of a range of blends of milk-based ingredients. The main ingredient used for substitution is whey or whey derivatives. Initially substitution was simply a replacement exercise with no thought of functionality. However, recent developments have produced an extensive range of blends of dairy based ingredients with basic milk powders with enhanced functionality due to the incorporation of these substitutes for a range of end uses, in particular, ice cream, confectionery, and bakery. It has also led to the creation of a new range of recombined products e.g. creamers as substitutes for conventional evaporated milk.

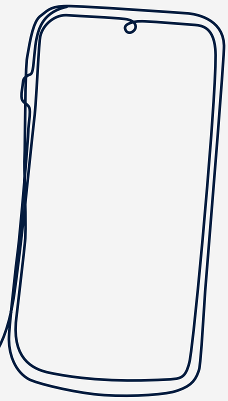
Nutritionally enriched powders

The need to supply the demands of the modern consumer for healthy foods has led to a range of nutritionally enhanced milk powders. There are many variations of conventional skim and full cream milk powder on the market shelves and they are used in formulations that now contain enhanced levels of such components as pre and post biotics, added calcium, enriched vitamin levels and omega three fatty acids.

This trend will continue as dairy products are an extremely convenient way of incorporating various nutritional ingredients into commonly consumed foods.

The development of milk powders for adult health is also becoming increasingly popular, especially in Asia, where the focus is on family nutrition, targeting middle and high income families with a range of standard, organic and nutritional powder varieties.

Furthermore, there is also another group of powders on the market with biological functional properties e.g. colostrum powders which can promote infant growth, immunity, and health.



4.6 Product handling

Packaging, transport, storage and handling

Figure 11 The sealing section of a 25kg bagging line

The packaging method and the conditions of transport and storage must afford the milk powder protection from contamination from dirt and microorganisms, prevent moisture and oxygen uptake and exclude light, insects, and odour. To this end there are several ways to package and transport milk powders.

Most of the milk powder for export is packed in 25kg or 15kg bags (see Figure 11) with some being packed into 500-1000kg bulk bins usually for re-packing into consumer packs. The bags are multi-wall with a mix of paper and plastic. Powder manufacturers use a mix of 3 and 2 ply paper (90 gsm), with a move to using 2 ply with a polyethylene liner only for environmental reasons, The polyethylene liner for SMP is typically 60 micron whereas for fat containing powders the polyethylene liner is slightly heavier at 65 micron and has gas barrier properties. It is also becoming popular to use barrier bags and liner of co-extruded polymers, for reduced oxygen and water vapour permeability.

The bulk bins are typically a bag-in-box construction with a large polyethylene bag filled with powder and closed by heat sealing, with the outer walls being made of rigid laminated board. Powders containing milk fat such as full cream milk powder and buttermilk powder are flushed with an inert gas (typically CO2 & N2 mixture) at the time of packaging to reduce the internal oxygen level and thus enhance the storage stability and shelf life.

The 25kg or 15kg bags are stacked onto pallets and are shrink wrapped in plastic sheeting with a top and bottom cardboard sheet for added protection during transportation and storage. Powders should be kept at a temperature of <28°C and relative humidity of <65%, during transport and storage.

Figures 12 and 13 show two methods of handling powder during the reconstitution phase of product application or for on-packing for domestic use. Retail packs used include bag in a box, plastic bags, and metal cans. The metal can is the perfect packaging for milk powders because it offers protection from moisture, light and physical damage. However, it is expensive and can be subject to rust.

Figures 12 and 13 Powder handling apparatus

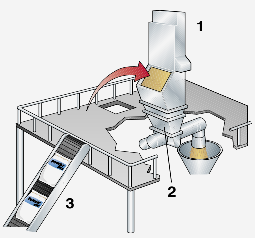


Fig. 18.1 Equipment for handling powder in sacks.
1 Dust collecting unit
2 Sifter
3 Sack elevator

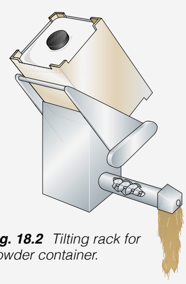


Fig. 18.2 Tilting rack for powder container.

From Tetra Pak Dairy Processing Handbook

Deterioration of quality during handling and storage

Moisture or more specifically water activity (*aw*) is the most important attribute influencing the quality of milk powders during handling and storage. FCMP has a higher *aw* than SMP at the same moisture level because fat does not affect the *aw* level. The main component that attracts water is the lactose, particularly if it is in the amorphous or non-crystalline form. Therefore, powders need to be well packed and because the *aw* increases with temperature, powders need to be stored at <28°C because an increase in *aw* often induces an increase in other deteriorative reactions. The following aspects are important:

- *Microbial and enzymic deterioration* are not often seen in milk powders as the *aw* is too low. However, enzymic reactions can occur slowly at low *aw* levels and thus fat-containing powders must be free of lipase. Also, powders must be free of all enzymes as these may cause problems in applications where they can subsequently be activated.
- *Caking* is a problem when a powder is too high in moisture or absorbs moisture from the air or surrounds. Water vapour condenses on the surface of the powder particles causing caking which leads to clumping and then ultimately to an overall hardening of the powder. This is caused by lactose content and state, with hydrolysed lactose more susceptible to rapid caking because galactose and glucose are both hygroscopic and attract water. Higher temperatures and humidities during storage promote caking. Mild caking can have a detrimental effect on dispersibility, solubility and flowability. The main method used to determine caking temperature is the turning of a propeller in a sealed vessel containing powder. The vessel is placed in a heated water bath and when there is a sudden increase in the force applied by the electric motor to keep the propeller at a constant speed the temperature is noted as this corresponds to the caking point (Chuy *et al*, 1994 and Hennings *et al*, 2001). Free fat can also cause soft clumping, especially if there is a rise and fall of temperature during storage.
- *Browning or off flavours* is caused by the development of Maillard reaction products which are formed by the reaction between proteins and carbohydrates (lactose in milk powders). This can also lead to an increase in insolubility index due to protein insolubilisation. Colour changes can also be monitored by determining L, a, b values using a colour meter. Maillard reaction extent is measured initially by furosine determination and later by hydroxymethylfurfural analysis and advanced reactions can be measured by non-enzymic browning products of low (Amadori compounds) and high (melanoidins) molecular weight.
- *Oxidation* of fat in full cream and buttermilk powder can give rise to tallowy off flavours. The oxidation of fat increases with a decrease in *aw*. An *aw* of around 0.3 provides a minimum reaction rate for auto-oxidation. Therefore, a balance must be struck for the *aw* to prevent oxidation (but not to promote caking) which together with gas flushing usually gives the powder a good storage life.
- *A loss of some nutritive components* and overall digestibility can occur during storage, this is mainly due to the Maillard reaction, as this reaction can impair some essential amino acids such as lysine by linking them with lactose. Vitamin A can also be adversely impacted during storage particularly if oxidation of the fat occurs.

Overall, when considering the storage of milk powders a general rule of thumb is to use them as soon as possible and preferably before 18 - 24 months for SMP, 12 – 18 months for FCMP, 10 – 12 months for BMP. Powders containing fat are particularly prone to deterioration and care must be given to initially selecting high quality powders and storing them under ideal conditions.

4.7 Product specifications

Table 17 shows typical specifications for SMP, FCMP and BMP. Functionality requirements should be added to this list such as heat classifications. Further, depending on the end use, functionality should be specified e.g. heat stability for REM or viscosity for RSCM. These requirements can be discussed and agreed with the manufacturer during negotiations for supply.

Table 17 Typical Specifications for SMP, FCMP and BMP

Constituent	Skim Milk Powder	Full Cream Milk Powder	Buttermilk Powder
Moisture %	Max 4.0 Range 3.0 –3.5	Max 4.5 Range 2.5–4.0	Max 4.0 Range 3.0–4.0
Fat %	Max 1.25 Range 0.5–1.25	Min 26.0 Range 26–28.5	Typical 6.0 Range 4.5–7.5
Protein %	Typical 32.5 Range 32–38	Typical 26.0 Range 24.5–28.0	Typical 31.0 Range 30.0–34.0
Ash %	8.2–8.5	5.4–6.6	8.2–8.7
Lactose %	48.5–51.5	35.5–38.5	46.0–49.0
Titratable Acidity %	Max 0.15	Max 0.15	Max 1.25
Insolubility Index	Max 1.25 Typically 0.1	Max 1.0 Typically, 0.5	Max 1.25 Typically, 0.5
Scorched Particles (ml)	Disc A	Disc A	Disc A
Colour	White to cream	Cream	Cream to yellow
Flavour	Clean	Clean	Sweet and clean
Standard Plate Count cfu/g	<30,000 Typically, Max. 10,000	<50,000 Typically, Max. 10,000	<50,000 Typically, Max. 10,000
Salmonella	Negative Typically, in 375 gm	Negative Typically, in 375 gm	Negative Typically, in 375 gm
Listeria	Negative	Negative	Negative
Coliform	Negative Typically, in 1.0 gm	Negative Typically, in 1.0 gm	Negative Typically, in 1.0 gm
Staphylococci	Negative Typically, in 0.1 gm	Negative Typically, in 0.1 gm	Negative Typically, in 0.1 gm
Yeasts & Moulds	Typical Max. 50/gm	Typical Max. 50/gm	Typical Max. 50/gm

From personal communication with Australian dairy manufacturers

4.8 Frequently asked questions

Dairy product applications

Physical Characteristics and Functionality

1. What is the difference between instant and non-instant powders?

An instant powder has enhanced reconstitution properties and is readily dissolved in cold as well as warm water. The most important aspect of instantising is the agglomeration process applied during powder manufacture where the amount of air between the powder particles is increased resulting in a coarse, cluster like, agglomerate structure. This structure allows more water to enter the powder particles and assists with better wettability and dispersibility.

The agglomeration process in powder manufacture can be done in a number of ways including:

- returning fines to the atomiser,
- forcing agglomeration at the time of atomisation,
- rewetting powder after the initial drying, and/or
- the use of multistage dryers - most often used for the best results using gentle final drying by way of fluid beds or rewet agglomeration of the moist powders that exit from the primary drying stage.

Production of instant FCMP requires the addition of a surfactant as normal powder particles are covered with a thin layer of fat making them repellent in cold water. Lecithin (e.g. from soya beans) is dissolved in AMF and applied to the powder as a fine spray during the final drying process in a fluid bed, at a rate between 0.1 and 0.3%. In evaluating instant powders several properties are considered: BD (max 0.48 g/cm^3), scorched particles (disc A), wettability (max 10 sec @ 25°C), dispersibility (min. 95%), sludge test (max. 0.1 g @ 25°C and 85°C) and free fat (max.1.5%).

2. What are the indicators of solubility, flowability, and dispersibility in milk powders?

Solubility or rather insolubility is determined for powder by mixing a prescribed amount of powder (13g for FCMP and 10g for SMP & BMP) with water (100ml) under controlled temperature conditions (usually 24°C but can be at 50°C if the powder is specifically intended for use at a high reconstitution temperature). The solution is mixed using a specialised mixing machine (defined mixing vessel and stirrer configuration) with subsequent decanting into prescribed centrifuge tubes where the insoluble particles are spun down and measured. Temperature is the single most important determinant in this evaluation where a powder may exhibit some insoluble particles at 24°C but little at 50°C due to the higher solubility of heat denatured protein and the release of any entrapped fat at these higher temperatures.

Figure 14 Schematic of a rewet agglomeration process

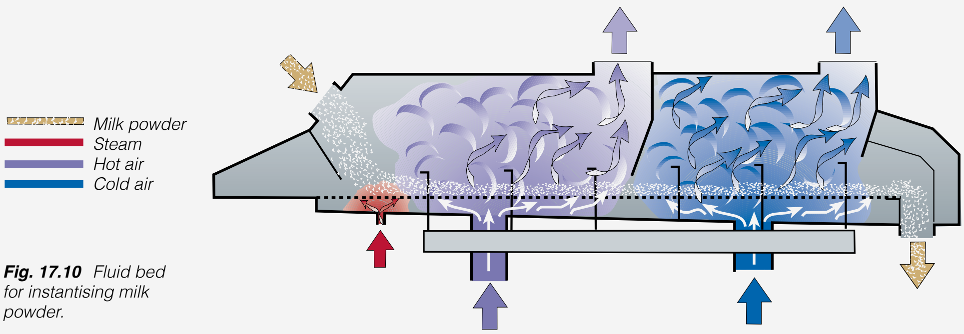


Fig. 17.10 Fluid bed for instantising milk powder.

From Tetra Pak Dairy Processing Handbook

Therefore, it is essential that insolubility index measurements be reported with the temperature being clearly stated.

Flowability is an important property of powders in respect to transport, weight measurement, packaging, and handling in subsequent applications. It is influenced by particle morphology (size, shape, and structure) and the distribution of the powder particle sizes. Good flowability is usually obtained with larger particles or from agglomerates with a minimal number of smaller particles. However, larger particle size distribution and agglomeration may have an adverse effect on BD. Lower "loose" BD improves flowability but this is less related to tapped BD. The fat content plays a key role in the flowability of powders; in particular, the degree to which the fat is in the "free" form or more particularly on the surface. The use of free flowing agents and the application of an instantising operation assist the flowability of powders.

Dispersibility is the ability of powder to dissolve without forming dry lumps and with instantaneous disintegration of agglomerates into single particles ready for dissolving. The agglomeration process is of primary importance for good dispersibility and needs to be optimised to ensure that there are few agglomerates >250 micron, few compact agglomerates and very little or no fine particles.

3. How is bulk density assessed and what does it mean?

Bulk density (BD) is a measure of the weight of powder that can be contained in a prescribed volume (weight of a volume unit of powder) and is usually expressed as g/cm^3 (or sometimes kg/m^3). It is a very important attribute when considering packaging and transport as most transport cost is calculated based on volume. Bulk density also influences other powder functionality such as dispersibility and instantising.

The method involves placing 100g powder in a 250ml measuring cylinder. The surface is levelled and the volume measured (poured BD), the cylinder is then tapped one hundred times (loose BD), the volume recorded and then tapped a further 525 times for a total of 625 (BD) and the final volume recorded. The volume measured after each of these operations is termed as poured BD, tapped BD and BD. There are several variations of this method and the method used must be quoted with the results.

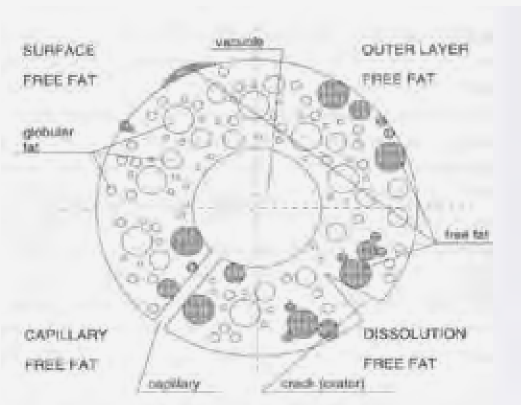
There are many factors that contribute to BD. During the manufacture of the powder the final BD can be influenced by concentrate characteristics, atomisation, drying temperatures and degree of whey protein denaturation (the greater degree of denaturation, the higher the BD). The critical measurements that determine the ultimate BD of a powder include the particle size distribution (the greater the spread, the higher the BD), occluded air or the amount of air incorporated within the powder particles, (higher occluded air yields lower BD), the shape of the powder particles which give rise to the amount of air between them known as interstitial air (higher interstitial air results in lower BD) and the density of the powder particle which is determined by the composition of the powder. The BD of a powder can increase with storage, due to attrition of the particles with subsequent packing down in the bag or container. This is not beneficial from a visual point of view nor does it assist in dispersibility when too many fines are formed.

One drawback of agglomerated powder is that it has a lower BD than non-agglomerated due to the uniformity and larger nature of the particles in an agglomerated powder.

4. What is free fat and how does it affect milk powder?

Free fat is that fat which is easily extractable from milk powder particles by a solvent under standard conditions of time, temperature, and agitation. As shown in Figure 15, the extractable fat is on or close to the surface but when there are cracks or fissures on the surface of the powder particle, fat that resides within the particle can also be extracted. This free fat can cause both physical and compositional defects. High free fat causes clumping and the hydrophobic nature of the fat causes reduced flowability and dispersibility. Its exposure to air facilitates oxidation which reduces the powder's shelf life and leads to flavour defects. It is therefore very important that during the manufacture of milk powder a good emulsion is formed prior to drying, the conditions of drying minimise cracking and case hardening and that the storage conditions of the powder are optimal to minimise the production of free fat.

Figure 15 Buma's free fat model

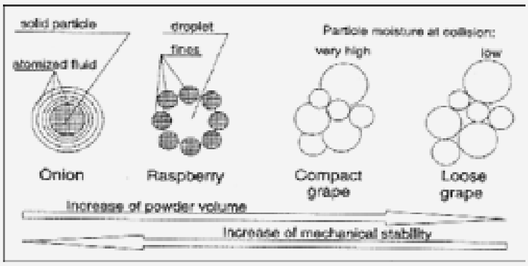


From Buma, 1971

5. What is agglomeration and how is it undertaken?

Agglomeration is the formation of clusters of powder particles. For milk powders it is used to increase the amount of air between the particles (interstitial air) which is required to assist powder dispersibility. There are four types of agglomerates that can be formed: onion, raspberry, compact grape, and loose grape. The first two types do not assist in dispersibility and are not used in the dairy industry. The latter two occur by collision of particles and fines and depending on the moisture content, a loose or compact formation occurs with the loose particles being superior for dispersibility. During the spray drying operation agglomeration can occur naturally by interaction or can be forced by the introduction of fines or cross over spray patterns.

Figure 16 Types of agglomerates (Pisecky 1997)



6. What is meant by particle size distribution?

Particle size distribution (PSD) gives a measure of the number of powder particles that exist within a specified range of sizes. There are several ways of measuring PSD including sieving, microscopic counting, and automatic counting apparatus. The sieving and microscopic counting are the least accurate as they tend to break down agglomerates and they are also time consuming. Apparatus such as the Malvern and Coulter are fast and very accurate as they use non-destructive laser beam methodology. PSD can influence a range of physical characteristics of powders including a decrease in dispersibility with increasing fines, a lowering of interstitial air with a broadening of the PSD particularly with large amounts of fine particles, an increase in BD with an increase in PSD. The ability of various spray dryers to produce PSD ranges is shown in Table 18.

Table 18 Mean particle size obtained from dryers of different configuration

Powder Characteristics	Dryer Configuration	Particle Size (micron)
Individual particles	Concurrent with pneumatic conveying	20–200
	Tall form – tower	30–250
Flakes	Roller dryer	200–5000
Loose agglomerates -open structure	Mixed flow with integrated fluid bed	100–400
	Concurrent with integrated fluid bed	100–200
Compact agglomerate -porous structure	Concurrent spray dryer with integrated belt	300–2000
	Mixed flow with integrated fluid bed	100–400

Personal Communication (E. Refstrup), Niro A/S, Denmark, and Niro (1998)

7. What are the special functional aspects of BMP?

BMP is the dried form of buttermilk which is a by-product of butter manufacture. During butter manufacture the natural milk fat globule membrane is ruptured during churning of cream. This membrane which represents approximately 2% of the total fat globule is composed of a mixture of phospholipoproteins (50% protein, 30% phospholipid and 8% other fats) and contains different complex surfactant materials some of which have very desirable functional properties. Buttermilk and hence BMP contains a very high proportion of these materials which have a range of positive effects on subsequent applications including enhanced flavour, improved heat stability and increased emulsification capability.

8. Is there a standardised way of describing the flavour components of skim milk powder?

A standardised descriptive language for SMP and dried dairy ingredients has been developed. The lexicon was initially identified from a large sample set of dried dairy ingredients. Twenty-one descriptors were identified for dried dairy ingredients. Seventeen flavours and tastes have been identified in SMPs with nine flavours and tastes observed in all SMPs (Drake *et al*. 2003).

9. Water binding is often a desired functionality in selecting an ingredient – what is the water holding capacity of dried milk products?

The water binding capacity of dairy ingredients in applications varies widely mainly depending on the type and amount of the protein present. Table 19 gives an indicative amount of water binding capacity of several milk powders.

Table 19 Water binding capacity for Powders and Constituents

Product	g water/g ingredient
Skim Milk Powder	0.96 – 1.28
Sodium Caseinate	2.95
Calcium Caseinate	1.59
Lactic Casein	0.97 – 1.28
Lactalbumin	0.96

Further information on the water binding properties of milk protein products can be found in Seiler & Kneifel 1993.

10. What are the foaming properties of milk products dependent on and what factors affect the foaming of milk?

The foaming properties are dependent on the ability of surfactant (the proteins) to lower the surface tension and then to stabilise the foam after its formation.

Factors affecting foaming of milk include composition (protein and fat level in particular), quality of fat, presence of low molecular weight surfactants, pH and mineral balance, temperature.

Quality and economics

1. How can optimum solution appearance be maintained?

The maintenance of optimum solution appearance depends on many factors. Firstly, the milk powders used for the application must be of the highest quality (e.g. no scorched particles). This means using powders with the best possible insolubility index and colour measurements and in the case of FCMP and BMP having no sign of fat oxidation. The process that most determines the appearance of the final product is the application of appropriate levels of heat. Therefore, optimisation of manufacturing conditions and regular checks of equipment are essential, with indicator gauges regularly checked and monitored. Hygiene regimes should ensure absolute cleanliness of the machines. The storage of the final product can also have a telling effect on the quality of its continuing appearance. Products subjected to heat, moisture, humidity, and light will results in loss of quality.

2. How to minimise the nutrient loss during processing and storage?

The most important aspect of milk powder that should be considered when discussing the possible deterioration of quality of powders is moisture level or more appropriately the water activity *(aw)*. WMP has a higher *aw* than SMP at the same moisture level because fat does not affect the *aw* level. The main component that attracts water is the lactose particularly if it is in amorphous or non-crystalline form. Therefore powders need to be well packed and because the *aw* increases with temperature, the powder should be kept at <28°C because an increase in *aw* often induces an increase in other deteriorative reactions. There are several deteriorative aspects to consider and be aware of:

- *Microbial and enzymic deterioration* are not often seen in milk powders as the *aw* is too low. However, enzymic reactions can occur slowly at low *aw* levels and thus fat-containing powders must be free of lipase. Also, powders must be free of all enzymes as these may cause problems in applications where they can subsequently be activated.
- *Caking* is a problem when a powder is too high in moisture or absorbs moisture from the air or surrounds. Caking leads to clumping and then ultimately to an overall hardening of the powder. The component primarily responsible for caking is lactose and higher temperatures of storage promote caking.
- *Browning or off flavours* are caused by the development of Maillard reaction products formed by the reaction between proteins and carbohydrates (lactose in milk powders). This can also lead to an increase in insolubility index due to protein insolubilisation
- *Oxidation* of fat in full cream and buttermilk powder can give rise to tallowy off flavours. The oxidation of fat increases with a decrease in *aw*. An *aw* of around 0.3 provides a minimum reaction rate for auto-oxidation. Therefore, a balance must be struck for the *aw* to prevent oxidation (and not promote caking) which together with gas flushing usually gives the powder a good storage life. A loss of some nutritive components can occur during processing and on storage. Loss can be minimised during processing by using staged drying i.e. multistage. The most vulnerable to this is lysine, which happens because of the Maillard reaction. Vitamin A can also be lost during storage.

3. What is oxidation and how to minimise fat oxidised flavour during storage?

Oxidised flavour is a consequence of the reaction between oxygen and radical species formed from unsaturated fatty acids in milk powders. Obviously FCMP and BMP are more susceptible to this reaction but it can still occur in SMP. It can develop quickly if the fat quality prior to separation was poor or the fat globules have been poorly handled to yield free fat which is easily oxidised. There are two stages of oxidation – the first being the formation of hydroperoxides and the second, and more important, is the formation of degradation products which primarily give the off flavours detected in milk powders. Traditionally, tests such as the ferric thiocyanate method were undertaken to determine the peroxide value (PV) as a measure of oxidation but as these hydroperoxides further react in the second stage this is not a good standalone method and PV values will rise and fall during storage. A better indicator is to evaluate for the secondary products by undertaking analysis such as the thiobarbituric acid determination. Other measures such as the determination of free sulfhydryl groups are also used as indicators of oxidation as they are antioxidants and a decrease usually correlates with an increase in oxidation (Thomas *et al*, 2004).

In order to minimise oxidised flavour, the best possible quality milk powder must be sourced and absence of oxidation included in the specifications. If there is any sign of oxidation the powder should be rejected as once oxidation starts it can only be controlled to a certain extent but not stopped entirely. Storage conditions are especially important – temperature in particular needs to be kept between 20 – 25°C if possible, as higher temperatures promote oxidation. Low humidity and minimal light exposure are also recommended. Stacking of powder at heights for extended periods can lead to possible rupture of the encapsulated milk fat globules leading to free fat and the possibility of oxidation in the presence of oxygen and air.

Packaging can also assist in minimising oxidation by using modified atmospheric packaging to reduce the O_2 to <1.5% using gas flushing, the use of barrier bags, and preheat treatment of the milk during processing produces natural antioxidants.

4. How can the microbiological quality of powders be improved?

The microbiological quality of the final product is dependent on the quality of the ingredients used, particularly milk. Downstream processing cannot improve quality challenges from poor quality milk. The other major factor is the cleanliness and operation of the processing plant. All efforts must be made to comply with standard operating conditions regarding plant operation, packaging, and staff hygiene always.

5. How can ingredient costs be optimised?

Optimisation of ingredient costs can be achieved in several ways. The most important way is to make sure that the ingredient purchased is firstly the best fit for the application i.e., not only does it exhibit all the common compositional and functional properties but it also has compositional and functional properties specific to the product.

The use of blends is becoming increasingly popular as an economic tool. The most common cheaper ingredient used is whey or permeate powder. The fact that these ingredients do not contain all the components of SMP, FCMP or BMP often means that they will not perform to the same level as these powders. The simple blending or substitution of SMP, FCMP and BMP by whey powder at the point of application can be problematic. There are a range of blends manufactured specifically for designated use e.g. ice cream blends and bakery blends. These are not only economical but often have enhanced functionality because the composition is based on the selection and blending of appropriate ingredients with enhanced specific functionalities required for specific end use. However, even with these specialised blends there may be trade off in some attributes, flavour, for example.

These powders still require the processor to get all the processing conditions correct and to have the flexibility to accommodate changes in formulation and processing conditions with changes in ingredients if required. Purchasing the right ingredient for the right application combined with the best quality will save money and prove an economic advantage in the long run.

Processing and storage

1. What is the most suitable packaging temperature for milk powders?

SMP is usually cooled to less than 30°C in the final stage of drying in a fluid bed prior to packaging to minimise any clumping and moisture migration. For the fat containing powders (FCMP and BMP) the temperature of packaging is usually higher particularly for instantised powders where the temperature is around 45°C to ensure that the lecithin and AMF applied to the powder have sufficient time while still in a relatively molten state to migrate and thus to completely coat all the powder particles. Care must be taken though not to maintain this temperature for too long as clumping could occur particularly if the free fat level is elevated.

Specifications and analysis

1. How is powder evaluated for scorched particles?

Scorched particles occur because of deposits in the spray dryer or other areas of manufacture and/or where the deposits or particles have been exposed to elevated temperatures, usually for a little while. Deposits can form on the atomiser where they are subjected to extremely elevated temperatures. This causes scorching and browning of the particles and leads to insolubility. There is also the possibility of burn-on in the evaporator.

The test method for the determination of scorched particles is as follows:

25g of SMP or 32.5 g of FCMP or BMP is mixed in 250 ml of water at 18 - 27°C for approximately 50 sec using a high shear mixer. The solution is then filtered through a filter pad (often made of cotton with a pore size of one hundred micron) of 32 mm diameter. There are several devices available that can hold the filter pad in position or the use of a simple funnel will be adequate. The solution is forced through the pad by either vacuum or pressure (50 kPa is sufficient). The pad is then visually compared to a standard for classification and the scorched particles are recorded as A, B, C or D depending on the intensity of the colour on the pad.

Figure 17 ADMI chart 'Scorched Particles Standards for Dry Milk'

2. What is Whey Protein Nitrogen Index?

Whey protein nitrogen index (WPNI) is a measure of the amount of undenatured whey protein remaining in milk powder and is expressed as mg of undenatured whey protein per gram of powder. The amount of undenatured whey protein is a measure of the degree of heat treatment the milk has been subjected to during manufacture. The preheat treatment given to the raw milk prior to evaporation and drying is the most important factor impacting denaturation of whey protein and functionality relevant to end use of the powder. During preheating of milk before evaporation most denaturation happens.

Very little denaturation occurs in the evaporation and drying stages even though the temperatures are relatively high, the contact time is low and the temperature which the milk solids are subjected to is relatively low.

3. What is the difference between low, medium, and high heat powder and what is heat classification of powders?

The degree to which the whey proteins are denatured during the preheat treatment determines many of the functional properties of the powder. Therefore, it is a common practice to classify powders according to their degree of whey protein denaturation. One of the most common classification methods is that from the American Dried Milk Institute (ADMI) where the concentration of undenatured whey protein nitrogen index (UWPNI) is calculated by precipitation and turbidity readings and then ranked as shown in Table 20. Another method of classification is the Heat Number (IDF Standard 114:1982) which is based on the procedure of Rowland (1938a) in which the casein number is determined by multiplying the ratio of casein nitrogen content and total nitrogen and multiplying by 100. The equivalent values for the heat number are also given in Table 14. However, it must be understood that a WPNI or Heat Number alone does not guarantee that the powder will perform or will perform consistently in a functional way e.g. not all high heat powders are heat stable and not all high heat powders with the same WPNI or Heat Number perform the same. Factors such as seasonal variation also need to be considered. Specific functional tests must be undertaken to determine the degree of functionality and suitability for application of all powders independent of their WPNI or Heat Number.

Table 20 Heat Classification According to WPNI and Heat Number

Heat Classification	WPNI (mg undenatured WPN/g)	Typical Heat treatment	Equivalent Heat Number (%)
Low heat	>6.0	72-75°C/15-30 sec	<80
Medium heat	1.51 – 5.99	75-95°C/1-3 min 85-105°C/1-2 min	80.1–83.0
Medium–high heat	–	75-110°C/1-5 min	83.1–88.0
High heat	<1.5	85°C/30 min 90°C/10 min 120-135°C/1-2 min	>88.1

4. How is WPNI measured?

All the casein in the powder and the denatured whey protein (which has complexed with the casein) are precipitated from a sample of reconstituted dried milk by saturation with sodium chloride with the precipitate being removed by centrifugation and subsequent filtration. The filtrate is tested for nitrogen (which is a combination of the undenatured whey protein nitrogen - UDWPN and non-protein nitrogen - NPN) by the Kjeldahl method. A second aliquot of the filtrate is acidified with hydrochloric acid to precipitate the UDWPN and the NPN remaining in the filtrate is determined. The UNWPN or WPNI is then calculated by the difference between the two determinations i.e. (UDWPN + NPN) – NPN = UDWPN or WPNI. SMP is often classified by WPNI as a broad classification of heat treatment.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Applications

1. Is there a simple guide for the use of SMP, FCMP and BMP in applications according to desired functionality?

Table 21 gives a general guide for the use of SMP, FCMP and BMP. The exact attribute required will change from specific product to product but the general principle will apply.

Table 21 General guide to powder usage and functional property

Application	Powder and Heat Treatment	Desirable Functional Attribute/s
Dairy		
Yoghurt	SMP or FCMP and usually high, but low heat can be used if yoghurt milk given high heat treatment during manufacture	Water binding, viscosity, and gelation
Ice cream	SMP, FCMP & BMP with low to medium heat	Foaming, whipping, and emulsifying
Milk (Pasteurised)	SMP & FCMP with low heat	Lack of cooked flavour
UHT Milk	SMP & FCMP with low to medium heat	Heat stability and Pyruvate <9 mg
REM	SMP, FCMP & BMP with high heat	Heat stability
RSCM	SMP, FCMP & BMP with medium heat	Viscosity
Cheese	SMP & FCMP with low heat	Ability to form curd
Beverages	SMP & FCMP with low to medium heat	Nutritional, viscosity & texture
Bakery		
In general,	SMP, FCMP & BMP with medium to high	Water binding, emulsifying, foaming, whipping, and gelling
Bread	SMP with high heat	Water binding, emulsifying, foaming, and gelling
Confectionery		
In general,	SMP & BMP with medium to high heat	Water binding, whipping, foaming, viscosity, colour development and emulsifying
Chocolate	FCMP & BMP with high heat	High "free fat," flavour and viscosity
Smallgoods		
In general,	SMP with low to medium heat	Gelation, water binding and emulsifying
Health Foods		
In general,	SMP, FCMP & BMP with low heat	Nutritional, water binding & emulsifying

2. How does the fat component of milk products enhance a confectionery and bakery product?

In confectionery the fat component of milk powders helps prevent stickiness in high sugar environments such as caramel & toffee. It also has a unique flavour profile and acts as a carrier for oil soluble flavours especially for cream centres. Fat is highly compatible with cocoa butter and helps to minimise fat bloom in many products. Cream powders are a substitute for fat as a standalone product. In bakery the fat adds an appealing colour, contributes to a rich flavour, can act as a carrier of fat soluble vitamins and enhance the structure to cakes, pie crusts and pastries.

3. Is there one single factor that determines the suitability of milk powders for chocolate manufacture?

There is no single factor that determines the suitability of a milk powder for the manufacture of chocolate. There is a complex interplay between both the composition (fat content in particular) and the physical attributes (particle size, free fat, and status of the lactose.

4. What is the preferable composition (%) of dried dairy ingredients used in chocolate?

A range of dairy based ingredients are used in the manufacture of chocolate. See Table 17 for typical composition of SMP, FCMP and BP. Table 22 below shows the composition of other dairy based ingredients used in chocolate manufacture.

5. What are the main attributes of concentrated and dried milk when used in bakery?

The main attributes of dried milks when used in bakery include, an increase in nutritive value, enhanced water binding and processing, a contribution to browning and colour, the formation of dense and fine air bubbles, a subtle pleasant flavour and formation and stability of emulsions.

6. What is the best method for the manufacture of FCMP for use in chocolate manufacture?

Chocolate is traditionally made from roller dried milk powders because of >90% free fat and their enriched flavour due to the intense heat applied during manufacture. However, modern methods are now available where spray dried FCMP can be tailor made by ensuring relatively high levels of free fat (>40% consistently), enriched caramelised flavour, and other special requirements important for chocolate manufacture such as particular powder morphologies. Care must be taken with these powders as the high amount of free fat makes them susceptible to oxidation and they therefore have a shorter shelf life.

Table 22 Composition of dairy based ingredients used in chocolate manufacture

Product	Water	Protein	Fat	Lactose	Mineral
Cream Powder	2.6	15.4	55.0	23.6	3.5
Caseinate	3.3	91.4	0.9	0.2	4.1
Whey Powder	4.6	13.0	1.1	73.0	8.2
Demin Whey Powder	4.6	14.5	1.0	76.6	3.2
Milk crumb	1.3	7.6	31.0	7.9	1.7

4.9 Glossary

Age thickening

An increase in viscosity or 'thickening' on storage. Usually associated with REM, RSCM and UHT milks.

Atomisation

This is the formation of a spray or mist of the feed concentrate into the spray dryer to enable intimate contact with the drying air in the main chamber.

Agglomeration

Agglomeration is the formation of clusters of powder particles to assist in the inclusion of more interstitial air and thus to aid dispersibility.

BMP

Buttermilk powder is the dried form buttermilk which is the by-product from the manufacture of butter.

Bulk Density

Bulk Density (BD) is a measure of the weight of powder that can be contained in a prescribed volume (weight of a volume of powder) and is usually expressed as g/cm^3 (or sometimes kg/m^3).

Caking

Is the natural propensity of a powder to form a semi solid or solid lump when exposed to air or pressure. The degree to which this occurs is related to hygroscopicity and free fat.

Coffee test

Is an observation and quantitative measurement of undissolved particles formed when milk powder is added to a coffee solution.

Cyclone

Is part of the spray drying system. It is conical shaped and by control of the air flow patterns it can separate powder particles from the outlet air.

Dispersibility

Dispersibility refers to dispersing of powder particles after they have wetted and sunk below the surface of water during dissolving of powder in water. It is affected by wettability, sinkability and solubility.

Emulsifiers

Assist in the formation and maintenance of stable emulsions in many dairy applications. Many dairy ingredients also have emulsion capability.

Emulsion capacity

Is a measurement of an ingredient, including dairy based, to exhibit emulsion forming capacity.

Evaporation

The removal of water from a solution by evaporation of water. Thermal evaporation under vacuum is the major way of concentration of milk prior to drying.

Fat bloom

Is a defect in chocolate where the surface appears to shine.

Fat separation

Is a defect in many dairy products that contain fat. It is usually caused by unstable emulsions, which allow fat to rise to the surface.

Fines

Fines are the particles at the lower end of the particle size range of powders. They usually do not separate from the exhaust air in a spray dryer with the bulk of the powder and are removed by cyclones and often returned to the main chamber to facilitate agglomeration.

Flowability

This is the ability of a powder to freely flow when placed on an incline or during transportation within the manufacturing plant or point of application. It is of particular importance in the handling of powders.

Foaming

Is the ability of a solution to incorporate air and is of particular importance in the manufacture of ice cream and mousse type products.

Free fat

Free fat is that fat which is easily extractable from milk powder particles by a solvent under standard conditions of time, temperature, and agitation.

Generally free fat is obtained when the fat globule is ruptured and the fat globule membrane is removed.

Free moisture

Free moisture is water that is easily extractable when the powder is subjected to a temperature slightly >100°C at atmospheric pressure. It is moisture not involved in any chemical reaction.

Flowability

This is a measure of the free flow characteristics of powders.

Fluid bed

A fluid bed is a unit used during powder manufacture, which can either, be incorporated into the main body of the dryer or more typically external to the dryer. It has a twofold function in that it acts as a secondary or tertiary dryer and is used for instantising action.

Functionality

Is a characteristic of a powder that can be (1) physical in that it imparts physical & sensory properties, (2) nutritional in that it is a source of nutrients, or (3) biological value and physiological in that is has a bio modulating response.

Gelation

Gelation refers to cross linking between proteins to form a gel network which is semi solid or solid. This is accomplished by heat and occurs as a two step process, with heat denaturing the whey protein and unfolding them, and then they aggregate to form a network.

Heat classification

This is a means to distinguish milk powders that have been subjected to different heat treatments, predominantly preheating of the raw milk prior to evaporation and drying. A typical classification is low, medium, and high heat.

Homogenisation

Homogenisation is a process used to reduce the size of fat globules in milk and milk products. The process usually involves passing the product through a small opening under high pressures. The process also induces the coating of the fat with protein.

Inlet temperature

The temperature of the air used for spray drying whether primary for the main chamber or secondary for fluid beds.

Insolubility

This is a defect in powders and is a measure of the amount of solids in a powder that are not soluble under specified conditions of temperature and mixing

Instantisation

This is a process to enhance the reconstitution properties of powders and in particular assists dissolving at cold water temperatures.

Interstitial air

The air that is entrapped between the powder particles is designated as the interstitial air.

Lactose crystallisation

In milk, lactose crystallisation is the conversion of the beta-lactose, which is hygroscopic into the non-hygroscopic alpha-form. Due to the fast water evaporation during spray drying this conversion does not take place to any great extent. However, a crystallation step prior to drying is often required for dairy powders with a high lactose content. In recombined dairy products e.g. sweetened condensed milk, lactose crystallisation occurs as sediment on the bottom of the product due to poor nucleation during processing that results in large crystals that give a grainy mouth feel.

Lecithination

This is the use of lecithin, usually derived from soy, which has both hydrophilic and lipophilic properties and is sprayed onto WMP to improve the wettability and solubility of WMP.

Lipase

Lipases are enzymes that cleave fat both in milk and milk products often resulting in unpleasant flavour defects.

Maillard reaction

The Maillard reaction takes place when heat is applied to a protein and carbohydrate mixture. The most obvious result of this reaction is the enhancement of browning. A positive outcome is the manufacture of antioxidant agents.

Mechanical Vapour Recompression

Mechanical Vapour Recompression (MVP) is a method by which the temperature of the vapour removed from a thermal evaporator is increased by applying pressure by mechanical means and the water vapour is then used as a heating medium in subsequent effects.

Occluded air

This is the air that is entrapped in the powder particles.

Outlet temperature

This is the temperature of the air as it exits the spray dryer or fluid bed. It is the major factor impacting the moisture level and functional properties especially powder morphology.

Powder density

The powder particle density is a measure of the density of the powder solids including the occluded air. Whereas the powder solids density is the density of the solids not including any air and is depends on the product composition.

Preheat

The preheat is the heat treatment given to the raw milk during powder manufacture prior to evaporation and drying. This heat determines many of the resultant powder functionalities especially the low, medium, and high heat powders.

Scorched particles

Insoluble particles in the powder that are usually caused by heat damage during powder manufacture.

Sediment

Sediment is the film or individual particles that gather at the bottom of liquid dairy products, usually upon storage.

Sinkability

Once a powder particle has been initially wetted it then must be able to sink into the water for complete dispersion and solubility.

Solubility

Solubility is the attribute of a powder being able to be completely dissolved in water.

Thermal Vapour Recompression

Thermal Vapour Recompression (TVR) is a method by which the temperature of the vapour removed from a thermal evaporator is increased by injecting a small amount of steam and the resultant 'steam' mixture is used as heating medium in the next effect of the evaporator.

Water binding

Water binding is a functional attribute whereby milk solids, particularly proteins, can bind water to improve texture, viscosity or gel strength.

Wettability

Wettability is a property of milk powder which refers to the ability of water to penetrate the particle of powder to assist with dissolving the powder in water.

White flecks

These are insoluble parts of powder particle that form a layer on the surface of a reconstituted liquid.

Whey protein nitrogen index

This is a measure of the level of undenatured whey protein which is related to the degree of heat treatment given to the milk prior to the evaporation step. The degree of heat treatment determines the functional properties and applications of the powder.

4.10 References and further reading

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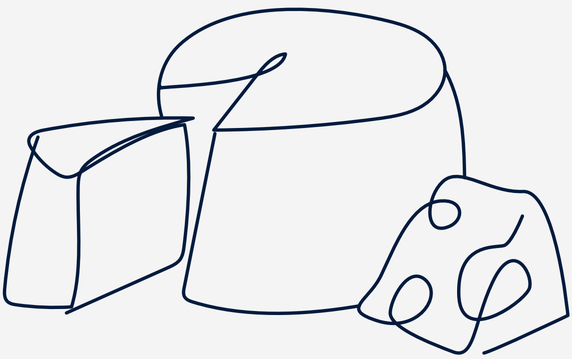
100% australian 100% cheese
Woombye Triple Cream Ash
Bay of Fires Cloth Aged Cheddar

05 Cheese Overview and Applications

5A Cheese overview content



5a.1 Introduction to cheese and cheese manufacture

What is cheese – a definition?

Cheese is a concentrated and preserved form of milk. The definition of Cheese is governed by the Codex Standard 283-1978. Essentially, this standard states that the whey protein/casein ratio of cheese must be lower than that of milk and is obtained through:

a the coagulation of the protein using rennet or other suitable coagulating agents and partially draining the whey resulting in a concentration of milk protein that is higher than that of the milk it is made from.

b other processing techniques involving coagulation of the milk protein which give an end product that has similar physical, chemical and sensory characteristics as the product defined in part (a).

Most cheeses are made using an enzyme (rennet) to coagulate the milk. Most, but not all cheese is made using fermentation from bacterial starter cultures. The preservation of the cheese is assisted by one or more of the following: acidification, salting, dehydration, packaging, heating and refrigeration.

Basic steps in cheesemaking

1. Milk storage

Milk is stored at 4°C when received at the cheese factory. It is made into cheese as soon as possible but generally within 24 hours.

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2. Milk standardisation

One of the aims of standardising milk for cheesemaking is to adjust the composition of the milk so that there is enough fat in relation to solids-not-fat to produce cheese which complies with the specifications for fat-in-dry matter (FDM). This is achieved by separating the whole milk into the skim and cream portions and then blending them back to provide the desired protein:fat ratio which will yield the required protein and fat levels for that cheese variety.

Cheese milk can also be standardised for protein where the skim portion is passed through an ultra-filtration (UF) membrane which concentrates the protein as the retentate and filters out some of the water and lactose (permeate). This process can be used to increase the protein in the milk which will increase the capacity of the manufacturing equipment and occasionally will also improve the cheese yield depending on the type of cheese being manufactured.

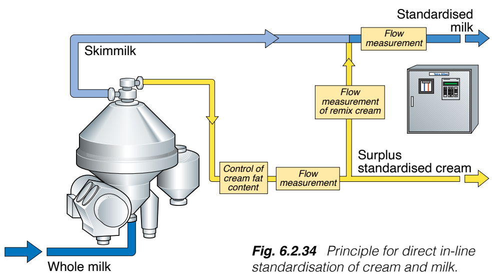

Fig. 6.2.34 *Principle for direct in-line standardisation of cream and milk.*

Dairy Processing Handbook/chapter 6.2

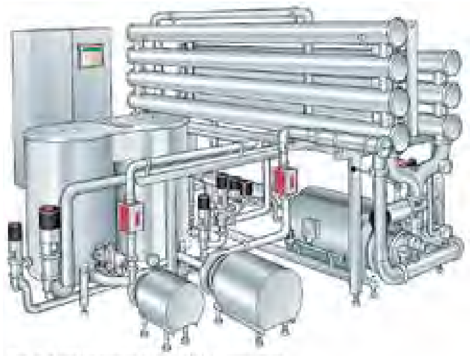

Fig. 6.4.20 *Production module for UF processing*

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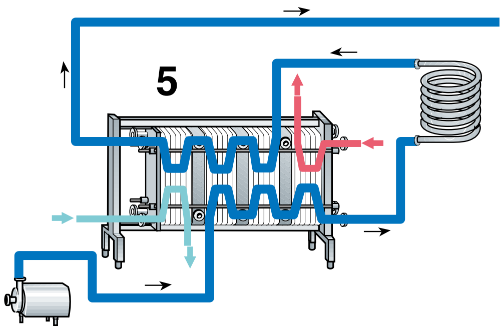
3. Milk pasteurisation (72°C x 15 Seconds)

Pasteurisation is defined as a heat treatment in which the combination of the temperature and the time is sufficient to destroy ALL pathogenic (disease-producing) organisms and most of the spoilage organisms.

Pasteurisers are typically Plate Heat Exchangers (PHE) design where hot water or steam is used to heat the milk to the pasteurisation temperature across a series of stainless steel plates and the milk is then held in holding tubes for the required time to kill all pathogenic organisms.

4. Addition of starter cultures

Bacteria used in cheesemaking are usually called starter cultures and are used to convert lactose to lactic acid, lower the pH and to produce desirable flavour and texture characteristics in the matured cheese.



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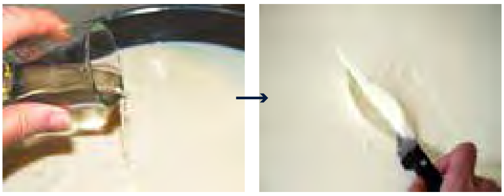
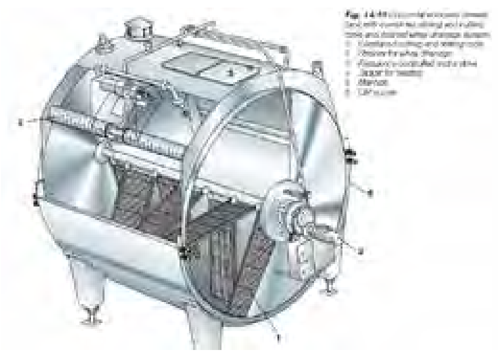
5. Enzyme addition and coagulation of milk

There are two means to coagulate or set the milk - enzymic and acidic. Generally, all semi-hard to hard cheeses use enzymic coagulation whilst most soft and fresh cheeses use acid coagulation to produce what is known as an acid curd.



6. Removal of moisture (Syneresis)

Moisture is removed from the curd by cutting it into small pieces. After cutting, the curd and whey are heated thereby shrinking the curd particles while stirring the curd in the whey. The whey is then drained off. Modern cheese vats can perform all of these functions in the vat.



A modern cheese vat with cutting blades and stirrers.

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7. Whey removal

When the curd has attained the desired level of firmness and acidity/pH, the curds and whey are separated, usually by whey removal. This is usually carried out in draining belts in large factories using continuous systems for manufacturing.

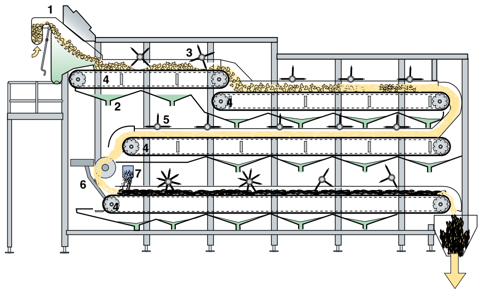

Fig.14.20 Continuous system for de-wheying, cheddaring, milling, and salting curd intended for Cheddar cheese.

1 Whey strainer (screen)
2 Whey sump
3 Agitator
4 Conveyors with variable-speed drive
5 Agitators (optional) for production of stirred curd Cheddar
6 Chip mill
7 Dry salting system

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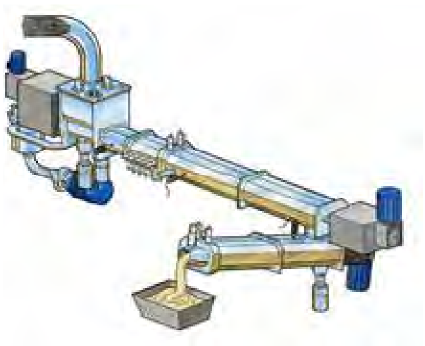
8. Texturing of curd

The handling of curd after the removal of whey determines the final body and texture characteristics of the cheese. For example, in Cheddar cheesemaking the cheese curd is turned to encourage matting or Cheddaring whereas in Mozzarella and pasta filata cheeses the curd is diced then placed into hot water in a cooker-stretcher where it is stretched before moulding into shape.



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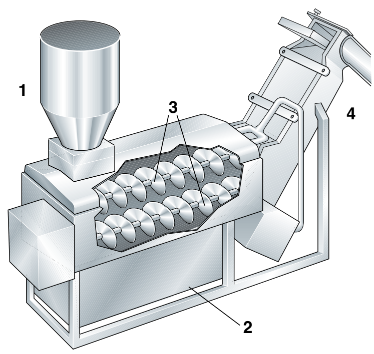

Fig. 14.25 *Continuous operating Cooker-Stretcher for Pasta Filata types of cheese.*
1 Feed hopper
2 Container for temperature-controlled hot water
3 Two counterrotating augers

9. Milling of curd

The curd is cut into small pieces approximately 1cm x 1cm x 15cm. This increases the curd surface area to facilitate salting.

10. Salting

The salt may be added directly to the curd (dry salting) or indirectly by placing the pressed cheese in a brine (salt) bath (brine salting). The addition of salt slows the acid production thereby limiting the production of lactic acid. The salt also contributes to the final flavour.

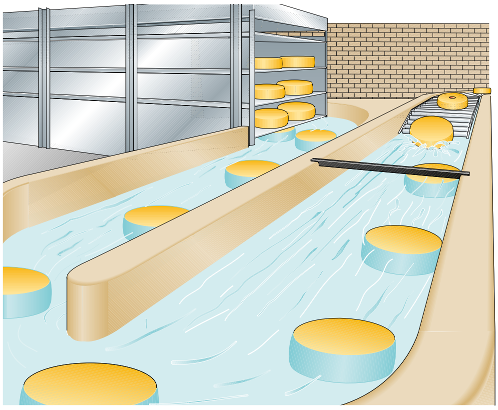

Fig. 14.30 *Deep brining system. The cage, 10 x 1.1 m with 10 layers, holds one shift's production.*

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11. Moulding, pressing or hooping the curd

Pressing gives the cheese its final shape. It may take place using the curd's own weight or by using external or vacuum pressure such as presses or block forming towers.

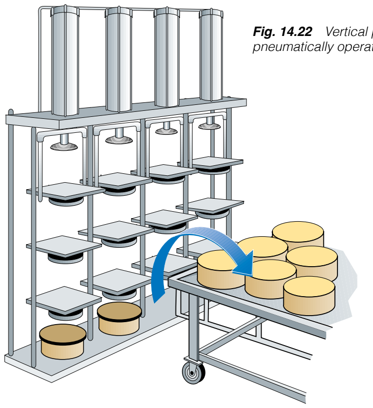

Fig. 14.22 *Vertical pressing unit with pneumatically operated pressing plates.*

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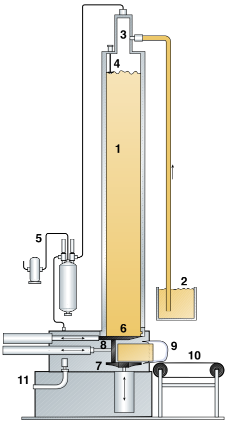

Fig. 14.24 *Block former system for Cheddar-type cheese.Principle and exterior (right).*

1 Column
2 Curd feed
3 Cyclone
4 Level sensor
5 Vacuum unit
6 Combined bottom plate and guillotine
7 Elevator platform
8 Ejector
9 Barrier bag
10 Conveyor to vacuum sealing
11 Whey drainage

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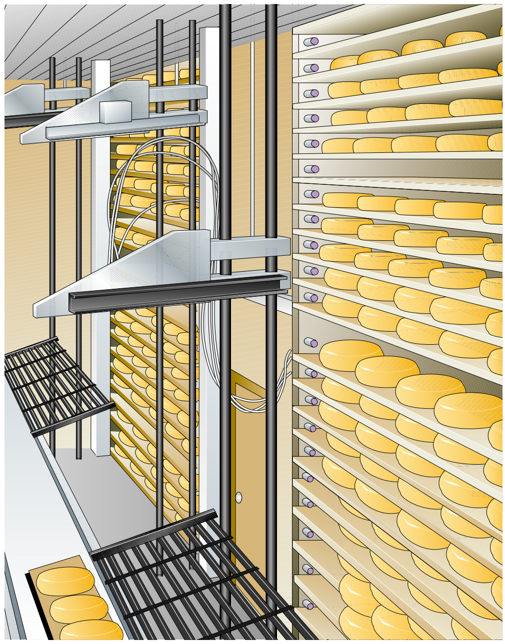
12. Cheese storage and maturation

During storage and maturation at low temperatures, the fat and protein in cheese curd very gradually break down to develop the body, texture and flavour characteristics. The time period and temperature of storage need to be chosen carefully to allow the cheese to mature as required. The rate of maturing can be accelerated or slowed for some of the cheeses by changing the temperature of storage but this must be carefully done to avoid undesirable flavours developing.



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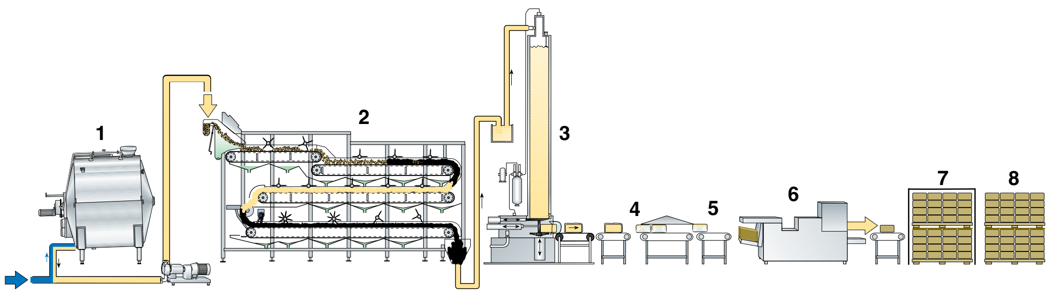
Overall summary of cheese making (Cheddar)



Milk
Curd/cheese

Fig. 14.35 *Flowchart for mechanised production of Cheddar cheese.*

1 Cheese vat
2 Cheddaring machine
3 Block former and bagger
4 Vacuum sealing
5 Weighing
6 Carton packer
7 Palletiser
8 Ripening store

Dairy Processing Handbook

5a.2 Types of cheese

It is possible to classify hundreds of varieties of cheese into different cheese types. There are several ways of classifying cheese types such as by the source of milk: cow's milk, goat's milk or sheep's milk.

A second method is to classify cheese by the fat content of the milk used: full fat, such as Cheddar, part skim, such as Edam and Parmesan, and skim milk such as Cottage cheese. There are other cheeses where extra cream is added to the milk Examples of high fat cheese include Cream cheese, Double Cream Brie and Triple Cream Camembert.

Another classification method is by type of ripening: interior ripened (mainly by bacteria), or surface ripened (mainly by moulds).

Another classification is by firmness based on moisture content and is detailed in Codex Standard 283 – 1978 which bases the firmness on the composition parameter 'moisture on a fat-free basis %' (MFFB %):

Codex designation according to firmness and ripening characteristics		
According to firmness: Term 1		According to principal ripening: Term 2
MFFB%	Designation	
<51	Extra hard	Ripened
49–56	Hard	Mould ripened
54–69	Firm/Semi-hard	Unripened/Fresh
>67	Soft	In Brine

MFFB equals the percentage of moisture on a fat-free basis, i.e:

$$\frac{\textbf{Weight of moisture in the cheese}}{\textbf{Total weight of the cheese} - \textbf{Weight of the fat in the cheese}} \times 100$$

The simplest classification classifies cheese as either natural or processed cheese.

The following tables show the basic composition and description of the main Australian cheese varieties.

Natural cheeses

Cheddar cheese		
Type	% moisture	% fat
Natural Cheddar	34–38	33–35
Reduced fat Cheddar	39–42	24–26
Low fat Cheddar	55	14-16

Hard Grating cheese		
Type	% moisture	% fat
Romano	35	24–25
Parmesan	32	23–24

Stretched Curd cheeses		
Type	% moisture	% fat
Mozzarella	46–50	40–45
Pizza cheese	44–46	35–39

Eye Cheese types		
Type	% moisture	% fat
Gouda	39–45	26–30
Swiss	39	26–28

Fresh Unripened cheese		
Type	% moisture	% fat
Cream cheese	45	35
Feta	54	20

Mould and Surface Ripened cheeses		
Type	% moisture	% fat
Camembert and Brie	50–52	25
Blue Vein several styles	42–50	25–30
Washed rind cheese	48–50	24–26

5a.3 Natural cheese types and their applications

Fresh unripened cheese

Cream cheese has a creamy texture and slightly sour flavour, therefore is an excellent ingredient cheese. Feta cheese has a salty and acidic flavour and white crumbly body. Reduced salt versions of Fetta are also manufactured.

Examples of fresh unripenedcheese

- Cream Cheese
- Ricotta Cheese
- Fetta Cheese
- Cottage Cheese

Functionality

Fresh unripened cheeses are best used in cold dishes or stirred into a heated dish at the last moment, as their high moisture content means they will lose body and texture when heated.

Ricotta and block cream cheese can be baked, Fetta can be grilled.

Except for Fetta, fresh unripened cheeses can be used as an ingredient in both sweet and savoury recipes.

Selection of fresh unripened cheese

Applications

- Cheesecakes (Cream cheese)
- Salads (Fetta)
- Gelatine-based desserts (Cream cheese)
- Dips (Cream cheese, Cottage cheese)

White mould cheese

Australian white mould cheeses are produced using white *Penicillium* spp moulds. The mould plays an important role in changing the flavour and softening the body of the cheese. The ripening process starts from the surface and progresses to the centre as the cheese matures. The cheese is ready for eating when it is soft to touch, with the interior of the cheese being of uniform creamy golden colour and an almost flowing consistency. The edible rind associated with surface ripened cheese adds to the flavour of the cheese.

Examples of white mould cheese

- Camembert
- Brie
- Triple cream

Functionality

Camembert and Brie may be grilled or baked but also deep-fried. They can be added to sauces if the rind is removed first, as it can affect the texture of the cooked recipe.

Examples of white mould cheese

Applications

- Eat natural cheese with bread, dry biscuits and other compatible food
- Crumbed and deep-fried
- Warmed in sandwiches, rolls and baguettes
- On gourmet pizza
- In sauces over pasta and gnocchi
- In salads

Semi-hard cheese

As distinct from processed Cheddar, natural Cheddar is a firm textured cheese, light yellow in colour with a delicate to full rich flavour depending on age of the cheese. Reduced fat Cheddar has approximately 25% less fat than normal Cheddar. The texture is slightly firmer and more elastic. Low fat Cheddar has a tougher body and does not have the typical Cheddar flavour.

Examples of semi-hard cheese

- Cheddar
- Gouda
- Edam
- Red Leicester
- Goshred

Functionality

These cheeses have excellent melting, grilling and baking qualities.

Cheddar cheese

Applications

- Cheddar is the most used ingredient for processed cheese
- Eat natural cheese with bread, dry biscuits and other compatible food
- Grated cheese for cooking can be frozen, however it will become dry and crumbly
- Shave over soups and roasted vegetables
- Grill on toast and pasta bakes
- Stir mild Cheddar through sauces

Eye cheese

Gouda cheese is made in two styles, rinded and rindless. The rinded traditional form has higher moisture than the rindless form which is usually made in mechanised Cheddar plants.

Swiss cheese contains large holes known as eyes. The flavour is sweet and nutty due to the addition of *Propionibacterium* bacteria species.

Examples of eye cheese

- Gruyere
- Emmenthal
- Edam
- Gouda

Functionality

These are the perfect melting cheeses - their texture becomes stretchy when cooked. Care must be taken to ensure the cheese used is not too young or too dry as these impact melting qualities.

Selection of eye cheeses

Applications

- Cheeses can be eaten with bread, dry biscuits and other compatible foods
- Cheeses can be grated, grilled, sliced, melted, and baked on pasta and other foods
- Cheeses can be used in sauces or when a smooth flowing consistency is required
- Cheeses can be sliced in sandwiches, hamburgers or focaccias
- Cheeses can be grated into soups, fondue, and tarts
- Cheeses can be baked onto roasted vegetables

Hard cheese

Australian hard grating cheeses have a firm body with mild or strong flavour depending on their age. Hard grating cheeses are often fully matured. The relatively low moisture content extends the cheeses shelf life.

Examples of hard cheese

- Pecorino
- Parmesan
- Romano
- Pepato

Functionality

These cheeses will melt completely with other ingredients to add taste and texture, with great depth of flavour. If aged cheeses are used, small quantities can be used because of their much stronger flavour. They have good grating properties.

Examples of hard cheeses

Applications

- Eat natural with bread, dry biscuits and other compatible food
- Shave on pizzas
- Grate into soup
- Combine with breadcrumbs as a crumbing base
- Stir through in Risotto
- Shave into salads or over vegetables
- Add to sauces

Blue cheese

Australian Blue Veined cheeses are characterised by a network of green-blue veins of mould throughout the body of the cheese. Several Australian Blue Veined cheeses are unique to Australia, but others are made in the style of many classic European Blue cheeses. The characteristic lines or veins are produced by piercing with fine stainless steel rods to allow air into the cheese, thus encouraging the internal growth of blue mould.

Examples of blue cheese

- Gorgonzola
- Blue Vein
- Blue Brie

Functionality

These cheeses can be melted and baked. It is important to ensure they are cooked with complementary flavours as they can overpower other foods. Small quantities should be used. White wine, cream or butter can be added to the recipe to soften the pungent characteristics of blue cheese and lessen the possibility of the blue cheese dominating the flavour.

Variety of blue cheeses

Applications

- Eat natural with bread, dry biscuits and other compatible food
- Crumble onto salads
- Stir into bechamel sauce
- Mix with chicken mince as a filling for tortellini
- Add to quiche
- Stir into soups
- Serve on pasta, especially gnocchi

Stretched curd cheese (pasta filata cheese)

These cheeses are produced by working the curd to a dough-like mass in hot water so that it may be pulled and stretched. At this stage it is soft and semi-fluid. It is then extruded into moulding machines for individual cheese shape and uniform weight control. In the making, the heat of the curd helps expel moisture and produces a smooth, stringy, closed texture in the finished cheese. Individual cheese shapes are retained by placing the shaped cheeses in cold water to set.

Examples of stretched curd cheese

- Mozzarella
- Bocconcini
- Haloumi

Functionality

Stretched Cheeses melt very well but are best cooked quickly at higher temperatures.

They can also be grilled, baked, melted, grated or sliced. Grated Cheese can be frozen and used only for cooking.

Haloumi is often dry and highly salted; this style should be cooked to improve its eating quality.

Mozzarella is best served cooked due to melting benefits and relatively mild taste.

Soft moist Mozzarella

Applications

- Pan fry Haloumi
- Mozzarella is used for toasted sandwiches, focaccia
- Mozzarella is used for pizza

Shredded and grated cheese

What is shredded cheese?

Shredded cheese is cheese which has been cut up into small pieces to enhance the application of the cheese.

Shredded Cheddar

Why is cheese shredded?

Cheese is sometimes shredded or grated for ease of use by the consumer. For example, Mozzarella cheese is shredded for use on pizza to facilitate heat transfer and easy melting and stretching of the cheese.

Which types of cheese are best for grating and shredding?

Generally, very hard cheeses with low moisture contents are grated whilst semi hard cheeses are shredded. These cheeses have good keeping qualities.

The best cheeses for grating are:

- Parmesan
- Romano
- Aged Pecorino

The best types of cheese for shredding are:

- Cheddar and Cheddar types
- Mozzarella
- Gouda
- Goshred (a natural cheese suitable for shredding to be used for pizza topping and bakery applications).

Are additives used to prevent the cheese sticking together?

It is a common practice to add anti-caking agents to the shredded cheeses to improve flowability as well as preventing the shreds from sticking together. This allows them to remain as discrete particles and flow easily from the pack when dispensed.

Uniform size pieces are desired. Pack weights are more easily controlled and packaging and manufacturing processes can be operated at higher efficiencies.

What are the typical applications for these cheeses?

Grated cheese is convenient to use for sprinkling on foods such as pasta, salads and for cooking in casserole dishes. Grated cheese is also used to flavour soups and sauces. Generally, only very small proportions of the cheese are required to provide enough flavour.

Shredded cheese is popular in cheese sauces and toasted sandwiches, on tacos, pizzas and baked potatoes.

Cheese powder

Another popular cheese product is Cheese powder that is used in snack food manufacture and as a flavour addition in a variety of foods. It is produced, by liquefying the cheese and then spray drying it. This is done in a normal processed cheese kettle. The addition of emulsifiers to maintain the homogeneity of the liquid is required. The cheese must be minced into a smooth paste before heating and addition of emulsifier (phosphates and citrates). Water should also be added to the mix as solids content in most cheeses is too high to enable them to become a flowable liquid. The solids content of the mix is approximately 32-35% and its temperature must be maintained above 75°C to reduce its viscosity.

A standard spray drier with a cooling fluid bed for production of milk powders may be used.

Cheese powder applications

Cheese powder is used in snacks, dips, dressings, crackers, corn chips, potato chips and soups.

5a.4 Processed cheese

There is no international Codex Standard definition for Processed Cheese. The Australian definition of processed cheese is "a product manufactured from cheese and products obtained from milk, which is heated and melted, with or without added emulsifying salts, to form a homogeneous mass".

The aims of processing cheese are to produce a cheese that has an extended shelf life and to reduce the need for refrigeration during transport and storage.

Cheddar is the basis of most processed cheeses. A blend of cheeses is selected, comprising of young, semi-matured and matured cheese. The cheeses are shredded, mixed and heated with vigorous stirring in the presence of emulsifying salts. This results in the formation of a thick homogeneous liquid. This liquid is pasteurised and pumped to machines for packaging.

Steam is injected into the mass of cheese to achieve the heating, or pasteurisation. This means that the moisture level of processed cheese increases as the steam condenses in the cheese. For this reason, processed cheese is permitted to contain more water than the unprocessed cheese.

The addition of certain salts, such as sodium citrate or sodium phosphate, to heated cheese assists emulsification. These are therefore called emulsifying salts. Emulsifying salts act in the following ways:

- Act as a protein solvent.
- Promote emulsification of the fat and water.
- Provide a protective film around the fat globule to stabilise the emulsion.
- Control the final pH.
- Increase the water binding capacity.

The use of emulsifying salts in the production of processed cheese is essential. Without these salts the processed cheese would be unsuitable for cooking and sauce making. Commonly used emulsifying salts include citrates and phosphates.

The variety of processed cheese products available includes sliceable blocks, individually wrapped slices, unwrapped slices, spreads, sticks and dips. These may have various flavours and can be presented in various packages both rigid and flexible.

Processed cheese slices

Processed cheese slices require refrigeration from the time of production.

Processed cheese is not a gourmet item but it is excellent food available in a range of styles and is suitable for many cooking applications.

Processed cheese spread is similar to processed cheese except that a stabiliser and water are added. There are also two types of cheese. Those that are packed in aluminium foil and have a firmer consistency and those that are packed in cups, jars and tubes with a softer creamier texture. They are typically sold unrefrigerated. The soft consistency enables spreadability at room temperature.

Processed cheese food should contain a minimum of 51% cheese. Processed cheese food is the product prepared by mixing and heating together one or more varieties of cheese, with or without the addition of other ingredients such as cream, milk, skim milk, buttermilk, cheese whey, other foods, flavouring or condiments.

After heating, processed cheese intended for spreading undergoes a creaming step, which includes mechanical kneading of the hot cheese and addition of various dairy ingredients and other additives. Other processed cheese products include cold-packed cheese, cold-packed cheese food, and reduced fat cheeses. All processed cheeses may be enhanced with salt, artificial colourings, spices or flavourings, fruits, vegetables, and meats.

Processed cheese manufacture

Cheese selection – Processed cheese is made by using a blend of natural cheeses of differing origins, maturity levels and ages

Immature cheese

Mature cheese

Extra mature cheese

↓

Blending and mincing of cheese – The cheese is cut into small portions then mincers are used to grind the cheese into very fine particles.

↓

Water

Emulsifying salts

Other additions, could include, whey skim milk powder, colourings, flavourings, nisin, salt.

↓

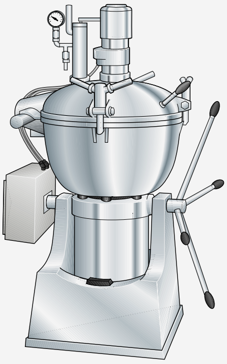
Blending of all ingredients.

↓

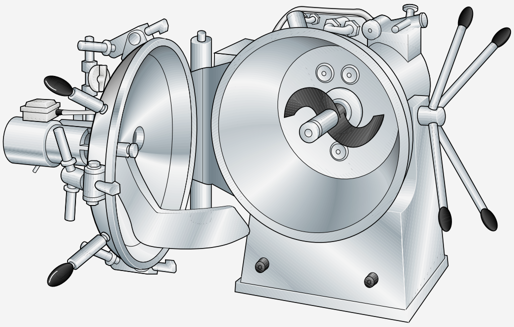
Melting and cooking – The cooking period takes 5-8 minutes with temperatures of 80-90°C. Higher temperature processing is also used.

↓

Packaging, cooling and storage – Typically processed slices are cooled rapidly to refrigeration temperature whereas block and long life products are cooled slowly.



Batch cooker for processed cheese.
Pictures courtesy: Tetra Laval Handbook.



Cooker open and tilted for emptying.
Pictures courtesy: Tetra Laval Handbook.

Processed cheese types

Processed cheese has a few basic types but many variations exist within each type.

There are two different types of processed cheese slices. Firstly, the slices with high remelting properties and others for normal consumption that do not require melting. The high remelt slices are typically used in hamburgers and must be able to melt during heating. The second type is not required to melt and is most often used in sandwiches. This type has higher moisture content and is usually individually wrapped.

Type	% moisture	% fat	Description and characteristics
Processed cheese block or sliceable	45	26	This is the oldest type of processed cheese. The cheese is relatively firm and can be cut without losing elasticity. The flavour varies according to the customer requirements.
Processed cheese slices, Individually wrapped. (IWS)	50	23–26	These have an even colour, free from holes, crystals and unmelted pieces. The cheese should tear smoothly.
Reduced Fat cheese slices	55	15–16	These have an even colour, free from holes, crystals and unmelted pieces. The cheese should tear smoothly
Processed cheese slices. (non IWS)	45	27	These have an even colour, free from holes, crystals and unmelted pieces. The cheese should tear smoothly.
Processed cheese spread	55–60	20	The texture of the spread is smooth and creamy. Flavour may vary according to customer requirements.
Processed Cream cheese spread	52	31	The texture of the spread is smooth and creamy. Flavour is creamier and has less cheese flavour.

Processed cheese – common defects and causes

Defect	Possible Causes
Soft Consistency	Lower proportion of young cheese
Crystals	Type and level of emulsifier
Marbling	Not emulsified properly
Bitter	Bitter peptides in cheese due to incorrect maturation
Oiling off	Fat not emulsified properly – emulsifier type or level
Syneresis – water leakage	Type and level of emulsifier Incorrect heating conditions and protein denaturation

5a.5 Grading of cheese

The purpose of grading is to provide a standardised assessment of cheese quality for flavour, body, texture, colour and condition. This assessment can be used as a basis for payment, and as a guide to the disposal of the cheese.

The grading system described here is used for Australian cheeses for export. This system is based on the allocation of 100 points for the various important characteristics.

The grades are as follows:

- Choicest Quality: 93 points or more
- First Grade Quality: 90–92 points
- Second Grade Quality: 88–89 points

The scoring points are allocated as follows:

- Flavour and Aroma: maximum 50 points
- Body and Texture: maximum 30 points
- Colour and Condition: maximum 20 points

Body refers to the degree of hardness, resilience, and cohesion of the cheese.

Texture refers to the presence or absence of openings, cracks, gas holes, etc.

The typical grading process for Cheddar is as follows:

- A representative sample of the batch is taken and brought to between 10°C and 14°C. Typically, this is a 20 kg block.
- A smaller sample (a plug) of the block is extracted by using a cheese trier.
- The subsample is inspected for aroma and then visually inspected for colour.
- The cheese plug is bent to assist the evaluation of body.
- A small portion is broken off and worked up between the thumb and fingers, to complete the evaluation of the body and texture.
- A small piece is then tasted for evaluation of flavour.

A plug of Cheddar about to be evaluated.

5a.6 Nutritional value of cheese

Nutritional values for selected cheeses (per 100gm)

Cheese	Energy kJ	Protein gm	Fat (total) gm	Fat (saturated) gm	Carbohydrates gm	Sodium mg	Calcium mg
Blue Vein	1570	20.3	32.4	20.8	0.0	1090	510
Cheddar	1663	24.6	32.8	21.5	0.5	684	760
Edam	1482	28.0	27.2	17.2	0.0	700	770
Feta	1170	17.8	23.3	15.3	0.3	1070	530
Gouda	1583	26.1	30.8	19.6	0.0	710	750
Haloumi	1025	21.3	17.1	11.0	1.8	2900	720
Mozzarella	1258	26.0	22.0	14.1	0.1	375	817
Parmesan	1949	40.6	33.3	21.1	0.1	1503	1120
Romano	1568	31.3	27.9	17.7	0.2	1040	1120
Pecorino	1486	28.0	27.2	17.3	0.2	950	1120
Cream	1413	8.5	33.1	21.2	2.6	420	82
Processed, Cheddar type	1304	20.9	24.9	17.4	0.1	1350	5409
Brie	1406	19.3	29.1	18.6	0.1	605	464
Camembert	1291	18.6	26.3	16.9	0.1	650	464
Cheddar, Reduced fat (25% Less fat)	1368	28.7	23.8	15.1	0.0	720	870
Cheddar, Reduced fat (50% Less fat)	1106	31.3	15.5	9.9	0.0	690	940
Cheddar, Low fat	844	33.9	7.2	4.7	0.1	660	960
Cottage	514	15.2	5.8	3.8	2.4	315	180
Ricotta	617	10.5	11.3	7.2	1.2	198	230

In comparison to many other foods cheese is a good source of energy, but its greatest value is as a source of protein. Cheese contains more protein than other high protein foods such as meat, fish and eggs.

In most cheeses the protein is nearly all casein, because the whey proteins present in milk are drained off in the whey. Casein is a complete protein and supplies all the essential amino acids.

The vitamin content is also variable. When cheese is made from whole milk, the fat-soluble vitamins in the milk are retained in the cheese, but most of the B group vitamins which are water-soluble are lost. However, since cheese contains some moisture, it may still be a useful source of B vitamins. During the cheesemaking process the starter and other bacteria which grow in the cheese produce and use the B group vitamins, replacing some of those lost in the whey. The extent to which this occurs and how much of the original lost vitamin B is replaced varies from cheese to cheese. However, there will nearly always be more microbially produced vitamins in mature cheese than in the younger cheese. In surface ripened cheese such as Camembert and washed rind cheese there will be more vitamins and calcium near the rind than in the centre of the cheese.

5a.7 Cooking and heating cheese

When heat is applied to cheese, the first thing that happens is that the cheese becomes soft and appears to melt. This is due to the fat in the cheese melting. By the time the temperature reaches about 40°C all the fat has melted into a liquid. The fat begins to leech out and become separated from the proteins of the cheese.

Upon further heating the water also separates out until there are three distinctive phases, the curds, water and milk fat.

The milk fat may be reincorporated at about 60°C, because at this temperature, some of the proteins act as emulsifiers. Emulsifiers enable water-based substances and oil-based substances to mix and become stable. This stable mixture of water and oil is called an emulsion. When the proteins act as emulsifiers, they cause the water and milk fat components to remerge, preventing the separation that causes a problem in cooking. The level of stability of the cheese depends on the particular variety of cheese being heated.

When cheese is heated to high temperatures, the proteins coagulate and toughen, and they become denatured. At higher temperatures or with prolonged heating, denaturation of the protein can cause the cheese to become matted, stringy, or tough. The surface of the cheese dries out and forms a tough skin. At even higher temperatures it will char. These matted, stringy or charred cheeses cannot be used in cooking. Water is not lost from the cheese as the temperature increases, because it forms a stable gel with the proteins.

5a.8 Cheese packaging

Around 1960s a technique was developed for making rindless cheese where the curd was packaged in rectangular blocks. After making the cheese it was vacuum sealed in a plastic bag. The result was a block of rindless cheese which was cut into consumer size units easily and with virtually no waste.

This technology was of enormous economic benefit and brought about the easy cutting of the blocks into consumer size units which were then sealed in plastic wrappers by vacuum or gas flushing. This process keeps water in and thus prevents dehydration. It also keeps the oxygen out and thus prevents mould growth. As long as these bags are completely sealed, the film remains undamaged and the units are kept refrigerated, the packaged cheese will have a longer shelf life.

Processed cheese was traditionally packed in cans, jars and cartons lined with tin foil coated with a heat sealable compound. This has been replaced by new protective coatings. Plastics, both flexible, for processed cheese slices, and rigid for spreads and dips, have become common as a means of processed cheese packaging.

5a.9 Cheese storage and maturation

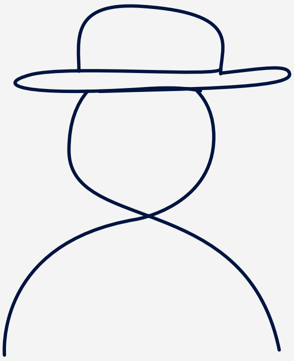
Cheddar cheese is typically matured and stored for several months before use. The temperature of maturation is 4-8°C. Maturation of the cheese occurs faster at higher temperatures. Should higher temperatures be used it is possible for the flavour of the cheese to developed faster but the risk of poorer texture and undesirable flavours developing increases as well. Therefore, elevated temperature maturation to reduce ripening time is not commonly used due to risk of undesirable flavours and poor texture.

Cheese maturation depends on a variety of factors and mainly includes the maturation temperature, time, humidity, the composition of the cheese and the cultures and rennet used.

During cheese maturation, the major components in cheese (fat, lactose and caseins) breakdown due to the actions of enzymes naturally present in milk, residual rennet, the starter bacteria and non-starter lactic acid bacteria.

Maturation		
Lipolysis	Glycolysis	Proteolysis
Fats breakdown	Sugars breakdown	Caseins breakdown

Mozzarella may be stored at <4°C if it is to be used within a few weeks and down to -2°C if it is to be used within a few months. However, if storage of more than a few months is needed, it should be frozen at -18°C. If Mozzarella is stored at elevated temperatures, the high moisture allows for rapid proteolysis and loss of quality and functionality. If brine salted Mozzarella needs to be frozen, it is important that the salt be given time to diffuse throughout the cheese before freezing takes place. Correct thawing of the frozen cheese prior to use is critical to ensure optimum Mozzarella cheese functionality is achieved.



5a.10 Frequently asked questions (FAQ)

A Milk and cheese manufacture

1. Is milk from certain breeds of cows better suited for cheesemaking?

The most common cow breeds such as Holstein Friesian, Jersey and Guernsey all produce milk well suited to cheesemaking. For most cheesemaking some of the milkfat must be removed to enable cheese to be made to specification. The Holstein Friesian cows usually produce milk of greater volume but with lower fat content and require less or no fat removal whereas the Jersey produces a lower volume of milk but with higher levels of milkfat which therefore requires more fat removal before the cheesemaking process begins.

2. Is milk containing antibiotics suitable for cheesemaking?

Every tanker of milk is checked by the dairy factory for the presence of antibiotics. If the result of the test is positive indicating that the milk contains antibiotics, then the milk is immediately discarded and not used for cheesemaking. It is not possible to make normal cheese from milk containing antibiotics because the starter cultures that perform the fermentation task will not grow in milk.

3. What additives are used to coagulate milk to make cheeses?

An enzyme called rennet or a coagulant is used to coagulate milk to make cheese

There are three main types of rennet/coagulant:

- Calf rennet
- Fermentation Produced Chymosin
- Microbial rennet

4. What is the source of the rennet used to make cheeses?

The use of milk clotting enzymes has been practised for centuries. Traditionally an extract of the abomasum (fourth stomach) of the unweaned or milk fed calf provided the source of the enzyme chymosin, which was used as a milk coagulant. Several enzymes including chymosin are present in rennet extract. In calf rennet, chymosin makes up approximately 85-95% of the enzymes with the remainder comprising mostly bovine pepsin.

Calf rennet played an important role in world cheese production until the early 1960's when a reduction in the cow population meant less calves were available for slaughter and a reduction in the number of calf stomachs for rennet production. An increase in cheese production at this time meant that rennet substitutes were used.

The rennet substitute Fermentation Produced Chymosin (FPC) is also available. This product is produced via the biological fermentation of a yeast or fungi. This product contains 100% chymosin and is suitable for vegetarians. Another rennet substitute class includes the microbial coagulants. These products are plant proteases with similar enzymes to chymosin. The most common microbial protease used in cheese making is that manufactured from the fungus Mucor mehei. The microbial coagulants are also suitable for vegetarians.

5. Is all cheese made using rennet and are there rennet free cheeses?

Apart from fresh cheeses such as Cream cheese, Mascarpone and Cottage cheese all hard cheeses use rennet to coagulate the milk.

6. What is Fat-in-Dry Matter or FDM?

One of the aims of standardising milk for cheesemaking is to adjust the composition of the milk so that there is enough fat in relation to solids-not-fat (SNF) to produce cheese which complies with the specifications for fat-in-dry matter (FDM).

The value is calculated from the following formula:

$$\% \text{ FDM} = \% \text{ fat} \div (100 - \% \text{ moisture}) \times 100$$

It is important to note that the percentage fat content of the cheese and the FDM are different. The fat content of the cheese is calculated as the fat percentage of the entire cheese whereas FDM calculates the percentage fat in the cheese solids.

7. Why are Australian cheeses often yellow when the same cheese type from Europe is white in colour?

The origin of the yellow colour of cheese is the cow's diet. Cows eating green pastures can produce milkfat containing a vitamin known as beta carotene. Beta carotene is responsible for the rich yellow colour of milk fat and cheese. Beta carotene is a natural antioxidant which is responsible for vision, immune function and skin health. It is the precursor for Vitamin A.

8. What causes some cheeses to be coloured orange or red?

The colour of the cheese may be changed by the addition of annatto. Annatto cheese colour is obtained from the covering of seeds of the Annatto tree that grows in the tropics. It contains red and yellow colouring matter, and the ratios of these colours are standardised in commercial preparation of annatto solutions.

The rate of addition may be small to give pale cheese a small 'lift' in colour, or larger quantities may be added to produce cheese, which is noticeably coloured, within a range 'deep straw' to deep brick red.

9. What additives can be used in cheesemaking?

For natural cheese, the additives are:

- Starter cultures
- Food grade Acid (optional) – some cheeses
- Rennet
- Salt
- Colour (optional)
- Lipase enzymes

Other additives that may be used on the surface of natural cheese:

- Natamycin

For processed cheese:

- Nisin
- Emulsifying salts
- Colourings

10. What is Natamycin and when is it used on cheese?

Natamycin is a food grade mould inhibitor that is manufactured from natural sources. It is naturally derived from fermented milk using lactic cultures and is organic in nature. Natamycin has been used in the cheese and food industry for at least 20 years. Natamycin is not soluble in water or fat and consequently passes through the intestines without getting absorbed. It is not an antimycotic and not an antibiotic. It has no effect on any bacteria; it only prevents growth of yeast and mould.

Natamycin is used on the surfaces of some rinded cheeses.

11. What anti caking agents are added to grated and shredded cheese?

The products approved for use are cellulose based, for many years the use of microcrystalline cellulose was exclusive, but eventually powdered cellulose replaced the use of microcrystalline cellulose as the anti-caking agent of choice. Another product -silicon dioxide is also approved for use. These products have been tested and approved for use at levels up to 20 grams per kilogram of cheese.

B Using cheese

1. What properties are desirable when cooking with cheese?

When cooking with cheese as an ingredient, it is important that the cheese melts uniformly to enable even dispersion into the other foods. The cheese should also remain intact rather than separating into its layers of protein, fat and water.

2. What are the factors affecting cooking quality of cheese?

Age: As cheese ripens, the proteolytic (protein splitting) enzymes from the rennet break bonds in the protein molecules which makes them more soluble. This increase in solubility progressively improves the cooking quality of natural cheeses, especially during the first twelve months of maturation.

Fat content: The cooking quality of cheeses that are low in milk fat does not improve with age even though the amount of soluble protein increases. The greater protein solubility is offset by a greater tendency to stringiness, matting, and toughness in low-fat cheeses.

Water content: The increase in solubility of the proteins is more rapid in a high moisture cheese and such cheeses are better for cooking than cheese with low moisture content.

Acidity: If acid is added to a cooked dish containing cheese, it increases the tendency for the cheese to separate and become stringy. This occurs at pH 5–6. If more acid is added to cheese (pH 4–5), the proteins will separate from the cooking liquid and form curd-like pieces. Under more alkaline conditions (pH 6–8) the cheese disperses readily. These effects are due to the calcium. Under acid conditions calcium is free to combine with casein to form insoluble calcium caseinate. When alkali is added the calcium tends to be held in a complex with phosphate so that it cannot combine with casein. This makes the cheese more soluble.

3. Is it possible to freeze cheese?

The ice crystals that form when cheese is frozen tend to destroy the texture and therefore if the cheese contains free moisture freezing is not recommended. Freezing does not affect flavour but tends to create a crumbly or grainy texture. Firm cheeses may have a crumbly texture when thawed and can be frozen for up to three months. Mozzarella and Cheddar have been successfully frozen.

To keep the crumbling effect due to freezing to a minimum, freezing should take place as fast as possible so that smaller ice crystals form. The cheese should be frozen in small portions to allow rapid freezing.

Wrapping in vapour-proof material such as heavy duty foil or plastic film is also necessary to prevent loss of moisture during freezing.

Thawing of cheese should be done slowly in a refrigerated cool room under controlled conditions. Thawed cheese should be quickly used and should not be refrozen.

4. What is the shelf life of cheese?

The key factor determining shelf life of cheese is cheese moisture. Cheeses with lower moisture content have a longer shelf life than high moisture varieties and vice versa.

Mozzarella cheese if made to a low moisture (45% or less), is capable of being stored for 4-6 months and maybe stored for longer if frozen.

Cheddar cheese with moisture of 34-38% has a shelf life of a few years if packaged, stored and matured properly. The duration of maturation of Cheddar depends on its end use. Cheddar to be consumed as mild flavoured cheese can be made to higher moisture levels (38%) whereas Cheddar destined to be matured for longer periods should have lower moisture levels (35%).

Parmesan cheese with moisture levels below 32% has a very long shelf life of many years.

5. What is the difference between use-by dates and best-before dates?

In Australia, use-by date specifies the retailer may not sell the product after the specified date. Use-by dates are appropriate when the likelihood of the cheese being unpalatable or unsafe past its use by date is high. Best before dates are used for the consumers benefit. Typically, cheese consumed after the best before date is stronger in flavour and may not be acceptable to the consumer.

6. What advice should we give consumers for the best way to store cheese?

Cheese should be purchased in small quantities more often rather than large quantities less often. If refrigeration is not possible, in hot weather buy only the cheese needed for the day of purchase. In colder weather buy what is needed for just a few days. It should be eaten on or before the best before date, and once opened must be properly stored to retain flavour and moisture. To prevent hard cheeses and soft mould ripened cheeses drying, wrap in foil, greaseproof paper, plastic cling wrap or waxed paper. Cheese should not be stored near strong flavoured foods such as onion or garlic because cheese easily absorbs flavour from these foods.

Soft cheeses such as Cottage and Ricotta cheese are best stored in the container in which they are purchased. These cheeses do not keep as well as hard cheeses and should be eaten within a few days of purchase. For best results, cheese should be stored in a refrigerator.

Soft cheeses like Blue Vein and Mozzarella will keep for a few weeks. Firm cheeses such as Cheddar keep for several months, whereas hard, low-moisture Parmesan keeps almost indefinitely. Blue Vein style cheeses should be stored separately from other varieties.

There are three processes that can occur in cheese during storage which determines its effective shelf life. The first is the continual drying out of the cheese. Small pieces of cheese become very hard and dry in the low humidity of a refrigerator if not correctly wrapped. The second is the absorption of off flavours of foods stored near the cheese. The third is a continuing biological change. This change may be the normal advance of maturity caused by bacterial enzymes. It may be the growth of mould and invading bacteria, or it may, in fresh cheeses, be a continuing souring by the starter bacteria.

All these changes are more likely in fresh and high moisture cheeses which explains their much shorter shelf life. These changes are also more likely in small pieces of unprotected cheese than in large pieces that are wrapped and sealed. Heat treatment also extends life. Cream cheeses that have been heat treated then wrapped will last for 2-3 months in a refrigerator. The main defences against dehydration and breakdown in cheese are wrapping in foil or plastic film to keep moisture in and taints out, and cool storage to slow down the bacteria, moulds and enzymes.

The fresh cheeses need cold storage (2-3°C) and they should be kept in the coldest part of the refrigerator close to the freezing compartment. The firmer cheeses are better kept in the warmer zones of the refrigerator - the lower shelves or door shelves. Small left-over pieces are most susceptible to drying out and they are best grated and stored in plastic containers for use later in cooking.

Most cheese should be served at room temperature and should be taken from the refrigerator no more than 15 minutes before use. Fresh cheeses, on the other hand, are best served chilled.

C Consuming cheese

1. Can people who are lactose intolerant eat cheese?

Certain people are unable to properly digest the sugar in milk (lactose) because they have low levels of the enzyme, lactase in their digestive system. This means that they can usually deal with consuming only small quantities of lactose; if they consume large amounts of lactose at once they suffer discomfort due to lactose not being fully digested. This condition is known as lactose intolerance.

During the production process of cheesemaking 90% of the lactose from the milk is removed with the whey when the whey is removed from the cheese. Most of the remainder is converted into lactic acid by the starter cultures during the process. In semi hard cheeses like Cheddar, there is virtually no remaining lactose one day after manufacture of the Cheddar.So Cheddar and other semi hard or hard cheeses are suitable for those who are lactose intolerant. A few cheeses made without the use of starter cultures contain some lactose and they should be avoided by lactose intolerant people. Ricotta and Haloumi are two such cheeses.

2. Does grated cheese have the same flavour as the original product?

Grating cheese increases the cheese surface area manyfold. This has the potential to release and lose some flavour. Therefore, cheese should be grated and packaged in a sealed package as soon as possible. Failure to do so will result in some flavour loss.

3. Is the rind of a hard cheese edible?

The rind from a very hard cheese is very tough and may not be suitable for eating as is. However, it can be grated finely and used to flavour soups, and sauces or sprinkled on pasta or other foods.

4. What causes mould growth on cheese?

Mould requires two elements to grow - moisture and air. Mould can develop on cheese once the package is opened and the product is exposed to air and potentially mouldy environments. Most cheese is packaged under vacuum and thus with the exclusion of air, mould growth can be minimised. Cheeses at higher risk of mould growth include shredded, cubed and grated cheese, because they have more surface area. Shredded cheeses are commonly packaged in modified atmosphere conditions containing nitrogen and carbon dioxide gases to remove the oxygen.

Some cheeses require the deliberate addition of moulds to the cheese to create the unique flavours and characteristics, such as Camembert, Brie and Blue mould cheeses.

5. What does the best before dates on packaged cheese mean?

Best before dates are specified by manufacturers and it is their judgement as to when the product in its packaged state will reach the end of its ideal quality for consumption. This does not mean that the product is unsafe after the best before date. Many consumers prefer stronger flavoured cheeses and deliberately seek cheeses beyond their stated best before date. Such cheeses can be safe to eat beyond the best before date but consumers should check quality before consumption. Once the package is opened and the cheese is exposed to air, there is the potential for mould to develop quickly.

6. What are the main differences between normal and reduced fat cheese?

Milk fat is an important contributor to the body and flavour of cheese. Reductions in the fat levels will bring about some change to the flavour and body of a dairy product. With current technology, it is difficult to make reduced fat cheese with the same flavour and consistency as regular cheese. The milk fat levels of the cheese contribute significantly to the melting properties and thus reduced fat cheese may have poorer melting characteristics. If fat levels of the cheese are reduced, the protein levels will be higher. Therefore, the body of the cheese will become harder and tougher. It is important to increase its moisture level to improve or soften the body.

D Mozzarella

1. How is Mozzarella made?

Mozzarella is made by a process similar to that for Cheddar. However after the cheddaring process, the curds are milled and then transferred to hot water. The curds are worked into a smooth mass by mechanical devices called an extruder. This process changes the texture to have long fibrous strands which is ideal for use in pizza for its stretchability. The curds are then moulded into shape before cooling in cold water.

2. What are the important functional properties of Mozzarella?

With Mozzarella cheese the functional properties are more important than its flavour. The important functional properties of Mozzarella are shreddability or machinability, stretchability, meltability, browning, blister formation and free oil release The major factors influencing these properties include cheese composition, pH, degree of maturation, age and storage conditions.

3. What are the important properties to look for with respect to the shreddability and sliceability of Mozzarella?

Important properties are:

- Ability to shred and / or slice the cheese
- Uniformity of the cheese shreds
- Amount of fine particles or fines produced on shredding
- Ability of the cheese to flow freely.

4. What are the important things that affect the shreddability and sliceability of Mozzarella?

High Moisture cheese and low salt cheese will stick not only in the machines but also shreds will stick together.

Dry cheese will be difficult to shred and will shatter easily and form short shred and fine particles. Old cheese will become softer and pasty and will not shred well without clogging the machine and the particles sticking together.

The temperature of Mozzarella at shredding also plays an important role and should generally be -2 to 4°C, preferably close to 0°C.

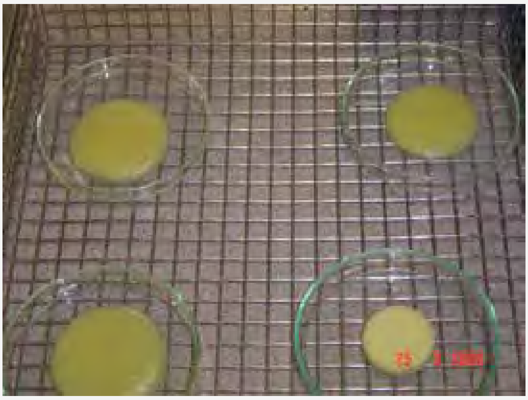
5. What is meltability and what affects the meltability of Mozzarella?

This relates to the ability of the cheese to melt and flow. The ideal character is for the individual cheese shreds to flow together on a pizza.

Cheese becomes more meltable as it ages, and when it has higher moisture and becomes less meltable if the cheese has a high pH and a high salt content.

Ma et al., 2013b

Results of the meltability test of Mozzarella are shown below. The section on the lower right shows the unmelted cheese. The other 3 are different samples of cheese after the melt test. The diameter of the melted cheese is measured to determine the meltability.



Meltability testing (pictured left).

6. What is stretchability and what factors affect it?

This relates to the ability of the cheese when heated to high temperatures such as in the baking of pizza to form fibrous strands when stretched using a fork.

The stretchability of the Mozzarella is largely dependent on its pH but is also influenced by its composition, age, maturity, and the length of storage.

A simple stretch test using a fork.

7. What is meant by the term "free oil formation" and why is it important?

This relates to the amount of free oil released from the cheese during the pizza baking process. This is important because the pizza consumers object to large pools of oil on the surface of a pizza but It is important to have enough free oil produced to ensure a shiny appearance but not too much oil released during the baking process.

Ma et al., 2013b

8. What are the factors that affect the "free oil formation"?

The amount of free oil increases with cheese age, higher moisture cheese, low salt levels, and higher Fat in Dry Matter levels of the cheese. For example, if Mozzarella is over matured, the protein breakdown is too high and on heating, the protein is unable to bind the free oil resulting in too much oil being released.

9. What are the factors that affect the browning of a cheese during pizza baking?

This relates to the cheese blister colour, blister size and blister coverage during the pizza baking process.

In general browning increases with higher levels of residual sugars in the cheese, namely lactose and galactose. The age of the cheese, either too young or too old can also increase the browning of the cheese. Low fat Mozzarella browns more than full fat Mozzarella. Reducing the oven temperature and/or the time of cooking will help to reduce the browning.

Ma et al., 2013b

Pizza with typical blister and browning

Pizza with excessive browning

E Processed cheese

1. Why does processed cheese sometimes melt or flow when heated?

This may be caused by the use of whey powder or milk powders in the formulation. Using too much old cheese, rapid cooling after processing and use of re-worked processed cheese causes this defect.

2. Why does the processed cheese burn during baking?

The cheese will burn and turn brown if there is too much lactose or galactose in the processed cheese. This may be due to overuse of whey or skim milk powders in the blend.

3. What can be done to reduce the cheese flavour level of the processed cheese?

The flavour of the processed cheese is the sum of the ingredients used. If too much old and strong cheese is used the flavour will be too strong. Using younger raw material will reduce cheesy flavour in processed cheese.

4. What is the cause of white specks in the processed cheese?

There are several possibilities. To reduce or eliminate the problem, the key steps required include:

- the formulation should use lower proportions of very old cheese,
- ensure that the correct emulsifying salts are used
- all the emulsifier salts are dissolved, and
- review the use of emulsifier salts to ensure that excessive levels are not being used.

5. The cheese has crystals which are a little different to the white specks. What are these?

They are most likely lactose crystals so this defect can be prevented by using less whey powder or skim milk powder in the formulation and ensuring that the correct emulsifier combination is used.

6. What is the cause of holes in the processed cheese?

There are two main possibilities. Firstly, the cheese raw material may contain spores which are not being deactivated by the heating process. The addition of nisin or ensuring that the temperature of processing is high enough to kill the spores will eliminate this problem. Secondly, ensure that the vacuum on the processing system is working properly.

7. What are the causes of the processed cheese slices becoming fragile and break readily?

There are several possibilities:

- Inadequate processing time or temperature
- Low cheese moisture
- Low cheese pH
- Too much emulsifier salt
- Too much young cheese
- The cheese is being cooled too slowly.

8. Why is the cheese too sticky after processing?

Sticky processed cheese could be caused by the one of more of the following:

- Increased quantities of younger cheese
- Increased agitation during the processing
- Increased processing time
- Reduced moisture content
- Emulsifier suitability.

9. What can cause the body of the cheese to become grainy in appearance?

The pH of the final cheese may be too low and should be corrected using acidity correction salts. The processing time may also be too short or the level of emulsifier used may be too low.

5a.11 Glossary

Acid curd

The gel-like state that milk is brought to when a high level of acidity is achieved. The acidity is produced by the activity of starter culture bacteria, and it precipitates the milk protein into a solid curd.

Acidity

The amount of acid (sourness) in the milk.

Bacteria

Microscopic single cell organisms found almost everywhere. Lactic acid-producing bacteria are useful and essential in the production of fermented products.

Body

The inside of a product which is assessed by graders using terms such as, firm, soft, weak, grainy, pasty, flaky, close, short etc.

Brine

A solution of salt and water used for salting certain cheeses.

Calf rennet

Calf rennet is derived from the fourth stomach of a milk-fed calf. It contains the enzyme Chymosin, which can coagulate milk.

Casein

The major protein in milk.

Cheddaring

The process during cheesemaking after the whey is drained from the curds. The curds are then kept warm for approximately 90 minutes.

Chymosin

The name of the active enzyme in most rennets.

Coagulation

The solidification of milk through the action of acid and/or enzymes. The enzymatic method uses a product known as rennet.

Colostrum
The milk produced for up to 3 days after calving.

Cooking
A step in cheesemaking during which the cut curd is heated to assist in whey removal from the curds.

Curd
The soft rubbery solid produced when milk is coagulated.

Cutting the curd
A step in cheesemaking in which the curd is cut into small sized curd particles.

Draining
The step in cheesemaking in which the whey is separated and removed from the curd.

Dry matter
All parts of milk products excluding the moisture: i.e. fat, protein, lactose and minerals. Also known as the cheese solids.

Enzyme
A biological catalyst that accelerates a chemical reaction. Enzymes are proteins that may contain some minerals. Each enzyme has a specific action on a specific substrate. For example, enzyme lactase will only break down lactose into glucose and galactose. Enzyme chymosin is responsible for rapid coagulation of milk while lipases break down fat and proteases break down protein.

Eyes
They round openings or holes found in certain cheese caused by gas formation by introduced starter culture bacteria.

% Fat-in Dry Matter
Refers to the percentage of milk fat as a proportion of the cheese solids.

Hooping
A step in cheesemaking during which the curd is placed in a cheese mould (hoop).

Inoculation
The addition of microbes such as bacteria to milk.

Lactic acid
The acid produced in milk or curd during cheese and yoghurt making. Starter culture bacteria break down the milk sugar (lactose) and produce lactic acid as a by-product.

Lactose
The sugar naturally present in milk. Lactose can constitute up to 5% of the total weight of milk. It is not a very sweet sugar compared to sucrose.

Lipase
Lipase is an enzyme that is added to the milk for selected cheese varieties. The enzyme is extracted from the epiglottis of animals. The lipase enzymes act on the fat molecules. It splits the fatty acids from the fat molecule. These components are then known as free fatty acids. Once released from the fat molecule the flavour of the fatty acid becomes important.

Lipolytic
The type of enzymes which break down fat.

Maturation
A step in cheesemaking in which the cheese is stored at a particular temperature and/or relative humidity for a certain time to develop its distinct flavour and/or for the body and texture to form as per the cheese variety.

Milling
A step in cheesemaking during which the curd is diced into smaller potato chip like pieces before being salted.

Pasta filata
Italian expression for plastic-curd cheeses, where thin strips of cheese curd are placed into a hot water bath and worked up until homogenous.

Pasteurisation
The heating of milk by either batch method i.e. 63°C and holding it for 30 minutes or by a high temperature / short time method of 72°C and holding for 15 seconds. The aim is to destroy all pathogenic organisms that may cause disease in humans.

Pathogenic
This word refers to the potential of some micro-organisms to cause disease in humans. The disease may be caused by eating the microorganisms in the food or by consuming a poisonous substance produced by these types of organisms.

Pressing
A step in cheesemaking during which the curds are placed under pressure to remove whey and create a closer textured cheese.

Rennet
A substance containing powerful enzymes capable of coagulating milk. Calf rennet is derived from the fourth stomach of a milk-fed calf. It contains the enzyme Chymosin that can coagulate milk. Animal rennet is commonly available in liquid form.

Rind
The outer surface of a cheese which is drier and denser than the rest of the cheese.

Soft cheese
A cheese that is not pressed, contains a high moisture content, and is eaten very soon after production. E.g. Ricotta and Cottage.

Standardisation
This term refers to adjustment of the fat, protein or SNF levels in milk to achieve the desired specifications of the end product. Fat may be removed and protein or other solids added.

Starter
A bacterial culture added to milk as the first step in making cheeses or fermented milk products. The bacteria produce an acid in the milk and in the curds.

Starter culture
Same as starter.

Vegetarian Rennet
Types of rennet that are not derived from an animal origin and are suitable for Vegetarians.

Whey
The liquid portion of milk which separates from the curds after coagulation of the milk protein. Whey contains water, milk sugar, whey proteins, minerals and small proportions of fat. It should be a clear greenish colour and not milky.

Whey protein
Water soluble protein in milk which is not precipitated by the addition of rennet.

5B Cheese applications content

5b.1 Introduction

The manufacture and description of the major cheese varieties has been covered previously in the cheese chapter. This cheese applications chapter further explores the major cheese types, and how they can be used as ingredients in food systems.

Cheese is widely used as an ingredient in food applications to impart benefits such as appearance, texture, flavour, and enhance the cooking properties of selected foods.

Cheese provides the essential texture in many foods designed for quick heating and eating, such as pizzas and frozen entrees.

Some cheese varieties contribute a flaky or crumbly texture, which can add contrast to a melting cheese in heated applications. These cheeses can be used cold or heated in salads, or as toppings for soups, pastas and casseroles. Smooth flowing cheese sauces are often used to add flavour and to thicken soups and sauces.

The diverse use of cheese is further extended when it is subjected to secondary processing to provide ready-to-use grated, sliced and shredded cheeses, cheese powders and processed cheese products.

Throughout this chapter, references to a variety of cheese types and examples of their use in food applications are provided. For full details of the recipes referenced in this chapter, please visit Dairy Australia's Legendairy website: **legendairy.com.au**.

5b.2 Cheese and the consumer

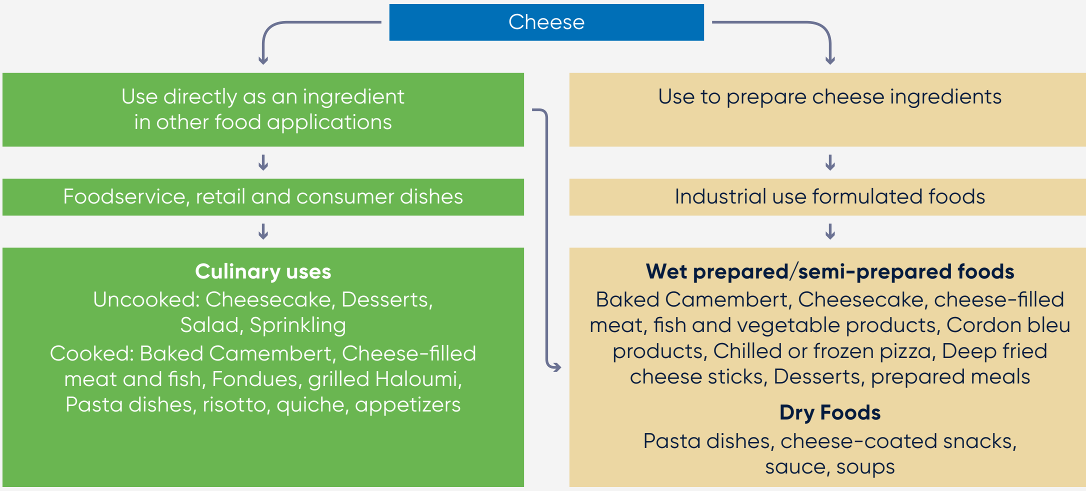
The cheese ingredient market

Cheese is available to the consumer through three main sectors:

- The food service sector – cheese may be presented in the form of a cheese board or cheese platter or used as an ingredient in various dishes
- The retail and consumer sector – cheese is in the form of portions, such as blocks and slices, or pre-packed shreds, shaves and spreads which are consumed in the home directly as a table food, or indirectly as an ingredient in various dishes.
- The industrial sector – cheese can be used as an ingredient in several types of assembled products, such as pizzas and hamburgers, or formulated foods such as prepared meals and desserts.

A summary of cheese use by the consumer is provided in Figure 1.

Figure 1 Use of Cheese as an Ingredient



Cheese availability in the consumer market

Cheese is available in numerous varieties, types and sizes for several food applications. A summary of the types of cheese available for the food service and the retail/consumer sectors is provided below in Table 1 and 2.

Table 1 Cheese availability in the Food Service sector

Cheese Variety	Type	Size Available	Application
Cheddar	Individually Wrapped Slices (IWS)	100g, 250g, 500g, 625g bags	Route trade foodservice, use in sandwiches and burgers.
	Slice on Slice (SOS)	1kg, 1.5kg bags	Busy food service areas such as fast food and sandwich bars. Used in burgers and sandwiches.
	Shredded	250g, 500g, 750g, 2kg bags	Many food service applications, including sauces, pizzas and salads.
	Cubed Cheese	250g, 500g, 2kg bags	Use in salads and entrées.
	Portions	20g bags	Used by airlines and hotels for a quick, nutritious snack.
Mozzarella	Block	5kg, 10kg, 20kg in box	Used for high melt applications, such as pizza and pasta bakes.
	Shredded	2kg bag, 12kg box	Used for high melt applications, such as pizza and pasta bakes.
Pizza Cheese	Block	10kg, 20kg in box	Blended specifically for use on pizzas.
	Shredded	12kg in box	Blended specifically for use on pizzas.
Cream Cheese	Block	2kg box	Used in Cheesecakes, dips, spreads and frostings.

Table 2 Cheese availability in the Retail/Consumer Sector

Cheese Variety	Type	Size Available	Application
Cheddar	Individually Wrapped Slices (IWS)	216–250g (12 slices), 432–500g (24 slices), 648g (36 slices) and 1kg (48 slices)	Use in sandwiches and hamburgers.
	Slice on Slice (SOS)	10, 12, 24 or 75 slice packs	Use in hamburgers and sandwiches.
	Block	250g, 500g, 550g, 625g and 1kg	Many applications, including snacks, and accompaniment to a cheeseboard, sliced for sandwiches or shredded for baked dishes.
	Shredded	250g, 400g, 500g, 550g and 600g bags	Many applications, including sauces, pizzas and salads.
	Cubed Cheese	250g, 500g bags	Use in salads and entrées.
	Portions	20g bags	On the go nutritious snack.
Mozzarella	Block	250g and 625g block	Use for high melt applications, such as pizza and pasta bakes.
	Shredded	250g, 500g and 600g bags	Use for high melt applications, such as pizza and pasta bakes.
Mozzarella Blends	Shredded	200g, 450g and 600g bags	Provide food melt and stretch on a pizza, provide flavour and browning to baked dishes, use in melting and grilling applications.
Cream Cheese	Block	250g box	Use in Cheesecakes, dips, spreads and frostings.
	Spreadable	250g tub and 4 x 40g portions	Snack tubs, sandwich filling, cracker topping.
	Cream cheese spread	250g and 500g Jar	Accompaniment to vegetables, as a spread in sandwiches.

5b.3 Functional benefits of cheese as an ingredient

Cheese is mostly used for flavour enhancement, texture improvement, better mouthfeel, colour improvement or binding other ingredients. Cheese can also be tailor made to provide specific functional properties such as controlled browning, restricted melt, and sharper flavour profiles. The functional properties of cheese are an integral element in the development of cheese applications.

Flavour, aroma and flavour enhancement

Food applications benefit not only from the background flavour that cheese can provide, but also from the ability of cheese to carry, shape, refine and improve the flavours of other ingredients. Cheese helps to ensure complete flavour release when used in combination with fat-soluble ingredients, spices, herbs and sweet flavours. Cheese also helps evenly distribute

flavour throughout the product due to the low melting point of the milkfat in cheese.

In low moisture products, cheese powders may be used to boost the cheese flavour profile of foods such as dry soup mixes, sauces, bakery and snack food applications. The flavour and aroma of cheese is influenced by its fat and protein content, together with other contents such as starter cultures, mould and ripening bacteria. Ripening or ageing, together with curd washing and salting can also affect the flavour of cheese.

There are several cheese varieties each with differing flavour profiles for specific applications. Blending of cheese varieties further increases the variety of available cheese flavours.

Texture and mouthfeel

Higher moisture cheeses, such as fresh ripened cheeses, have a smoother mouthfeel than hard grating cheeses, which are low in moisture and high in protein. Temperature treatments also affect the texture of most cheeses, although some cheeses are designed to keep their integrity during cooking (no melt) or during freeze-thaw cycles.

Cooking ability and melt

The physical properties of melted cheese are highly complex, giving rise to the following attributes:

1 Meltability
2 Flowability
3 Stretchability
4 Elasticity
5 Free oil formation, and
6 Browning and blistering.

Meltability refers to the ability of cheese particles to join to form a uniform continuous melt when heated. It may also be referred to as shred fusion.

Flowability refers to the ability of a cheese to flow once it has melted. Cheese with a high flowability, such as soft Cream Cheese, is desirable for use in cheese-filled meat applications such as chicken cordon bleu, while a cheese with a low flowability, such as Haloumi, is more suited to fried applications, such as grilled Haloumi.

Stretchability is the ability of the melted cheese strands to form cohesive fibres, strings or sheets that elongate without breaking under tension. It may also be referred to as stringiness.

Elasticity, sometimes referred to as flow resistance or 'strength of the stretch', is the resistance to elongation of the fibrous strands as they are stretched, which in turn inhibits flow.

Free oil formation, also known as 'oiling off' or 'fat leakage', is the separation of liquid fat from the melted cheese body during cooking into oil pockets, particularly at the cheese surface. Free oil formation ranges from none to excessive. Free oil release is generally dependent on the cheese type and the duration of the ripening. For example, over ripened Mozzarella is expected to have excessive oil release due to the inability of the protein to bind the fat when exposed to heat such as in baking cheese on pizzas.

Browning and blistering occur at the surface of cheese during high temperature baking. It is characterised by the formation of a skin-like layer containing colour patches known as blisters, that may range from light or golden brown to black in extreme cases. Generally, both the size of the blisters and their colour is important as observed in Mozzarella application on pizzas.

When heating or cooking foods that contain cheese, the best results are usually obtained when items are

cooked at a low temperature for a minimum time. For example, in sauces, cheese should be added as the last ingredient and heated until just melted. Dicing, shredding or crumbling the cheese can reduce melting time in any application. In Mozzarella, for example, browning is generally related to the composition of the cheese, particularly the levels of protein and fat.

Colour development and browning

In melted applications, cheese performance is

influenced by the same factors that determine cheese texture: pH, cheese composition and the degree of protein breakdown through maturation. The factor to best consider depends on how the cheese is heated, i.e. microwave, thermal, or forced air. For thermal heating of young cheeses, melt is less influenced by protein breakdown, although it becomes more important for aged cheeses. In microwave applications, degree of protein breakdown is very important, as is cheese pH and amount of fat in the dry matter. Depending on the degree of melt required (restricted melt versus flow) and the type of heating that will be used, specific cheeses may be better suited for certain applications

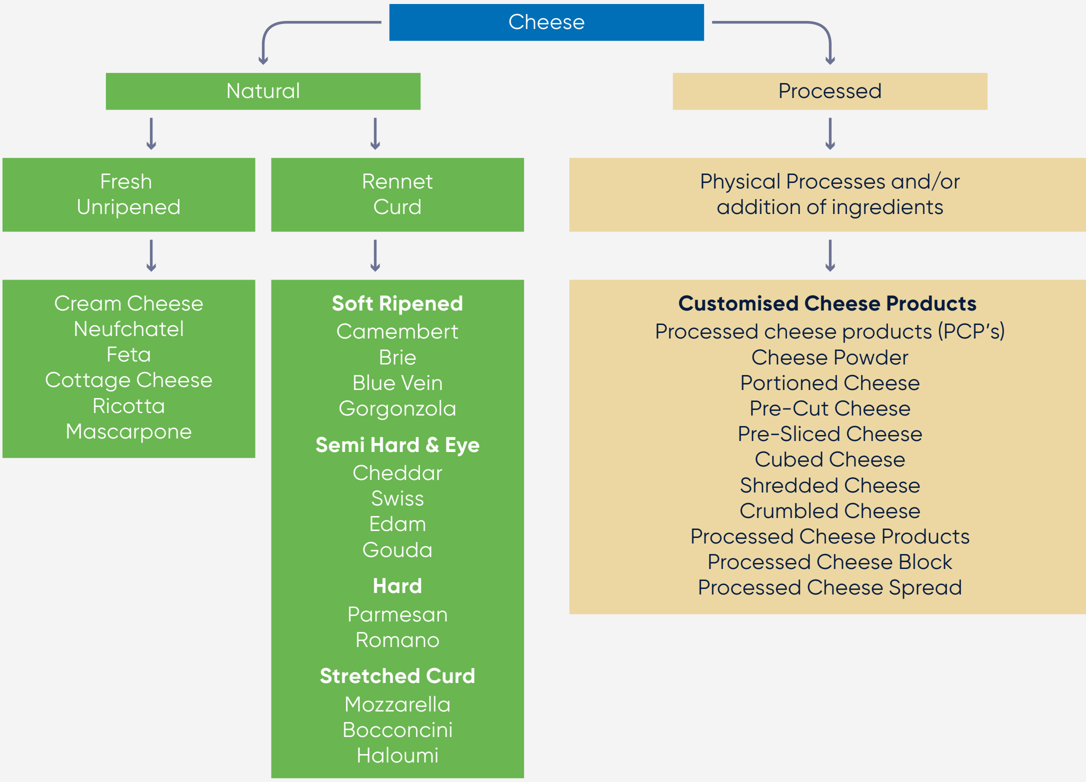
Cheese colour can be tailored for specific applications. Regardless of its original colour, cheese can brown when heated or cooked. Surface browning of cheese is usually caused by the Maillard reaction, a heat induced reaction that occurs between proteins and sugars during the baking of cheese. Maillard browning often occurs in Mozzarella cheese, where the selected starter cultures and high temperatures used during mixing result in incomplete fermentation of lactose, or an accumulation of galactose. For pizzas or other products cooked at very high temperatures (>200°C) for extended time, Maillard browning can cause undesirable browning or even burning to a dark colour.

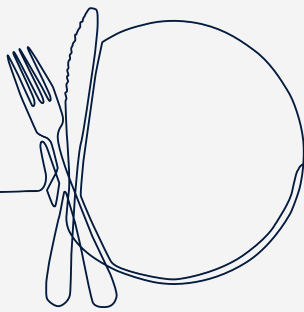
5b.4 Cheese varieties and use in bakery and foodservice

Cheese is a highly versatile ingredient that adapts well to many food systems. In some applications, the primary role of cheese is browning or melting, while in others it is used to contribute flavour, colour, or nutrients. Forms of cheese available for bakery and foodservice applications include natural cheese, processed cheese, and cheese powders. Based on performance objectives, specific cheese varieties and forms are selected to best deliver the desired product benefits.

A summary of the available cheese types is listed in Figure 2.

Figure 2 Cheese types and industrial cheese ingredients





Natural – fresh unripened

Examples of cheese types in this category: Cream Cheese, Neufchatel, Feta, Cottage Cheese, Ricotta Cheese, Mascarpone.

Functional benefits of fresh cheese use in Foodservice and Bakery Applications include:

- Has a neutral flavour profile, making it a suitable flavour carrier for other ingredients, and can be used in sweet or savoury dishes.
- Imparts a fresh, creamy, mild and delicate flavour.
- Provides density in applications such as dips, spreads and baked cheesecakes.
- May be used as a binder or texture agent.
- Used in baked goods, such as cheesecake, at low temperatures to provide even browning without blistering or cracking.
- The high moisture content of this cheese variety (45–55%) makes it suitable as an ingredient within wet foodservice and consumer applications, such as dips, frostings, sauces and fillings.

A summary of the application and use of fresh unripened cheese is shown in Table 3.

Table 3 Application and use of fresh unripened cheese

Cheese Type	Application	% Use
Cream Cheese	Icing and Frosting	30–45
	Dip	60–70
	Cheesecakes – Baked	20–50
	Cheesecakes – Refrigerated	30–40
Feta	Pizza	20–35
	Meat dishes – as a stuffing or topping	35–50
	Salads	Sprinkled on top, as desired
	Soup	Stirred through, as desired
Cottage Cheese	Vegetable Dishes	20–30
	Baked Meals	20–60
	Muffins	20–35
Ricotta Cheese	Baked Meals	10–50
	Muffins	20–30
	Pasta	25–40
	Appetizers	60–70
	Topping	60–70
	Icing	80–85
Mascarpone	Dessert	15–35
	Pasta	5–10
	Risotto	2–5

Cream cheese

- Contributes a creamy appearance and fresh dairy notes to Cream Cheese icing and frosting. The incorporation of a beating action at room temperature with other ingredients incorporates friction into the mix, which in turn causes the Cream Cheese to change from a solid mass into a smooth, spreadable mix.

Example
Lemon Blueberry Cupcakes with Fluffy Lemon Frosting

- Contributes a creamy appearance and a bland flavour to dip and spread applications. May be made sweet or savoury, depending on the application. The incorporation of a beating action at room temperature with other ingredients incorporates friction into the mix, which in turn causes the Cream Cheese to change from a solid mass into a smooth mixture, perfect for dipping and spreading applications.

Example
Basil, Lemon and Pinenut Dip

- Acts as a flavour carrier in baked and refrigerated cheesecakes, and contributes to the density and a creamy, rich colour in the final product. Baked cheesecakes are cooked at 150-160°C for 50-60 minutes. The long baking time at the lower temperature ensures even baking of the cheesecake without excessive browning. Following baking, cheesecakes are left in the oven to cool, with the door ajar to ensure escape of heat. The slow cooling prevents the surface cracking of the baked cheesecake.
  Examples: Baked Cheesecake and Basic Lemon Cheesecake

Feta

- Can be crumbled and used alone or in combination with other cheese varieties in pizza applications. Pizzas are baked at 200–230°C, with the Feta providing a curd-like consistency with no melt, maintenance of a firm texture, a bland flavour profile and some browning.

Example
Char-Grilled Vegetable Pizza

- May be crumbled and used as a meat stuffing. Meat dishes are baked at 180–220°C for 30–40 minutes to impart some browning in the stuffing. The meat dish is left undisturbed for 10 minutes prior to carving to allow the stuffing to firm up and create a sliceable, stuffing-filled meat.

Example
Turkey Breast with Feta and Craisin Stuffing

- High moisture content and loose curd allows it to break into small, irregularly shaped pieces when rubbed. These can be crumbled over a final prepared salad for fresh cheese flavour.
  Example: Marinated Julienne Salad in a Crouton Bowl
- Can be stirred through soup just before serving or may be crumbled over the soup as a garnish just before serving, imparting a mild cheese flavour.

Cottage cheese and ricotta cheese

- Can be used in vegetable dishes for its binding properties and to add bulk to the final product. Cottage Cheese also provides a smooth texture with a mild cheese profile. Baking conditions range from 180–200°C for 20–30 minutes.

  Example: Cheese and Broccoli Flan

- Can be used in meat dishes to provide a smooth creamy product with a mild cheese flavour. May be used as a substitute for béchamel sauce in low-fat lasagna products.

Example

Trim and Terrific Beef Lasagna

- Can be used in muffins where it acts as a flavour carrier for sweet ingredients. Muffins are baked at 180°C for 20–30 minutes, with the Cottage Cheese retaining its curd-like structure during baking, imparting a curd-like texture throughout the final muffin product.

  Example: Apricot Cottage Muffins

Ricotta cheese

- Combines well with other ingredients, provides binding and acts as a flavour carrier in baked meal applications. Baked at 180–200°C for 10–30 minutes, Ricotta provides a smooth texture and contributes some colour to the final baked product.
- Can be used in muffins where it acts as a flavour carrier for sweet ingredients. Muffins are baked at 180°C for 20–30 minutes, with the Ricotta cheese acting as a binding ingredient, imparting a smooth texture in the final baked muffins.

  Example: Apricot Cottage Muffins

- Acts as a binding ingredient and a flavour carrier for savoury ingredients within pasta dishes and appetizers. These products are baked at 200°C for 10-30 minutes.

Example

Smoked Salmon, Rocket and Ricotta Linguine, Mini Roast Capsicum and Olive Baked Ricotta

- Can be whipped with fruit and used as a carrier for topping applications, where Ricotta acts as a flavour carrier for the fruit, and provides density, which allows it to hold as a topping on pancakes.

  Example: Buttermilk Pancakes with Whipped Raspberry Ricotta

- Can be utilised as the main ingredient in icing for baked applications, where Ricotta acts as a flavour carrier for sweet ingredients, and provides body to the icing mix, allowing it to remain on top of the baked good once applied.

Example

Banana Sultana Muffins with Honey Ricotta

Mascarpone

- Can be whisked and combined with other ingredients to impart a smooth, creamy flavour and texture to desserts. Mascarpone also acts as a flavour carrier for sweet ingredients, and provides the body to the final product as in the case of Tiramisu

Example
Tiramisu

- Can be used at low levels in pasta dishes to bind, act as a flavour carrier and impart creaminess to the final pasta dish.

Example
Macaroni Cheese

- May be stirred into a final prepared risotto to provide a creamy mouthfeel and flavour, and to enhance the flavour of the savoury ingredients within the risotto.

Example
Three Cheese Risotto with Chicken, Rocket and Roasted Red Capsicum

Soft ripened cheese (White and blue mould cheese)

Examples of cheese types in this category: Camembert, Brie, and Blue Vein.

Functional benefits of soft ripened cheese in foodservice and bakery applications include:

- Provides strong, distinctive flavour profiles that add intensity to foodservice applications such as sauces and dressings.
- Soft cheeses have an adhesive property, yet undergo flow when force is applied; making them suitable materials in the preparations of fondues and sauces, as well as appetiser spreads.
- Have good binding characteristics, making them suitable to combine with other ingredients for baked meat fillings.
- Can be baked alone or in combination with other cheese varieties at 190–230°C as a pizza topping, a meat topping or in filled pasta applications to impart browning and a firm texture.

A summary of the application and use of soft ripened cheese is provided in Table 4.

Table 4 Application and use of soft ripened cheeses

Cheese Type	Application	% Use
Camembert	Meat Dishes	35–50
Blue Vein	Appetizers and baked dishes	30–40
	Meat Garnish	25–35
	Salad	10–20
	Sauce	10–20
	Risotto	1–3

Examples of soft ripened cheese use in foodservice and bakery applications:

Camembert

- Can be sliced and used as a meat stuffing, where its function is to bind dry ingredients, and provide a nutty, mushroom flavour. Meat dishes are baked at 180-220°C for 30-40 minutes to impart browning in the stuffing. The meat dish is left undisturbed for 10 minutes prior to carving to allow the stuffing to firm up and create a sliceable, stuffing-filled meat.

Example
Camembert Turkey Fillet with Creamy Cranberry Sauce

Blue cheese

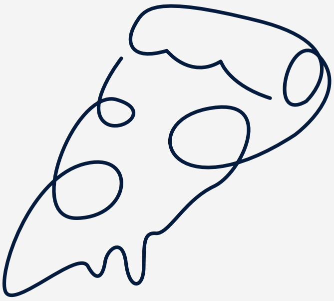
- Can be used in appetisers and baked dishes, where it is sliced or crumbled with other ingredients, and baked at 200°C for 20 minutes. Used to impart a distinctive tangy flavour.

Example
Smoked Chicken and Blue Cheese Tart

- Used as a meat garnish when combined with other ingredients, creating a distinctive flavour that complements red meat.
  Example: Beef Fillet with a Creamy Blue Cheese Topping
- Can be crumbled and used as a garnish for salads, where it imparts a distinctive tangy flavour and adds to the texture of the salad.

Example
Char-Grilled Asparagus, Blue Cheese and Walnut Salad

- May be melted with other ingredients to create a cheese sauce with a distinctive flavour. When preparing a cheese sauce, all ingredients other than the cheese are combined and heated on the stovetop at around 75-90°C. Once these ingredients have combined, the sauce is removed from the heat and the cheese is stirred through the mix to create the sauce. Stirring in the cheese following the application of heat allows for a final cheese sauce product with a smooth texture and a moderate flavour profile, without excessive browning.
  Example: Blue Cheese and Chive Fondue



Semi hard cheese and eye cheese

Examples of cheese types in this category: Cheddar, Swiss, Edam, and Gouda.

Cheddar

Cheddar cheese can impart various flavour and texture profiles, depending on how long Cheddar has been matured.

- **Mild Cheddar** is ripened for 1-3 months and imparts a low flavour profile and a smooth, firm texture. Mild Cheddar can be easily sliced, cubed or shredded. Mild cheese is useful in applications such as children's meals, and blended with other cheese ingredients for pizzas, where other functional benefits of Cheddar may be required, but the smooth, low flavoured profile is preferred.
- **Tasty Cheddar** is ripened for 9-12 months and imparts a well-rounded, mature flavour, with a slightly weaker body and texture compared with mild Cheddar. Tasty cheese can also be sliced, cubed or shredded, and is the most commonly used Cheddar type in bakery and foodservice applications, such as muffins, soups, pastas, pizzas, hamburgers, sandwiches and sauces.
- **Vintage Cheddar** imparts a sharp, distinctive cheese flavour, with a crumbly texture, and is best suited as an ingredient in soups, salads and pasta dishes.

A summary of the key Cheddar properties, with their levels of maturity, is shown below in Table 5.

Table 5 Properties of Cheddar Cheese

Cheddar Type	Maturation Period	Body	Flavour
Mild	1–3 months	Firm	Clean, mild, slightly acidic
Tasty	9–12 months	Semi-weak	Balanced sharp, creamy flavour
Vintage	16–18 months	Crumbly	Extra sharp, 'bite'

A summary of the application and use of Cheddar cheese is shown in Table 6.

Table 6 Application and use of Cheddar cheese

Cheese Type	Application	% Use
Cheddar	Snacks	30–65
	Vegetable Dishes	20–30
	Soup	10–20
	Sauce	10–20
	Baked Pasta	10–30
	Quiche	10–20
	Pizza	10–15
	Muffins	5–25
	Risotto	1–3

Cheddar

- Can be grated, mixed with other ingredients and baked at 200°C for 10-15 minutes to provide a cheese snack that has a strong cheese flavour and imparts a golden yellow colour.

Example

Cheese Straws

- May be heated on the stovetop and melted with other ingredients to provide a sauce for baked vegetable dishes. These dishes are baked at 200°C for 20-60 minutes, with the Cheddar cheese contributing to good melting properties, imparting a strong cheese flavour and providing a golden brown colour.

Example
Caramelised Onion, Pecorino and Potato Flan

- Can be stirred through a simmering soup, or sprinkled over a soup as a garnish, where it contributes a good cheese flavour, has good melting properties and adds body to the soup.
  Example: Pumpkin soup with Tasty cheese
- Can be stirred in with other ingredients over a low heat stovetop and be used in the preparation of fondues. The excellent melting properties of Cheddar allow it to provide a smooth texture and contribute a good cheese flavour.
  Example: Cheese and Beer Fondue
- Can be stirred in with other ingredients following heating on a stovetop, and used in pasta bake dishes, where its melting properties allow it to combine well with other ingredients providing cheese flavour and a golden brown colour to the final baked pasta dish.
  Example: Macaroni cheese
- May be placed on top of a quiche and baked at 180°C for 20-30 minutes, where the Cheddar melts and creates a smooth, well flavoured and slightly crisp golden brown surface.
  Example: Asparagus and Capsicum Bread Quiches
- Can be combined with other ingredients and baked at 180°C for 20 minutes for the manufacture of muffins. Cheddar provides flavour, melts on heating, and contributes a golden brown colour to muffins.
  Example: Cheese and Buttermilk Corn Muffins
- May be shredded and used over the top of other ingredients in a pizza base, where it is baked at 200-230°C for 10-15 minutes. The good melting properties offered by Cheddar cheese enable it to hold together other ingredients on the pizza, whilst at the same time providing cheese flavour and a crisp, golden brown texture and colour to the pizza surface.

Example
Vegetable Pizza

- May be stirred through a risotto at the end of cooking, where its excellent melt properties allow the ingredients to combine, and it also contributes a cheese flavour.

Example
Three Cheese Risotto

Swiss, edam and gouda cheese

Swiss, Edam and Gouda Cheese, also known as eye cheeses, can be used interchangeably with Cheddar in many bakery and foodservice applications.

- Swiss cheese provides unique, buttery and nutty flavours to food applications. Its texture is firm and contains large eyes throughout.
- Swiss cheese is available in shredded or sliced form, and has superior melting properties, making it useful as an addition to soups, fondues, sandwiches, sauces and microwave applications.
- Edam and Gouda cheese have mild buttery and nutty flavours, with Edam having a smooth and firm texture, whilst Gouda has a smooth and creamy texture.
- Edam and Gouda cheese can be sliced or cubed, and have good melting properties, making them suitable for a variety of cooking applications, including soups, sauces, grills, melts, and sandwiches.

A summary of the application and use of semi hard eye cheese is shown in Table 6.

Table 6 Application and use of semi hard and eye cheeses

Cheese Type	Application	% Use
Swiss	Baked Pasta	15–20
	Meat	10–15
	Sandwiches	10–15
Edam	Frittata	10–15
Gouda	Savoury topping	30
	Pie	15–20
	Soup	10

Swiss

- Can be combined with other ingredients and stirred on the stovetop until melted, providing a sauce for baked pasta applications. Swiss cheese adds flavour and excellent melting properties to pasta bakes and works well as a binder for other ingredients.

Example
Swiss Cheese, Pasta and Ham Bake

- May be sliced and melted over the top of meat, where its excellent melting properties allow for a smooth, melted mass with a unique, nutty and buttery flavour.

Example
Swiss Cheese, Pork and Apple Steaks

- Can be sliced and used as a sandwich filling, where it provides good melting properties when toasted, and contributes to flavour.

Example
Crispy Swiss Cheese Finger Sandwiches

Edam

- Can be whisked together with other ingredients and heated on the stovetop to form a frittata. Edam melts well and acts as a binding agent for other ingredients when heated within the frittata, and the cheese also contributes to a golden-brown colour in the final product.

Example
Turnip and Sweet Potato Frittata

Gouda

- Can be combined with breadcrumbs and used as a topping for savoury sides.
  Example: Crunchy Top Italian Tomatoes

- Can be used to add flavour and texture to baked savoury dishes.

Example
Puffed Gouda Pie

- Can be grated and blended with bread for a sweet and buttery flavoured topping for soups.

Hard cheese

Examples of cheese types in this category: Parmesan, Romano

Functional benefits of hard cheese used in foodservice and bakery applications include:

- Parmesan offers a buttery, sweet and nutty flavour, while Romano provides a sharp, piquant flavour. The flavour of hard cheeses intensifies with age, and imparts a strong, fresh, and clean flavour.
- The low moisture content of Parmesan and Romano cheese causes them to have a hard, granular texture that is brittle in nature and is well suited to grating.
- Provides good melting properties, melting rapidly and evenly when used in applications such as pasta, soups, stuffing and sauces.
- Can be grated, shaved or powdered to provide good free-flowing properties that are ideal where sprinkling or measured delivery is required.

A summary of the application and use of hard cheese is provided below in Table 7.

Table 7 Application and use of hard cheese

Cheese Type	Application	% Use
Parmesan	Meat Coatings	3–20
	Meat Topping	5–15
	Pasta Sauces	5–15
	Baked Meals	2–5
	Salads	2–5
Romano	Sauce	30–40
	Meat Coatings	3–20
	Baked pasta	2–5
	Salad	2–5
	Risotto	1–3

Parmesan and Romano cheese can be used interchangeably to provide the same characteristics to a variety of food applications.

Parmesan

- Can be combined with other ingredients and used as a meat coating, which is baked at 180-200°C for 10 minutes. Parmesan contributes to a crunchy texture when baked and provides a good cheese flavoured coating.

Example
Cheesy Chicken Nuggets

- The rapid melting properties of Parmesan make it suitable as a binder for other ingredients on a meat topping, where it is grilled and provides a smooth, molten cheese with a golden surface appearance and a strong cheese flavour profile to the meat topping.

Example
Chicken Parmigiana

- Can be combined with other ingredients and gently brought to the boil under stirring to form a pasta sauce. The rapid melt of Parmesan adds body to the pasta sauce and provides a smooth texture and a strong cheese flavour.
  Example: Creamy Mushroom Parmesan Pasta
- May be sprinkled over the top of a pasta dish and baked at 180°C for 20-25 minutes, where it provides a crisp texture, a golden brown surface colour and buttery, nutty flavours.
  Example: Chicken Macaroni Cheese
- Can be shaved and added as an ingredient to salads, giving a strong cheese flavour with a brittle, granular texture that easily breaks in the mouth when consumed.

Example
Grilled Chicken, Rocket, Pear and Parmesan Salad

Romano

- Can be stirred in with other ingredients over a low heat stovetop and be used in the preparation of fondues. The rapid melting properties of Romano allow it to provide a smooth texture and contribute a strong cheese flavour.
  Example: Cheese and Beer Fondue
- Can be combined with other ingredients and used as a meat coating, which is baked at 180-200°C for 10 minutes.
- Romano contributes to a crunchy texture when baked, and provides a strong cheese flavoured coating.

Example
Parmesan and Herb Crumbed Lamb Cutlets

- May be sprinkled over the top of baked pasta dishes and baked at 180°C for 15-20 minutes. Romano provides good melt, as well as contributing to cheese flavour and a golden-brown surface colour.
  Example: Swiss Cheese, Pasta and Ham Bake
- Can be shaved and added as an ingredient in salads, where it provides a strong cheese flavour that complements the other salad ingredients.
  Example: Romano Nicoise Style Salad
- Can be stirred through risottos, where its quick melting properties allow it to bind with other ingredients and provide a smooth, creamy texture. Romano also imparts a strong cheese flavour.
  Example: Three Cheese Risotto

Stretched curd cheese

Examples of cheese types in this category: Mozzarella, Bocconcini, Haloumi.

Functional benefits of stretched curd cheese use in foodservice and bakery applications include:

- Stretched curd cheeses have sweet, mild flavours that can complement other flavours and are compatible with a wide range of flavourings, spices and herbs.
- Have a closed texture which is smooth, soft and moist, allowing this cheese to be sliced, shredded or cubed for use in food applications.
- Offer a range of cooking properties and may be used in applications in grilled, baked or melted forms to provide body and mouthfeel.
- Provide a uniform and consistent melt.
- Add visual appeal to Italian-style dishes.

A summary of the application and use of stretched curd cheese applications is shown in Table 8.

Table 8 Application and use of stretched curd cheese

Cheese Type	Application	% Use
Mozzarella	Appetizer	60–70
	Baked Pasta	5–15
	Pizza	5–10
	Meat Topping	5–10
Bocconcini	Appetizer	20–30
	Pasta	10–20
	Salad	70–80
Haloumi	Appetizer	80–85

Mozzarella

Can be used to complement meats, such as prosciutto and chicken in appetisers, which are baked at 180°C for 12-14 minutes. Mozzarella melts well and acts as a binding ingredient for the meat. The mild flavour of the cheese is well suited to meat, while the cheese imparts a soft, smooth texture to the application.

Example: Prosciutto Wrapped Mozzarella and Chicken Bites

- May be sprinkled between pasta sheets and meat in a baked pasta application and baked at 180°C for 30 minutes. Mozzarella melts on heating providing a smooth, molten mass with a mild cheese flavour that complements the flavour of the meat/sauce mix. Mozzarella also contributes to stretch, giving a stringy texture when consumed.

  Example: Beef Lasagna with Spinach

- May be grated and sprinkled over the top of pizzas and baked at 200°C for 10-15 minutes. Mozzarella melts evenly and assists in holding the other topping on the pizza; it contributes a mild cheese flavour that complements the other pizza toppings and provides stringiness and stretch to the pizza, together with the development of a golden-brown colour.
  Example: Char-Grilled Vegetable Pizza
- Can be used as an ingredient within a meat topping, where it is baked at 200°C for 15 minutes. Mozzarella melts well and assists in holding the other ingredients onto the surface of the meat. It also provides stringiness and stretch to the product when consumed, imparts a smooth mild flavour and contributes to surface colour of the meat topping.
  Example: Mozzarella and Asparagus Chicken

Bocconcini

- Can be combined with sliced meat and other antipasto ingredients and served as an appetiser. The mild flavour of Bocconcini complements the other ingredients, whilst the smooth texture imparts a pleasant mouthfeel.

Example
Eggplant, Basil and Bocconcini Spirali

- Can be torn and added to heated pasta, where it provides a sweet, mild flavour and moist texture to pasta dishes.
- The mild flavour profile and smooth texture of Bocconcini lends itself well within salad applications, where it can be coated with spicy ingredients and function as a flavour carrier.

Example
Spiced Bocconcini and Rocket Salad

Haloumi

- May be coated in savoury ingredients and pan fried to produce a savoury Haloumi cheese appetiser. The mild flavour profile allows Haloumi to be a flavour carrier for savoury ingredients, while the closed structure allows this cheese to be fried without melting or breaking.

Example
Pan-fried Haloumi with Tomato Salsa

Processed cheese

The major ingredient in processed cheese products is cheese, with the amount, variety and age of the cheese used in the processed cheese formulation dependent upon its application. Cheese spreads contain a minimum of 51% cheese of a medium-ripe maturity that breaks and melts when a shear force is applied. Block processed cheese accounts for up to 98% cheese of a young maturity, with a closed structure that maintains its form when sliced, cubed, or shredded.

Processed cheese spread products combine two or more cheeses with emulsifying salts under heating to create flavours that are richer and more complex than the flavour of a single cheese. Processed cheese spread products are created by combining two or more cheese varieties into a homogeneous blend using the application of heat, shear and the addition of emulsifying salts.

Functional benefits of processed cheese in the Foodservice and Bakery Applications include:

- Offer a variety of flavour, consistency and functional properties for food applications due to the variety of formulations and processing conditions available for this cheese type.
- Able to deliver consistent properties such as melt, stretch, flavour and colour.
- Allow food manufacturers to create specific dishes in a consistent and cost-effective manner.
- Lower manufacture costs compared to natural cheese, since they utilise low grade cheese types, together with low cost non-cheese ingredients.
- Have a long shelf life, assisting in minimising wastage.

Examples of processed cheese use in Foodservice and Bakery Applications:

- May be used in pre-sliced cheese applications to deliver excellent melt and hold properties for use in sandwiches and burger cheese slices.
- May be dried and used as a coating for savoury snack foods.
- May be used in foodservice to top a variety of dishes and fast food products and as ingredients in cheese-stuffed entrees, casseroles, microwaveable meals, soups, sauces and meat dishes.

Processed cheese block

Examples of processed cheese block products: Processed cheese, Processed Cheese Food.

Functional benefits of processed cheese blocks in the Foodservice and Bakery Applications:

- Can be manufactured to specific flavour and texture requirements for use in food applications.
- Convenient and ready to use.
- May be shelf stable products, making them convenient in areas where refrigeration may be unreliable or unavailable.

Examples of processed cheese block use in Foodservice and Bakery Applications:

- May be sliced and used in sandwiches or burgers to impart a uniform flavour and good melt properties.
- May be shredded and used in cheese sauces, risottos and pizzas, providing a uniform cheese flavour and contributing to melting properties.
- Can be partly or fully substituted for natural cheeses, making them useful in a wide range of food applications with savings in ingredient costs.

Processed cheese spread

Examples of processed cheese spread products: Cream Cheese, Cheddar blends.

Functional benefits of processed cheese spread in the Foodservice and Bakery Applications:

- Smooth cheese product that is a blend of two or more natural cheeses, being blended specifically for the application in which it will be used.
- Provide excellent spreadability and a good cheese flavour.
- Convenient and ready to use.
- Shelf stable products, making them convenient in areas where refrigeration may be unreliable or unavailable.

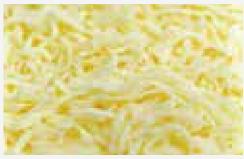
Examples of cheese spread use in Foodservice and Bakery Applications:

- May be used as a base for soups and sauces.
- May be spread and used as an appetiser topping, such as a dip or a spread, for bread or crackers.
- Used as a filling in baked goods.

Customised cheese products

Customised cheese products are developed to meet the specific needs of end users and are often subjected to size reduction operations involving a combination of shear and compressive stresses that result in fracture, and lead to the formation of a ready to use product.

Examples of customised cheese available for use include shredded cheese, cheese powder, portioned cheese, pre-sliced cheese, cubed cheese and stick cheese. Customised cheese products use cheese cuts as their primary source and are further processed to reduce the on-site labour required to prepare cheese for its end use. Many restaurants and food service outlets use customised cheese products not only for their labour savings, but also to ensure control over the consistency of final food products.



Shredded cheese

Examples of shredded cheese products: Mozzarella, Parmesan, Cheddar.

Functional benefits of shredded cheese in the Foodservice and Bakery Applications:

- Available in three forms:
  - standard shred (0.2–0.3cm diameter, 1.5–3cm in length)
  - fine shreds (<0.15cm diameter, 1.2–4.5cm length)
  - flat shreds (0.15–0.35cm diameter with a flat hand shred appearance)
- Provide the same flavour, aroma and texture properties as the base cheese material.
- Convenient and ready to use.

Examples of shredded cheese use in Foodservice and Bakery Applications:

- Shredded Mozzarella is best suited to high melt applications, such as pizzas, pasta bakes and toasted focaccia. Shredded Mozzarella works well in pizza as it provides the right mix of flavour, melting, stretch and elasticity characteristics. Its form is usually a flat and medium length shred.
- Shredded Parmesan cheese is used to add flavour and body to risottos. It is usually sold as a fine shred.

Shredded tasty cheese is used for its flavour and melt properties in baked goods, Mexican nachos and frozen manufactured foods. It is commonly sold as a standard shred.

Cheese powder

Examples of powdered cheese products: Parmesan, Romano, Cheddar, and Blue

Functional benefits of cheese powder in the Foodservice and Bakery Applications include:

- Provides good cheese flavour profiles with an enhanced cheese flavour, without providing additional moisture to foods, making them suitable for dry food applications.

- Imparts a dry, powdery texture and mouthfeel.
- Convenient and ready to use.
- Offer the flexibility of blending with other dry ingredients.
- Powdered form makes them easy to deliver into/onto a food.
- Can be used in baked goods, where it retains flavour under high temperatures.
- Contributes to a golden-yellow colour appearance on the surface of baked products.

Cheese powders typically consist of a base cheese material which is comminuted with other ingredients, including water, colours, milk solids, flavours, flavour enhancers, starches, maltodextrin and emulsifying salts. This mix in a concentrate form is spray dried to create a free flowing powder with a low moisture content of around 3-5%.

The final composition of a cheese powder can vary in solids content from low solids of around 20%, medium solids of around 35%, up to high solids of ~65%.

Cheese powders in Foodservice and Bakery applications can be used as flavouring ingredients in a wide variety of low moisture food applications, including:

- Snack coatings, such as potato chips, nachos and tortilla shells
- Cheese sauces
- Soups
- Savoury dressings
- Savoury biscuits
- Sprinkled over pasta as a garnish
- Value added and extended shelf life products

Portioned cheese

Examples of portioned cheese products: Cheddar, Edam, Tasty and Swiss Cheese.

Functional benefits of portioned cheese in the Foodservice and Bakery Applications include:

- Sliced into portion sized pieces and individually wrapped for consumer freshness and convenience.

- Provide the same flavour, aroma and texture properties as the base cheese material in a nutritious grab and go pack.
- Convenient and ready to use.
- Perfect shape for complementing dry biscuits.

Examples of cheese portion used in Foodservice and Bakery Applications:

- Perfect for catering services, airlines and hotels to provide a quick, nutritious grab and go snack.
- Used as a quick and convenient Children's snack in lunchboxes.

Pre-sliced cheese

Examples of pre-sliced cheese products: Cheddar, Edam, and Swiss

Functional benefits of portion cheese in the Foodservice and Bakery Applications include:

- Most popular type of convenience cheese available.

- May be sold as individually wrapped slices (IWS) that are ideal in domestic consumer use or for route trade food service, with the wrapping contributing to a hygienic, ready to use form.

- Can also be sold in Slice on Slice (SOS) format making them easy to use during busy service periods, in applications such as sandwiches and hamburgers in fast food restaurants.
- Provide the same flavour, aroma and texture properties as the base cheese material.
- Natural cheese products, or processed cheese blends specifically suited to an application.
- Convenient and ready to use.
- Available in variety of shapes, thicknesses and sizes to suit consumer needs.

Examples of pre-sliced cheese use in Foodservice and Bakery Applications:

- Used in sandwiches and toasted sandwiches for their flavour and good melt properties.
- Used in hamburgers, where the pre-sliced cheese has good shape retention on melt, and reduced overhang when added into the burger.

Cubed and stick cheese

Examples of cubed and stick cheese products: Cheddar and processed cheese

Functional benefits of cubed and stick cheese in the Foodservice and Bakery Applications:

- Available in rectangular or square shapes of 1.5-2.0 cm thickness.
- Available as rectangular sticks.
- May be cut to specified and consistent lengths.
- Provide the same flavour, aroma and texture properties as the base cheese material in a nutritious grab and go pack
- Convenient and ready to use.

Examples of cubed and stick cheese use in Foodservice and Bakery Applications:

- Cubes may be used as an ingredient in salads.
- Can be combined with other ingredients and used as appetisers.
- Cheese sticks can be used as a quick and convenient children's snack in lunchboxes.

5b.5 Conclusion

Cheese is widely used as an ingredient in food applications to impart benefits such as appearance, texture and flavour, and can enhance the cooking properties of selected foods.

The versatility of cheese ensures that it can be used in many foods, with some varieties imparting quick melt for use in baked goods, some contributing a flaky or crumbly texture for use in baked or cold foods, some as toppings for hot dishes and some providing smooth flow for sauce applications.

An understanding of the cheese types available, together with their functionality and application, enables those in the foodservice and consumer sectors to successfully select and use cheese as a food ingredient for specific applications.

5b.6 Frequently asked questions (FAQ)

A Natural fresh unripened cheese

1. How do I prevent cream cheese lumps in a baked or refrigerated cheesecake?

Ensure the cream cheese is warmer than refrigerator temperature before combining it with other cheesecake ingredients. The best way to quickly soften cream cheese is to place the unwrapped sample into a bowl and microwave on high for 30 to 45 seconds or until completely softened. For baked cheesecakes, it is important that all cheesecake lumps be removed from the mix before adding eggs, since eggs trap air in the batter, and excess air in the mix can lead to surface cracking.

2. How can I ensure the good textural properties of feta without causing too much saltiness in my product?

A. Feta is available in two varieties, soft and semi-hard. Soft feta has a higher moisture content and is sweeter and less salty than the semi-hard feta, which has a stronger flavour and aroma. If the feta is not to be consumed immediately, it may be stored in a shallow container of milk. This ensures the cheese is kept moist and helps to reduce its saltiness.

B Soft ripened cheese

1. What affects flavour development in soft ripened cheeses, and how do I select a cheese that best suits the food application?

Soft ripened cheeses such as Camembert develop in flavour over time. When young, 4-6 weeks before the use by date, the cheese has a chalky centre core and a firm texture. When at the peak of their maturity, just before the best before date, the core disappears, leaving a creamy luscious textured centre and a delicate flavour.

If mild flavours are desired in bakery and foodservice applications, select a young soft ripened cheese for use. If more mature flavours are desired, select a mature soft ripened cheese.

2. How do I ripen soft ripened cheese?

Ensure storage at 4°C in a refrigerator, and ensure cool air is circulating around the product, since the cheese generates its own heat as it matures.

Cut to check for ripening and if it is not ripened sufficiently cheese should be rewrapped in its silver foil packaging. The silver foil contains perforations, which allow the cheese to breathe and mature. It should not be wrapped in plastic film, as this does not allow the cheese to breathe properly, preventing proper cheese maturation.

C Semi-hard cheese and eye cheese

1. Can Cheddar cheese showing mould growth be used in food service or bakery applications?

Mould spots on cheese can contain harmful microorganisms and should not be consumed. Generally, if you see spots of green, blue or white mould on a Cheddar cheese block, the cheese may still be used, provided the mouldy part of the cheese is cut out of the block, and that the knife removing the mould from the cheese does not contaminate the good cheese with mould. The remaining cheese is then safe for consumption.

If the mould on the cheese is red, yellow or black or if the mould is white or brown in colour with hairy growth, the cheese is not safe for consumption and should be thrown out immediately.

To avoid mould growth on cheese, the cheese must be stored free from air by wrapping it in plastic film or placing it in an airtight container.

2. Can I use low fat cheese as a substitute for Cheddar in recipes?

The use of low-fat cheese in foods depends on the functionality required. Low fat cheeses are cheese products that contain no more than 3g of fat per serving and must contain a minimum of 25% less fat compared to their regular cheese counterpart. Low fat cheese contains a high moisture content, and, as such, requires lower cooking temperatures to achieve the same functional properties when used as an ingredient in food applications. Generally, low fat cheeses are more suitable for serving cold rather than for use in cooked dishes.

3. What is the best way to ensure cheese melts when used in food applications?

Some of the more common methods to ensure a good melt in cheese when using cheese as an ingredient in foods include:

- Shredding, grating or cutting the cheese into pieces before use.
- Adding cheese as a topping at the end of the baking process, giving it just enough time to melt over the surface of the food.
- When making cheese sauce, add the cheese at the end of the process, and continue to heat until it has just melted.
- For quick results, cheese may be softened in the microwave on medium to high power for a short period of time.

D Hard cheese

1. What form of Parmesan cheese is used in bakery and foodservice applications?

The physical form of Parmesan cheese used depends on the application. In baking applications, diced Parmesan is commonly used, whilst for non-baked applications, such as salads, a shaved or shredded Parmesan is preferred.

2. Why does parmesan retain its shape when heated?

Parmesan cheese has a higher protein content compared to many other cheese varieties; this causes it to melt slower and provides good shape retention in baked applications.

E Stretched curd cheese

1. How is the application of Mozzarella cheese in pizzas influenced by its maturation?

During storage at 4°C, Mozzarella undergoes characteristic changes in melt functionality. Following initial manufacture, Mozzarella melts to a tough, elastic consistency that is not suitable for pizza. During the first few weeks of ageing, however, the melted consistency of the product mellows substantially, and the cheese soon melts to a desirable, moderately elastic state. Upon further storage, the cheese becomes excessively soft and fluid when melted and is no longer suitable for use on a pizza. This is largely due to the breakdown of protein which is unable to hold the melting fat resulting in high oil release and poor stretchability. Under refrigerated conditions, Mozzarella has a relatively short shelf life and should be used shortly after the pack is opened.

2. Can cheese varieties be blended?

Cheese varieties can successfully be blended, and blends are commercially available to meet the specific applications. The most common use of blended cheese varieties is for pizzas, where Mozzarella is combined with other cheese varieties such as Cheddar, Parmesan, Gouda or Feta. Pizza blends require at least 50% Mozzarella in the final blend to ensure good stretching. A combination of Mozzarella with Cheddar provides a quick melt and a sharp flavour, while a combination of Mozzarella with Feta provides flavour development and contributes to browning.

3. Which cheese is best for colour development on a pizza?

In general, whole milk cheeses exhibit little or no browning, while part skim cheeses yield some browning during cooking. Hard cheeses such as Parmesan brown well, although they do not melt easily, therefore, it is best to place Parmesan under the Mozzarella on the pizza in order to prevent undesirable browning.

4. How should I evaluate oiling off for a pizza cheese blend?

The best way to evaluate for oiling off is to evaluate the blend on a pizza base containing just the tomato paste and the cheese, since meat ingredients used as pizza toppings, such as ham or salami, can also contribute to oiling off.

5. Can Mozzarella Cheese be frozen?

Mozzarella can be frozen; however freezing changes the texture of cheese, making it unsuitable for fresh applications, but is ideal for cooking.

To freeze, place mozzarella in an airtight, snap lock freezer bag. To use the cheese, thaw it slowly overnight in the fridge, and then use it as quickly as possible in. Frozen mozzarella should be thawed and used within 2 months of freezing.

F Processed cheese

1. What is the difference between processed cheese foods and processed cheese spreads?

Processed cheese foods are products that may contain dry milk, whey solids, or anhydrous milk fat added, which reduce the total amount of cheese in the finished product. Processed cheese foods must contain at least 51% of the cheese ingredient by weight, have a moisture content of less than 44%, and contain at least 23% milkfat.

Processed cheese spread is a product that may contain a sweetener and a stabilising agent, such as xanthan gum or carrageenan, to prevent separation of constituents. Processed cheese spread must be spreadable at 21°C, contain 44-60% moisture, and have at least 20% milkfat.

2. What is the shelf life of a processed cheese product?

The shelf life of processed cheese products varies, depending on how they have been manufactured. Processed cheese slices are cooled rapidly and thus have a shorter shelf life and require refrigerated storage. Block processed cheese is allowed to cool slowly over 24 hours. As it remains hot for several hours, it has a longer shelf life and is stored without refrigeration.

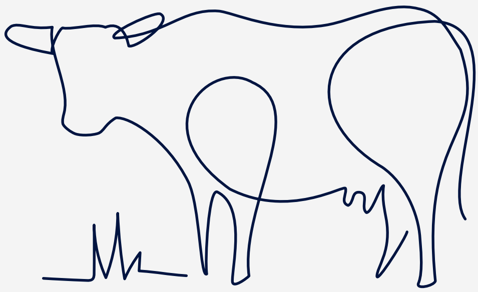
G Customised cheese products

1. What is the best way to store grated cheese?

Grated cheese contains a free-flowing agent that prevents clumping on storage and will prevent a grated cheese product from forming clumps if the cheese is kept for 3-4 days without refrigeration in a sealed container. If the opened bag of shredded cheese is not to be consumed within 3-4 days of opening, it can be frozen, and thawed later for use. This, however, will change the internal structure of the cheese and may compromise the texture of the product.

2. Will the storage of cheese powder affect its flavour and use in snack foods?

Like any perishable product, cheese powder will undergo changes if not stored under correct conditions. Exposure to air can cause deterioration in flavour due to oxidative rancidity, and colour deterioration can also occur due to non-enzymic Maillard reactions.



3. Is cheese safe for pregnant women to consume?

The only cheeses that are unsafe for pregnant women to consume are those with a high water content, such as cheese that has been aged for less than 8 weeks, like the soft cheeses, Camembert and Brie. The high water content of soft cheeses can promote the growth of harmful bacteria, such as Listeria, E.coli and Salmonella. Listeria has been found to contribute to complications in pregnant women, from infection to premature birth or miscarriages.

Other cheese varieties, such as Cheddar, Parmesan and Swiss cheeses are safe for consumption during pregnancy.

5b.6 Glossary

Body

Body refers to the structure of a cheese product. Terms used include weak, firm, soft, close and flaky.

Browning/blistering

Sensory attribute of cheese that occurs at the cheese surface during high temperature baking. It is characterised by the formation of a skin-like layer containing colour patches that may range from light or golden brown to black in extreme cases.

Curd

The soft rubbery solid produced when milk is coagulated.

Elasticity

Elasticity, also referred to as flow resistance or 'strength of the stretch', is the resistance to elongation of the fibrous strands as they are stretched, which in turn inhibits flow.

Eye

The round openings found in certain cheese caused by gas formation by introduced bacteria.

Flowability

Flowability of cheese refers to the ability of a cheese to flow on melting. Cheese with a high flowability, such as soft Cream Cheese, is desirable for use in cheese-filled meat applications such as a chicken cordon bleu, while a cheese with a low flowability, such as Haloumi, is more suited to fried applications, such as grilled Haloumi.

Free oil formation

Free oil formation, also known as 'oiling off' or 'fat leakage', is the separation of liquid fat from the melted cheese body into oil pockets, particularly at the cheese surface. Free oil formation can range from none to excessive largely dependent on age of the cheese and the ability of the protein to contain some of the oil released on application of heat during baking.

Individually Wrapped Slices (IWS)

Individually Wrapped Slices is a term used to describe processed cheese products that are sliced and individually wrapped for consumer convenience. The wrapping ensures extended shelf life, minimised wastage, and provides a hygienic barrier.

Maillard reaction

Maillard Browning is a heat induced reaction that occurs between proteins and sugars during the baking of cheese.

Meltability

The meltability of cheese refers to the ability of cheese particles to join to form a uniform continuous melt when heated.

Slice on Slice (SOS)

Slice on slice is a term that is used to describe cheese that is manufactured, and stacked in slices, without the use of individual wrapping. Slices are available in offset stacks for easy separation and are commonly used in food service applications.

Stretchability

Stretchability of cheese refers to the ability of melted cheese strands to form cohesive fibres, strings or sheets that elongate without breaking under tension. It may also be referred to as stringiness.

5b.8 References and further reading

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06 Butter and Milk Fat Products

Content

Abbreviations used in this chapter

AMF	Anhydrous milk fat
CLA	Conjugated Linoleic Acid
DAG	Diacylglycerol
FFA	Free Fatty Acid
FTV	Flavour Threshold Value
MAG	Monoacylglycerol
MFG	Milk Fat Globule
MFGM	Milk Fat Globule Membrane
MSNF	Milk Solids Non Fat
PV	Peroxide Value
SCFA	Short Chain Fatty Acids
SFC	Solid Fat Content
SFI	Solid Fat Index
SMP	Skim Milk Powder
SSHE	Scraped Surface Heat Exchanger
TAG	Triacylglycerol
UHT	Ultra Heat Treated

6.1 Introduction

Milk Fat products include butter, spreads, blends, anhydrous milk fat (AMF), butteroil, frozen cream and butter powder. These products are used as ingredients in a range of food applications such as bakery, confectionery, sauces and soups as well as in various recombining applications. Understanding the end use of milk fat is essential to enable customers to formulate and manufacture product that will match required composition, quality and functionality.

The processing of milk into milk fat products requires that the fat globules are separated out into cream, leaving behind the skimmed milk portion. The cream is then further processed into butter by churning and phase inverting the cream to form a bulk fat phase.

Milk fat products are manufactured to certain standards and specifications that define their chemical, physical and microbiological characteristics. Other specifications may relate to the functionality of a milk fat product related to a specific application. The quality and functionality of milk fat products can be influenced by various factors including handling, processing, storage and seasonality.

The milk fat product types discussed in this chapter include:

- **Butter**
  - The Codex Standard for Butter, CXS 279-1971 describes butter as 'a fatty product derived exclusively from milk and/or products obtained from milk, principally in the form of a water-in-oil type of emulsion'.
  - The standard states the composition of butter to be as follows:

Minimum milk fat content	80% m/m
Maximum water content	16% m/m
Maximum milk solids-not-fat content	2% m/m

- Butter can be divided into two main categories, sweet cream butter (standard butter) and cultured or sour cream butter. Cultured butter (also known as Danish butter) has a culture added to the cream before it is churned and is kept at a controlled temperature (usually overnight) until it develops a slightly acidic flavour. The modern and more cost-effective way to make cultured butter is to inject lactic acid and cultures into the butter granules after buttermilk has been removed. This method ensures that buttermilk is not acidic and is better value for the manufacturers. Salt is not usually added to cultured butter.
- Butter can also be further categorised according to salt content: unsalted, reduced salt, and salted.

Butter type	Salt level
Salted	1.6 – 2.0% salt
Reduced salt	0.8 – 1.0% salt
Unsalted	No salt added

- **Dairy blends** are a mixture of butter and up to 50% edible vegetable oils. This makes the mixture spreadable straight from the refrigerator, while keeping the taste of butter.
- **Milk fat blends**, where milk fat is blended with other ingredients to specification for a particular purpose. Milk fat blends may include milk fat blended with cocoa, sugar, oil, coconut oil, flour or other ingredients for use in bakery or confectionery products. This enables end users to save time and costs associated with ordering separate ingredient products as well as simplifying the manufacturing process.
- **Anhydrous Milk Fat (AMF)/Milk Fat Products** are defined in CODEX Standard CXS 280 – 1973 *Standard for Milk Fat Products* as: Anhydrous Milk Fat, Anhydrous Butter oil, Milk fat, Butteroil and Ghee as per Table 1 below.
- In this chapter the term 'AMF' will commonly be used to cover all the above products.
- AMF can be manufactured either from cream or from butter. Its manufacture from cream involves the concentration of milk fat to around 70-80% fat, phase inversion and finally oil concentration and moisture removal. Anhydrous milk fat is semi-solid at room temperature with a light yellow colour which melts to a bright yellow or golden coloured liquid on heating. Anhydrous milk fat has a clean and bland flavour which is free from foreign flavours and odours. This bland flavour makes AMF suitable for use in recombined products such as reconstituted milk.

This chapter considers the manufacture, specifications, functionality, applications and nutritional aspects as they relate to these milk fat products and then considers a range of frequently asked questions.

Table 1 Anhydrous Milk Fat, Anhydrous Butter oil, Milk fat, Butteroil and Ghee as defined in CODEX

Parameter	Anhydrous milk fat (AMF) Anhydrous butteroil	Milk fat	Butteroil	Ghee
Minimum milk fat (%m/m)	99.8	99.6	99.6	99.6
Maximum water (%m/m)	0.1	–	–	–
Maximum free fatty acids (%m/m as oleic acid)	0.3	0.4	0.4	0.4
Maximum peroxide value (milli-equivalents of oxygen/kg fat)	0.3	0.6	0.6	0.6
Taste and odour	Acceptable for market requirements after heating a sample to 40–45°C			
Texture	Smooth and fine granules to liquid, depending on temperature.			

6.2 overview of manufacturing principles

Butter

There are several stages involved in the manufacture of butter, with many factors influencing the functionality and quality of the butter at each stage. The basic steps in the butter making process are shown in Figure 1.

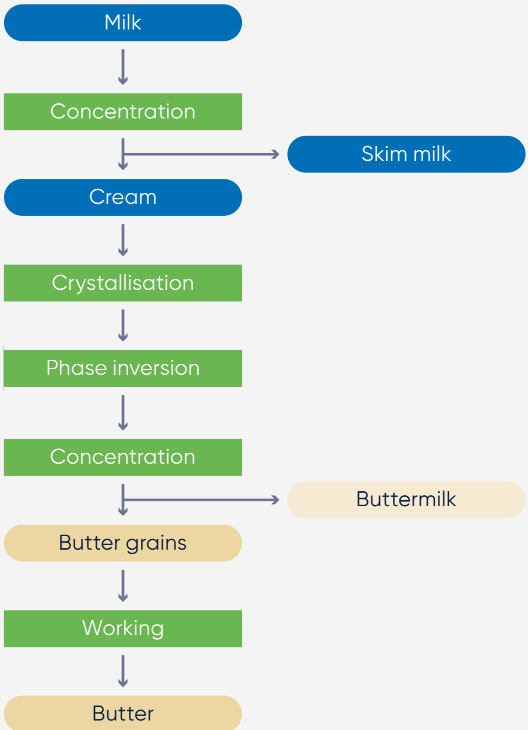
The first step is to concentrate the fat by separating the milk into cream and skim milk portions. The cream then goes through various treatments to prepare the fat for the churning step where phase inversion occurs.

Cream preparation involves pasteurisation, vacreation, cooling and ageing.

- **Pasteurisation** – In order to kill all the pathogenic and most of the spoilage microorganisms as well as inactivate lipolytic and proteolytic enzymes, the cream is pasteurised at 85-110°C for 10-30 seconds.
- **Vacreation** – The cream may be vacuum deodorised by exposure to vacuum to remove undesirable flavours or aromas.
- **Cooling** – The pasteurised cream is generally shock-cooled to 6–8°C to initiate fat crystallisation, although slow cooling may also be used.
- **Cream ageing** – The cream then undergoes a physical ripening stage to optimise the consistency of butter. The process lasts several hours at successive temperatures to control fat crystallisation in the fat globules. The heat treatments used for the cream will influence the final properties of the butter and relates to the fatty acid/triglyceride composition of the milk fat.
  - Cold-warm-cold ripening (hard fat)
  - Warm-cold-cold ripening (soft fat)

Once the cream is ripened in the ripening tank and the fat is in an appropriate state of crystallisation, it is ready for the churning stage. For Cultured Butter, lactic cultures are added to the cream ripening tank and incubated overnight to culture the cream to give a slightly lactic flavour as per the traditional process although the modern process does not involve ripening of cream.

Figure 1 Process steps for buttermaking



Churning – The churning process involves mechanical agitation of the cream at low temperatures which continues until the fat globules begin to destabilise and lose their protective membranes releasing liquid or 'free' fat. The fat released from the rupture of the globules begins to stick together or agglomerate and become visible as yellow 'grains' of butterfat. Eventually, partial phase separation and phase inversion occurs, and most of the aqueous phase is removed as buttermilk. Butter granules are then 'worked' and the remaining water is finely dispersed (water-in-oil emulsion) in the fat phase. Working the butter involves the kneading together of the grains, the squeezing out of further buttermilk, and the mixing and shearing of the resulting butter mass.

There are several types of continuous buttermaking machines available, with most following the principles of the Fritz method. A sectional view of a butter maker is shown in Figure 2. The prepared cream is first fed into a double-cooled churning cylinder (1) fitted with beaters that are driven with a variable speed motor. Rapid phase inversion takes place in the cylinder and, when finished, the butter grains and buttermilk pass on to a separation section (2), also called the first working section, where butter is separated from the buttermilk. As it leaves the separation section the butter passes through a conical channel and a perforated plate, into the squeeze-drying section (3), where any remaining buttermilk is removed. The butter grains then proceed to the second working section (4).

A more detailed view of the second working section, also known as a vacuum working section, is shown in Figure 3. Following the last working stage, salt may be added by a high-pressure injector in the injection chamber (5).

The vacuum working section (6) reduces the air content of the butter and is connected to a vacuum pump. The final working stage (7) is made up of four small sections, each of which is separated from the adjacent one by a perforated plate.

Perforations of different sizes and working impellers of different shapes are used to optimise the treatment of the butter. Moisture content is also regulated in this section through an injector. Transmitters (8) for moisture content, salt content, density and temperature can be fitted in the outlet from the machine. The signals from the instruments can be used for automatic control of these parameters. The finished butter is discharged from the end nozzle as a continuous ribbon into the butter silo for further transport to the packing machines.

Figure 2 A continuous butter making machine

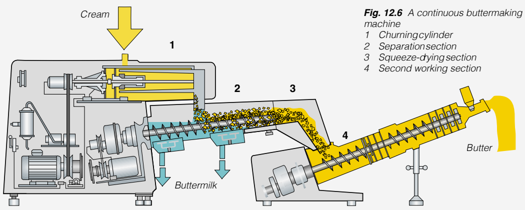


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Figure 3 The vacuum working section

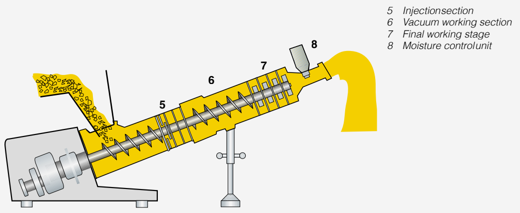

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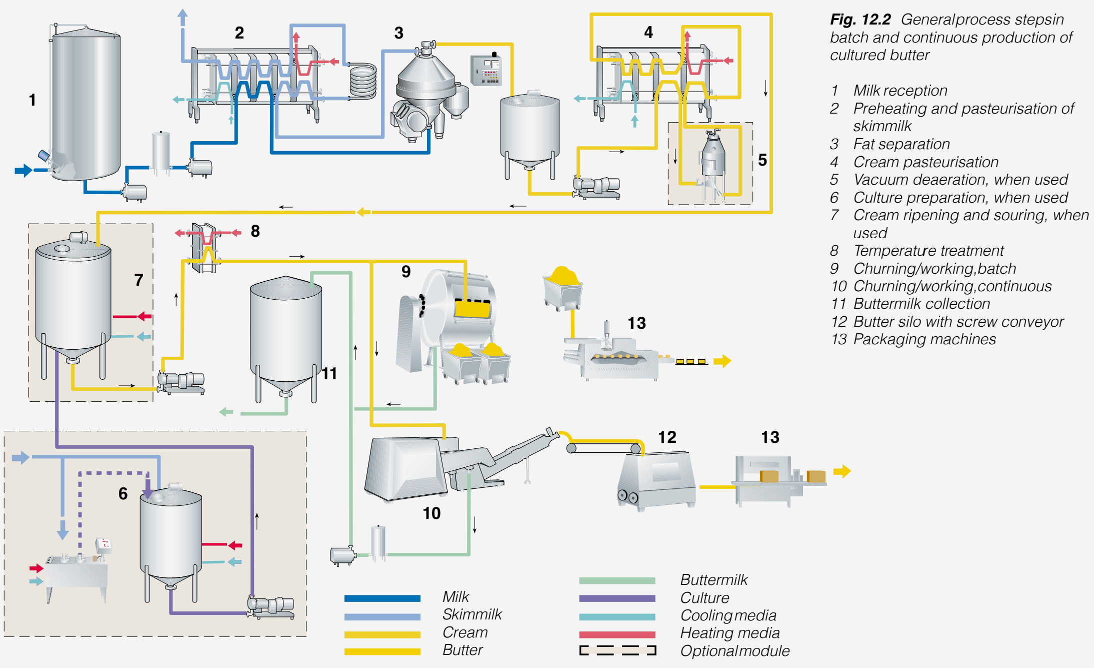
Figure 4 Process overview diagram for Butter manufacture



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Spreads and blends

There are many varieties of milk fat based spreads available, categorised mainly according to the total fat and milk fat content as shown in Table 2. Different manufacturing processes are used commercially depending on the starting materials.

Vegetable oil is added to the milk fat to improve the spreadability of the product at refrigeration temperatures. In some processes, the oil is added to the cream and blended prior to churning although this adversely impacts the quality of buttermilk and is not recommended.

Table 2 Categories of milk fat blends and spreads

Product	Fat content %	Milk fat as a proportion of total fat	Vegetable oil as a proportion of total fat
Butter	80	100%	–
Dairy blend	80	50% min	50% max
Reduced fat dairy spread	30–60	50% min	50% max
Low fat dairy spread	<30		

Dairy blends

Mixtures of butter and up to 50 per cent of edible vegetable oils help to make it spreadable from the refrigerator. Retaining the taste of butter, they are a dairy alternative to margarine.

Reduced fat dairy spreads

These products contain between 30 per cent and 60 per cent in total fat of which at least half must be milk fat. The remaining ingredients may include water, milk proteins, cultures, herbs, spices, gelatine, vitamins, sugar or salt. Gums and thickeners are used to replace the viscosity and bulking effect of the fat.

Low fat dairy spreads

This category of table spreads has a total fat and oil level below 30 per cent to which milk, vegetable proteins, flavourings, herbs, spices, vitamins, sugars, gelatines and starter cultures may be added. These spreads are not recommended for cooking due to their high moisture content.

Milk fat blends may also include customised blends of milk fat with a variety of other ingredients for particular applications such as cocoa, sugar, oil, flour or other specified ingredients.

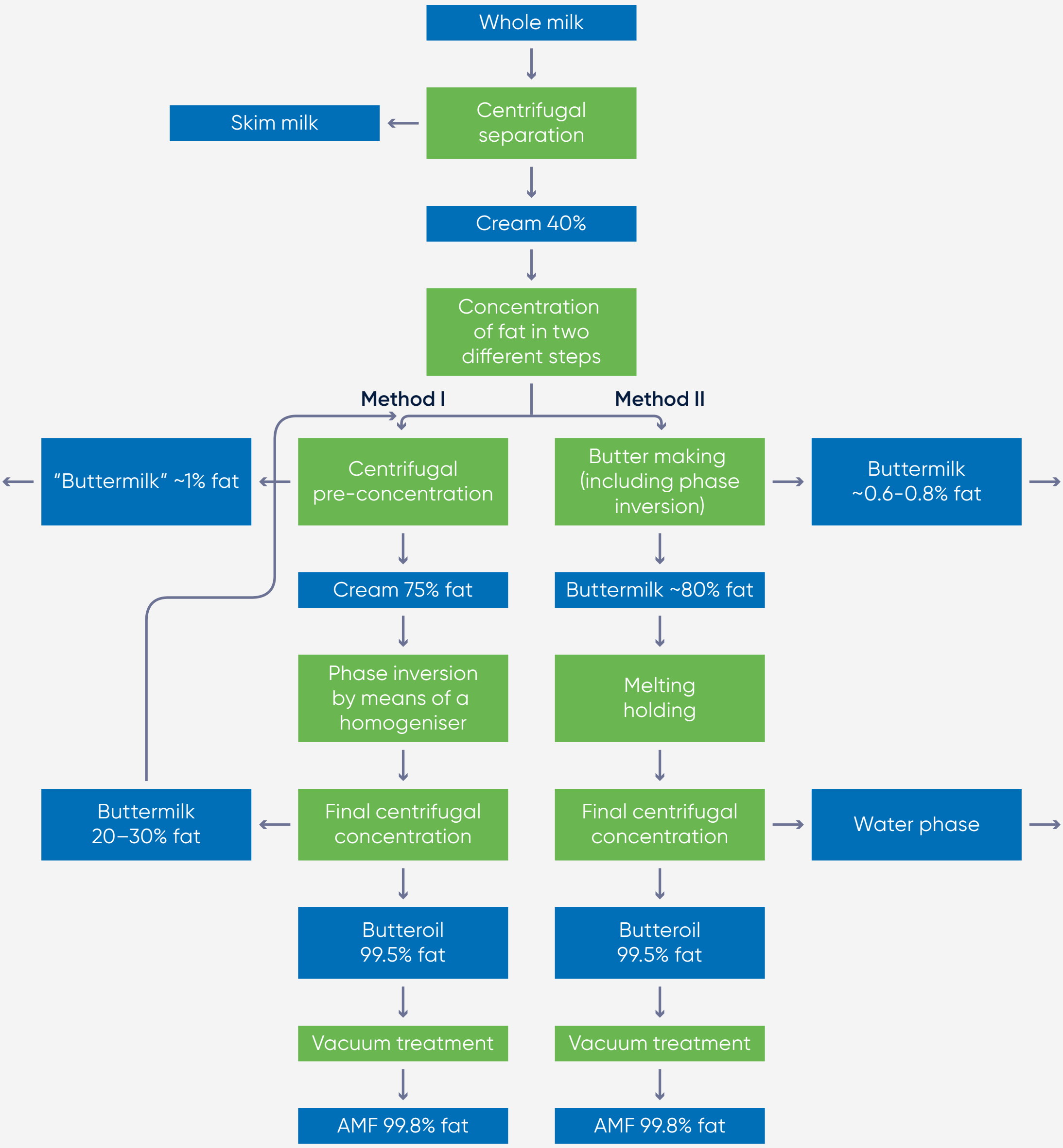
Anhydrous Milk Fat (AMF)

Anhydrous milk fat can be manufactured via two methods depending on the starting material. One method uses cream as the fat source, and the other uses stored butter as the fat source. In both cases, production starts with preconcentrating raw milk to a 35-40% cream, as for butter making. The cream is pasteurised and either churned or directly processed into butteroil. The flow-chart below in Figure 5 is typical for a plant for the manufacture of AMF from cream or butter.

AMF may also undergo additional refining processes for various purposes including:

- **Polishing** – involves washing of the oil with hot water to obtain a clear, shiny product.
- **Neutralisation** – to reduce the level of free fatty acids (FFA) in the oil.
- **Vacuum dehydration** – vacuum drying at about 90°C to further reduce moisture and remove some of the more volatile flavour compounds.

Figure 5 AMF Process Flow Chart



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6.3 Milk fat functionality

Chemistry of milk fat

Milk is a complex food and there are many factors that can affect its composition. The level of milk fat in milk is around 3.9-4.0% and exists in the milk as an emulsion of small milk fat globules dispersed in the milk serum.

The milk fat globules are stabilised by a milk fat globule membrane (MFGM), which surrounds the fat globules, protecting the fat from attack by lipase enzymes and keeping the fat suspended in the milk. The fat globules range in size from 0.5 to 5mm in diameter and there are some 15 billion globules per ml of milk.

Triacylglycerols form the major component of milk fat, while diacylglycerols, monoacylglycerols, phospholipids, fatty acids, sterols, carotenoids, vitamins and trace elements form the minor components of milk fat.

An example of the structure of a triacylglycerol is given below in Figure 7, where fatty acids are attached to a glycerol backbone in three positions. Fatty acids can differ in the length of the carbon chain and the degree of saturation. The type and amount of the individual fatty acids making up the triacylglycerols determines the physical properties of the milk fat. The shorter the carbon chain and the more unsaturated the fatty acids, the lower is the melting point. Therefore, softer fats have a higher level of unsaturation of fatty acids.

The fatty acid composition of milk fat is quite diverse and includes a high level of short-chain fatty acids from butyric (C4) to capric (C10) acids.

Table 2 shows a typical fatty acid composition in milk fat. This fatty acid composition can vary throughout the year, leading to variation in the triacylglycerol composition and therefore physical properties.

Figure 6 Milk fat globule schematic

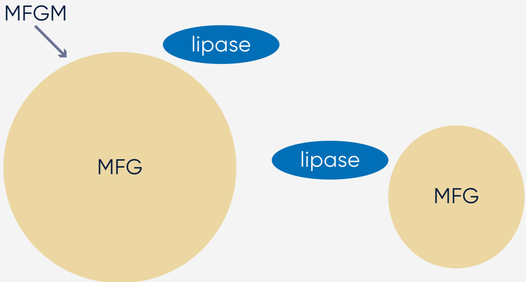


Figure 7 Triacylglycerol schematic

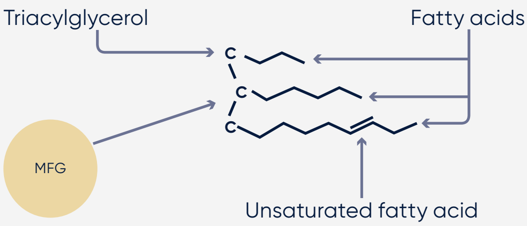


Table 3 Fatty acid composition of milk fat

Carbon number	Common Name	Melting point (°C)	Type	Typical Composition (% w/w)
4:0	Butyric	–8	short chain, saturated	3.9
6:0	Caproic	–4	short chain, saturated	2.5
8:0	Caprylic	17	short chain, saturated	1.5
10:0	Capric	32	medium chain, saturated	3.2
12:0	Lauric	44	medium chain, saturated	3.6
14:0	Myristic	54	long chain, saturated	11.1
16:0	Palmitic	63	long chain, saturated	27.9
18:0	Stearic	70	long chain, saturated	12.2
18:1	Oleic	16	long chain, unsaturated	21.1
18:2	Linoleic	–5	long chain, unsaturated	1.4
18:3	Linolenic	–10	long chain, unsaturated	1.0
Others				10.6

Physical properties of milk fat

Milk fat is one of the most complex fats, made up of a wide variety of triacylglycerols. Milk fat is liquid above 40°C and usually completely solid below –40°C. At intermediate temperatures, such as room temperature, it is a mixture of crystals and oil, the oil usually being the continuous phase. The state of crystallisation affects many properties, for example:

- the susceptibility of globules to churning or clumping.
- the resistance of the globules to disruption.
- consistency and mouthfeel of high fat products.
- and in some conditions, the creaming rate.

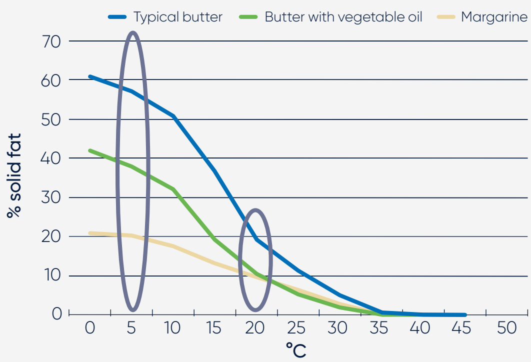
Melting range

Pure compounds have a sharp and constant melting point, but mixtures of many components like milk fat have a long and variable melting range, because of the large differences in melting point of the many component triacylglycerols.

The melting properties of fats can be examined by a solid fat content (SFC) analysis, where the proportion of fat in the solid state is measured over a range of temperatures. Examples of typical solid fat content diagrams are given for comparison in Figure 8 for butter, a blend of butter with vegetable oil and margarine.

As shown in Figure 8, although at room temperature (20°C) the three samples have similar % solid fat contents, at refrigeration temperatures (5°C), the % solid fat contents are quite different and reflect the relative spreadability of the three products. This is an example of the behaviour of milk fat in the bulk fat phase, however the behaviour of milk fat in the globular form, as in cream, will be different.

Figure 8 Solid fat content diagrams for butter, a butter blend and margarine



Iodine value

The iodine value is an indicator of the hardness or softness of the milk fat. The iodine value states the percentage of iodine that the fat can bind. Iodine is taken up by the double bonds of the unsaturated fatty acids. Since oleic acid is by far the most abundant of the unsaturated fatty acids, which are liquid at room temperature, the iodine value is largely a measure of the oleic acid content and thereby the softness of the fat.

The iodine value of butterfat normally varies between 24 and 46. The lower the iodine value, the 'harder' the milk fat. For butter of optimum consistency, the iodine value should be between 32 and 37.

Butter functionality

Flavour

Flavour is one of the most critical attributes of milk fat, and the likely effect of processing and handling on the flavour needs to be carefully considered. Many compounds which are below their individual flavour thresholds, contribute to the overall balance or profile perceived.

Flavour is a complex sensation arising from both the aroma and the taste. The aroma comprises compounds which are sufficiently volatile at body temperature to reach the nasal receptors, while taste attributes, such as sour and bitter, are usually attributed to more water-soluble compounds detected on the palate. The perceived flavour is influenced not only by the volatility of the various components, but also by the rate of release from the food. A complex emulsion such as butter, which contains both water and fat constituents, can vary in flavour depending on the melting properties of the fat, as well as on the distribution of the aqueous phase within the fat matrix.

Numerous factors play a role in the development of butter flavour, including the diet and breed of the cows, and the season and stage of lactation. In addition, more than 120 flavour compounds have been identified in butter. It is not completely understood to what degree or how all the flavour compounds in butter interact. However, there is general agreement that primary flavour compounds such as free fatty acids, methyl ketones, lactones and dimethyl sulphide are the principal flavour components in butter.

Fatty acids – Flavourful fatty acids play an important role in the flavour of butter and are present in various concentrations. Although long-chain fatty acids are present at higher concentrations in butter, they do not make a significant contribution to flavour. Short-chain fatty acids (SCFA), on the other hand, do play an important role in flavour of butter.

Typically, SCFA are found in the serum portion of butter (aqueous solution of all non-fat components) where their flavour potential is stronger. They occur below their Flavour Threshold Value (FTV): the minimum concentration level below which aroma or taste is not detected. Despite low concentrations, SCFA act together to provide characteristic flavours found in butter. Butyric acid is the most widely known and most potent SCFA and is attributed to providing intensity to fatty acid-type flavours associated with butter. Butter also contains a variety of fatty acid precursors, such as 4-cis-heptenal, a compound which provides butter with a creamy flavour.

However, high levels of free fatty acids (released from the triglycerides by a lipolysis reaction) are undesirable in milk fat products, firstly because the SCFA's can contribute to an off flavour typified by butyric acid and secondly because they can catalyse the oxidation reaction.

Lactones – In fresh butter, precursors to lactones and free lactones exist in small concentrations. Free lactones exist in the lipid phase of butter, where they have higher threshold values. Despite their low concentration in fresh butter, free lactones are important flavour compounds, which act in an additive manner to impart the perceptible sweet and fruity flavours characteristic of butter. Upon heating, the lactone precursors are converted to lactones and their total concentration rises above their FTV. Thus, they provide the rich flavour notes commonly associated with heated foods containing butterfat. Lactones in butter are also the major source of flavour in confections and high-quality candies where they provide the unique, pleasurable flavours associated with these products.

Methyl ketones – Methyl ketones exist in their precursor form in fresh butter as alkanoic acids. As such, they may be only marginally important in contributing to the flavour of fresh butter. However, when heated, the precursors are converted to methyl ketones and their total concentration rises above their FTV. Thus, they are very important in providing flavours associated with heated or cooked foods containing butter. Diacetyl is another ketone flavourant and is very important in providing the rich or heated note in butter flavour. Diacetyl is also the primary flavour compound in starter cultures and distillates which are used in producing cultured butter.

Dimethyl sulfide – Dimethyl sulfide is originally derived from the feed of cows and occurs in butter at concentrations above its FTV. Dimethyl sulfide helps to smooth the harsher flavour notes of diacetyl and other acidic substances in butter and is also largely responsible for the freshly cooked note associated with freshly churned butter.

Flavour of cultured butter

Cultured butter differs in flavour from sweet cream butter. Cultured butter has a more pronounced, distinct flavour which stems from starter cultures that are added to the cream during churning. Starter cultures are typically mixtures of flavour concentrates produced by one strain or mixed strains of bacterial cultures. *Streptococcus diacetilactis* produces diacetyl, the flavour most associated with flavoured butter and *Streptococcus lactis* is used to produce lactic acid, which contributes to the acidic flavour typically associated with cultured butter. Most commercial cultured butter is manufactured using the method of Indirect Biological Acidification (IBA) where the addition of culture/flavour concentrates and lactic acid occurs after the churning process. The major advantage of adding the lactic acid and the culture/flavour after the churning process is that the buttermilk produced is sweet and can be used to make butter milk powder. Cultured butter has a lower pH (4.4-5.6) compared to sweet cream butter (pH 6.0).

Functional properties

Colour and appearance – The natural yellow colour of butter, in combination with its smooth, slightly matt surface appearance, gives a particular impression of richness. A 'faultless' butter cuts cleanly when sliced and does not appear greasy or shiny. The yellow colour mainly results from β-carotene (provitamin A) which, dissolved in butterfat, originates from green plant nutrients in fresh or silaged feed. Lush spring pasture produces the highest levels of carotene in the milk fat, but these levels fall as pastures mature in summer and rise again in autumn. Lower milk fat carotene levels result from dried feeds such as hay, grain and other feed concentrates. Milk fat from pasture fed cows is thus more yellow than from grain fed cows, and varies throughout the season.

Texture and mouthfeel – The texture of butter is largely due to the specific melting properties of the butterfat. Butter undergoes a rapid meltdown in the mouth, is readily converted to an oil-in-water emulsion, releasing volatile and water soluble flavours. The heat required for melting the fat is drawn from the mouth resulting in a cooling sensation.

Setting and work softening – Freshly produced butter increases in firmness on storage at a fast rate initially and then more slowly over time. This process, called setting, can be attributed to a reversible build up of network structure. Reworking of butter where the crystal network is broken down by mechanical working, results in the butter becoming soft again.

Spreadability – One of the main disadvantages of butter is its poor spreadability at refrigeration temperature. Butter is a mixture of solid and liquid fats at most handling temperatures. Spreadability begins to become acceptable below solid fat levels of 45%. To obtain optimum spreadability, the butter must be allowed to soften at room temperature.

There are many factors that can influence the spreadability of butter including:

- *Seasonal diet and lactation stage* – This can lead to variation in the fatty acid and triacylglycerol composition of the milk fat, altering the ratio of solid and liquid fat at temperatures.
- *Physical cream ripening* – by special temperature treatments of the cream prior to churning the fat, changes to the resulting butter properties are possible which relate to controlling the microstructure of butter in terms of the spatial arrangement of solid and liquid fat, the size, number and shape of fat crystals and the overall ratio of solid to liquid fat.
- *Work softening* – Butter that has been stored can be mechanically reworked to break down the crystal network that has built up and results in a softer butter.

Other approaches to improve the spreadability of butter including whipping, blending and fractionation.

Measurement of textural properties

Many techniques measure the textural properties of butter, with butter hardness using a cone penetrometer being the most widely reported. Typically, hardness is determined by placing a cone on the surface of a butter sample and measuring the force required to depress the butter a certain distance.

6.4 Quality of milk fat products

Milk fat quality

Milk fat products are manufactured to certain standards and specifications that define their chemical, physical and microbiological characteristics. Example specifications for several milk fat products are given in Table 4. Other specifications may relate to the functionality of a milk fat product related to a specific application. The quality and functionality of milk fat products can be influenced by various factors including handling, processing, storage and seasonality.

Food manufacturers using butter must also work carefully to ensure that the maximum flavour potential of the ingredient is maintained. Butter should be stored in dry, tightly sealed, poly-lined cartons, away from highly aromatic food. Storage rooms should have controlled humidity of 80–85 percent. Butter stored under refrigeration can be kept for up to four months at 0–3°C and for up to one year at –23 to 29°C.

There are several reactions involving milk fat that are detrimental to the flavour and functionality of the milk product. Milk fat can undergo hydrolytic (lipolysis) and oxidative (oxidation) rancidity.

Lipolysis is the breakdown of fat into glycerol and free fatty acids catalysed by lipase enzymes. The development of free fatty acids and in particular, short chain free fatty acids can lead to off flavour development. Flavour defects are often called rancid, astringent, bitter, butyric and lipolytic. However this can only occur if the milk fat globules have been damaged, exposing the fat as shown in Figure 9.

Figure 9 Lipolysis schematic

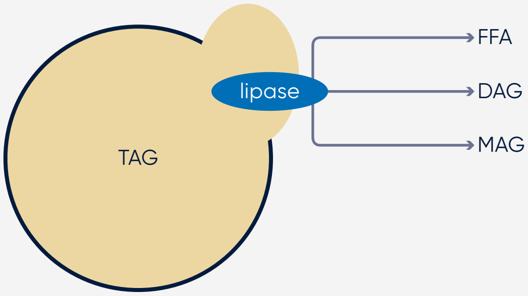


Table 4 Example specifications for milk fat products

	Butter	Unsalted Butter	AMF
Chemical and physical specifications			
Fat (%)	80.0 min	82.0 min	99.8 min
Moisture (%)	16.0 max	16.0 max	0.1 max
Salt (%)	1.4–2.0		–
Flavour and odour	Satisfactory	Satisfactory	Satisfactory
Appearance and colour	Satisfactory	Satisfactory	Satisfactory
Peroxide value (meq.O_2/kg)			0.1 max Up to 0.6 max for Butteroil and Ghee
Free fatty acids (%)			0.3 max Up to 0.4 max for Butteroil and Ghee
Microbiological specifications			
Standard plate count Cfu/g	20 000 max	20 000 max	<1000
Yeasts and moulds			<50/g

The native lipase enzymes naturally present in the milk are inactivated during pasteurisation. Contaminating psychrotrophic bacteria can also produce heat-stable lipases (microbial lipases) that are active after pasteurisation, even though the bacteria have been destroyed. It is the heat-stable lipase that can continue to act during storage, producing off flavours over time.

Treatments that damage MFGM and induce lipolysis include agitation, temperature fluctuations, homogenisation and foaming or air incorporation. Care must be taken during processing to minimise the effects of these treatments.

Spontaneous lipolysis usually occurs on farm and is initiated by cooling to less than 10°C. This type is typically associated with cow factors and can be inhibited by the mixing of spontaneous and 'normal' milks.

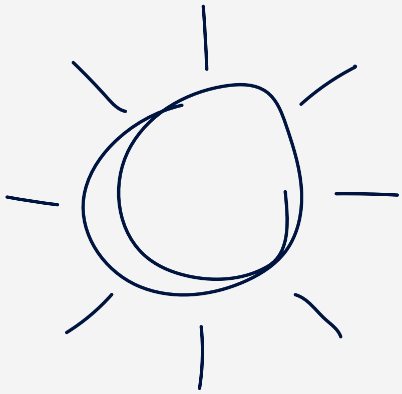
Lipolysis can be detected by different methods based on chemical or sensory (taste, smell) properties. The by-products of lipolysis can be analysed, particularly free fatty acids, which can be measured through titration. The amount of 'free fat', that is the amount of fat not contained in fat globules, can be measured as an indicator of the degree of damage to the MFGM and therefore the percentage of fat available for attack by lipase. 'Lipolyzed' flavours might also be detected by sensory grading to determine the acceptability of a product.

High microbial count in the raw milk may also indicate that the milk is contaminated and will be prone to lipolysis through the lipases produced from the contaminating bacteria. High microbial counts are usually accompanied by high free fatty acid levels.

Oxidation is the reaction between oxygen and the unsaturated fatty acids in the triacylglycerols. The oxidation reaction requires the presence of oxygen and is catalysed by light, heavy metals such as copper and iron, and by certain reaction products. It results in a metallic off flavour and gives butter an oily and tallowy taste. Lipolysis can promote oxidation, as it occurs more readily in free fatty acids than those attached to a triglyceride molecule.

The reaction begins when an energetic form of oxygen (singlet oxygen) attaches to an unsaturated fatty acid adjacent to a double bond. The resulting intermediate hydroperoxide is stabilised by the presence of additional double bonds, so that the reaction rate of linoleic acid may be of the order of 20 times that of oleic acid. The hydroperoxide is detected by the peroxide value (PV) test and has no flavour but rapidly decays through a variety of pathways to form highly flavoured compounds such as unsaturated aldehydes, ketones and fatty acids.

The inhibition of oxidation at low temperature is assisted by the fact that, during crystallisation, milk fat eliminates oxygen from the crystal structure. This factor, together with the reduction in oxidation rate with temperature, may partly explain why products stored frozen, such as butter and cartoned AMF, have better flavour than AMF stored at ambient temperature for the same time.



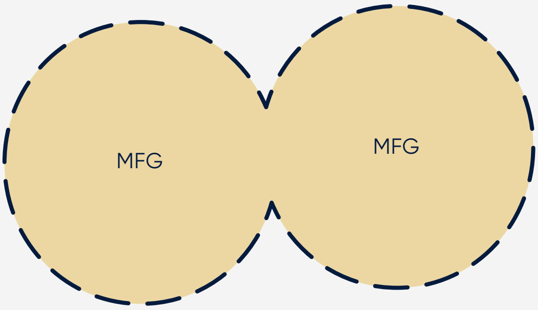
Assessment of milk fat quality

The main tests used to assess milk fat quality are the peroxide value (PV) and free fat acidity (FFA). The PV test is used as a measure of how far the milk fat has deteriorated because of oxidation, whereas the FFA test is used to determine the extent of lipolytic deterioration. The International Dairy Federation (IDF, 1977) standard for anhydrous milk fat provides for a maximum PV of 0.2mEquiv/kg and a maximum FFA of 0.3% as oleic acid. The results of these tests give some indication both of the probable flavour quality, and also how rapidly further deterioration may be expected to occur.

Cream

There are many factors that influence the quality of the cream during processing and on storage. Damage to the MFGM can result in the fat being released from the globule and forming free fat. Several damaged milk fat globules can also stick together resulting in aggregation or clustering of the fat globules as shown in Figure 8.

Figure 10 Milk fat globules agglomerating



The freezing of cream in bulk containers increases its shelf life greatly but can also lead to gross separation of fat and serum solids upon thawing. Cream processed in this manner is suitable for reprocessing into cream soups, recombined milk, butter or ice cream, where pasteurisation and homogenisation will restore the original fat emulsion. Frozen cream can also be used in applications where the retention of the cream emulsion is important for functional properties, such as whipped toppings.

Butter grading and defects

Butter can be graded using a points system to assess its quality. The maximum points allocated when grading butter is 100 with the flavour of the product accounting for 50 of the 100 points. For body and texture, the allocation is maximum 30 points, and maximum 20 points for colour and appearance. Based on the total points, butter can be classified into categories of Choicest (>93 points), first grade, second grade and pastry.

Trained graders can identify defects in the butter. As with other products, points are deducted if defects in the flavour, body, texture, condition and colour are noticed. The intensity of the defect also dictates number of points deducted. Some common butter defects are outlined in Table 5.

Table 5 Common butter defects

Defect	Possible cause/s
Flavour	
Tallowy, rancid	Oxidation of the fat, especially due to air incorporation
Soapy	Contamination with cleaning agent residues
Rancid, old	Enzymatic fat decomposition, improper and too long storage of butter
Empty, bland	Insufficient flavour development
Texture	
Open (holes)	Insufficient working, temperature of butter at working is too high and the butter is too soft.
Free moisture	Insufficient working or incorrect churning temperature
Leaky butter (moist, open)	Churning at too high a temperature
Colour	
Mottled colour	Improper salt incorporation
Streaky, marbled	Uneven salt distribution, uneven working, blending of different butters

6.5 Applications of butter and milk fat ingredients

Please note that the example recipes provided are available from the Dairy Australia website: **legendairy.com.au**

Non-dairy applications

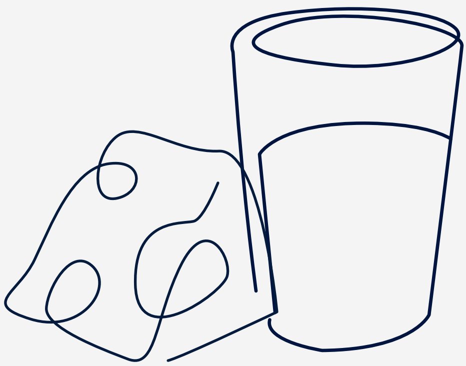
Butter is an important ingredient in a range of non-dairy applications, primarily for its unique pleasant flavour.

Bakery

Butter and various tailor-made milk fat products are important ingredients for great tasting bakery products. The role of fat in bakery products depends on the specific individual use. Not only do milk fat products help to impart the characteristic flavour to fresh baked goods, but they also help in maintaining crumb softness, aid in the development of flaky crusts and pastries and provide significant nutritional value. Several examples and typical levels of milk fat used in bakery products are shown in Table 6.

Flavour

Milk fat and butter are used for many reasons in baked goods, but one of the primary reasons is for flavour. Butter is used to add a rich, unique flavour to pastries, cakes, biscuits, pies and breads. Milk fat and butter can also act as a flavour carrier for fat-soluble ingredients, spices, herbs and sweet flavours.



Although there are over 120 different compounds that contribute to butter's unique flavour, the five primary factors responsible for butter's flavour include: fatty acids, lactones, methyl ketones, diacetyl and dimethyl sulfide. Methyl ketones and lactones are the primary components responsible for the cooked flavour associated with baked goods made with butter. Both methyl ketones and lactones are present in fresh butter at levels which are below their Flavour Threshold Value (FTV) or below the concentration at which their taste is perceptible. Upon heating, however, the total concentration of both lactones and methyl ketones exceeds their FTV. The two compounds also react in a synergistic manner, providing the rich flavour associated with baked goods made with real butter. The methyl ketones and lactones also interact with the flavours developed through the Maillard reactions (browning reactions between sugars and proteins) which occur during baking. The combination of all flavour compounds contributes to the overall appeal and flavour of the finished baked good.

Functional properties

Milk fat and butter provide various functional properties to different bakery products.

Pastry

Butter is the ideal ingredient for the development of a flaky crust or pastry dough. For pastry doughs, butter should be kept as hard and cold as possible so that the fat remains solid and separates the layers of dough with a well-developed gluten network. When butter is trapped between layers of dough, it melts during baking, making the batter slightly more fluid or flexible.

Carbon dioxide, which is released during baking, travels more easily to the air pockets left by the butter. The air pockets trap the carbon dioxide, and the resulting dough is flaky.

For puff pastries, a near-waxy consistency of the layering fat is required. To make puff pastry, cold butter is mixed into the flour to form a short consistency. The dough is then rolled around a thick slab of butter under a series of folding, turning and rolling steps until the butter is dispersed throughout the dough. The final dough contains hundreds of these dough layers separated by butter films. Butter causes the pastry to rise. When pastry is heated, the butter melts and boils, creating steam which lifts each dough layer higher and higher during baking. Butter also contributes to flavour and colour development within the pastry during baking.

Example: Apple Tarte Tatin (short crust pastry)

Chilled butter is blended with other ingredients in a food processor under high speeds until a dough is formed. Dough is baked at 200°C for 20-25 minutes until golden.

Butter is added chilled so that when baked, it combines with the other ingredients to form a well-developed structure. As the fat melts during cooking, butter acts as a binding agent, while the cooking also promotes the release of buttery flavour notes. Butter also contributes to the golden appearance of baked pastry products.

Cake

In cake batter, butter should be thawed prior to use and creamed well with the sugars to dissolve sugar crystals, incorporate air and ensure a complete, even distribution in the final batter. In most other bakery applications, butter can be added either in its solid or melted form.

Butter helps to improve crumb softness by retarding the development of gluten, coating the strands, making them shorter and hence keeping the product tender. As a result, butter contributes to the tenderness of cakes, breads and biscuits.

Example: Lemon Blueberry Cupcakes with Fluffy Lemon Frosting

Butter accounts for 14% of the total cake formulation, and is beaten with the sugar and baked at 180°C for 15–20 minutes.

The high butterfat content of butter contributes to the air bubbles incorporated within the cake batter. Lots of air bubbles in the fat ensure maximum aeration, which creates a cake batter with good volume and a soft crumb. Butter provides tenderness and flavour to the batter, as well as contributing to batter volume.

Biscuits

Butter also functions as an emulsifier, resulting in better distribution of the ingredients throughout the dough, and helping to prevent "fat bloom" spoilage in biscuits.

Milk fat and butter also add to the visual appeal of bakery products by contributing a golden yellow colour.

Example: Caramel Yo-Yo Biscuits

Butter accounts for 25% of the total biscuit formulation.

Butter is creamed with sugar and is baked at 190°C for 12–15 minutes.

Example: Basic Butter Shortbread

Butter accounts for 20% of the total biscuit formulation.

The butter is beaten together with the sugar until the two have creamed. The product is baked at 160°C for 12–15 minutes.

In both of the above cases, butter provides a fat surface that coats all the other biscuit ingredients, assists in the binding of ingredients, and contributes to the rich buttery flavour of the biscuits

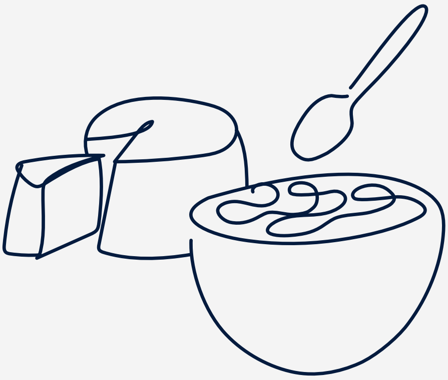


Table 6 Use of milk fat in bakery

Bakery product	Milk fat product	Typical usage levels (%)
Milk enriched bread	Butter	2
Scones	Butter	7–8
Pastry		
Sweet short crust	Butter	30
Short crust	Butter	21
Danish	Butter	23
Puff	Butter	30–34
Croissants	Butter	44
Cakes		
Madeira	Butter	20
Butter sponge	Butter	7–8
Biscuits		
Sweet biscuit	Butter	20–30
Shortbread	Butter	20–33

Confectionery

Many confections are made with butter and milk fat products, as they provide unique flavour and mouthfeel. The role of fat in confectionery products depends on the specific individual use. Several examples and typical levels of milk fat used in confectionery products are given in Table 7.

Flavour

As in bakery products, butter's flavour is important and confections which use butter typically require heating to bring out the full flavour and create a rich, buttery taste. Butter also interacts with flavour components which result from Maillard reactions (browning reactions between sugars and proteins), creating flavour notes traditionally associated with caramels, pralines, and toffee. Most sources agree that a good quality caramel must be made using condensed milk and butter.

Butter can also function as a flavour carrying agent for other ingredients, including vanilla and sweet spices. Food manufacturers producing confections with cream centres can use butter to produce a myriad of new flavours while maintaining the desired texture of the filling.

Functional properties

Butter contains 0.24 percent lecithin, a natural emulsifier. Although naturally present in small quantities, it performs a variety of important functions in confectionery products. The lecithin in butter aids in the emulsification of fat and aqueous products which would otherwise not mix thoroughly. This is important for the mouthfeel and it improves the overall product stability. In addition, emulsification aids in moisture control, thereby helping to extend the shelf life of many confectionery products.

The lecithin in butter is particularly important in helping to prevent stickiness in high sugar solutions, especially with products like caramels and toffee. Butter thus aids in simplifying the production of confections which otherwise might be difficult to handle.

Butter characteristically has a sharp Solid Fat Index (SFI) curve which stems from butter's narrow melting range (28–36°C). The sharp SFI curve of butter at these temperatures ensures quick flavour release and complete melting of butter at body temperatures, for a "melt-away" effect. This aids in smooth mouthfeel, which adds to the eating qualities and is of particular importance in confectionery products. Confections made with oils which have broader SFI curve at these temperatures tend to have a waxy mouthfeel and do not offer pleasant chewing characteristics. In addition, they have poor flavour release as compared to confections made with butter.

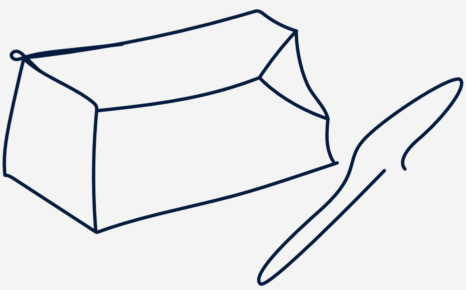
Example: Chocolate Fudge Squares

Butter accounts for approximately 8% of a total fudge formulation. The butter is melted on low heat in a saucepan with sugar-based ingredients until smooth. Butter contributes to a rich, buttery flavour and is added at the final stages to provide smoothness and inhibit large crystal formation.

Chocolate

Milk fat contributes to the flavour and smooth texture of chocolate. One of the most important functional properties of milk fat is its ability to form part of the continuous fat phase because of its compatibility with cocoa butter. Milk fat can be used to replace a portion of cocoa butter in many confectionery formulations to reduce costs

Anhydrous milk fat can be added with skim milk powder as a replacement for the combined protein/fat source of full cream milk powder. The advantage of the SMP/AMF combination is that 100% of the fat is available as free fat. This may reduce the viscosity of the chocolate and therefore reduce the quantity of cocoa butter required in the formulation to obtain a specific viscosity.



The use of milk fat in chocolate may provide a creamy flavour and a softer texture in milk chocolate when compared to dark chocolate. Milk fat can be added in very small quantities to dark chocolate to prevent 'fat bloom' and ensure the product remains visually appealing to the consumer.

Table 7 Use of milk fat in confectionery

Confectionery product	Milk fat product	Typical usage levels (%)
Milk chocolate	AMF	5–7
Caramel	AMF	2–3 (softer, lighter caramel)
	AMF	5–8 (harder, darker caramel)
Fudge	Butter	2–3 (soft ball)
	Butter	5–8 (hard ball)

Sauces

Milk fat and butter have many functional advantages when used as an ingredient in sauces. Not only does butter provide a unique, rich flavour, but it contributes to the smooth, creamy mouthfeel of sauces as well. Butter works well with sweet and savoury sauces, and is an important ingredient in dessert toppings, such as butterscotch. Several examples and typical levels of milk fat used in sauces are summarised in Table 8.

Flavour

Butter is used most often in sauce applications for its unique, delicious flavour. Butter flavour compounds not only react with one another, but with other flavour compounds as well, providing a full-bodied flavour. Butter can be used to provide the primary, characteristic flavour of a sauce, as in Bechamel-type sauces, or in dessert toppings, such as butterscotch. It can also be blended with other ingredients to add rich dairy background flavour notes, as in pasta sauces and gravies.

Butter can be heated to different temperatures to produce characteristic flavour notes associated with different sauces. For example, lightly melted butter is typically used in creamy, white sauces, such as Hollandaise, Bordelaise or Bearnaise, to provide rich dairy notes. Slightly overheated butter provides roasted, cooked notes which complement brown sauces and gravies.

Overheated, unburned butter will contribute flavour notes which complement flavours in barbecue and smoke flavoured sauces.

Functional properties

Mouthfeel and flavour are two of the most important characteristics of a sauce. Butter also provides a smooth, creamy consistency to sauces, which can be attributed to the mixture of nonfat milk solids and fatty acids naturally present in butter. The nonfat milk solids provide butter with body and mouthfeel, which are then transmitted into the final sauce.

Butter is unique in that it can also solubilise other flavours to create full-bodied condiments and uniquely flavoured butters. Butter can solubilise sweet spices and vanilla for sweet sauces and toppings, and herbs and spices for savoury applications, for added flavour. Butter's ability to function as a flavour carrying agent has led to the development of numerous types of flavoured butters which include, among others, dill, garlic and fennel. Manufacturers can create a wide variety of products simply by flavouring the butter itself or using the butter to solubilise other flavours.

Butter aids in the even distribution of oil-soluble flavours throughout sauces and soups. Butter can sometimes be used as the sole emulsifier in sauces. Its narrow melting range ensures quick flavour release and complete melting of butter at body temperatures for a "melt-away" effect, which aids in smooth mouthfeel.

Butter contributes a visually appealing golden colour, or a darker colour after heat treatment, to sauces and soups.

Example: Bechamel Sauce

Butter accounts for ~7% of the total Béchamel sauce formulation. Butter is melted in a saucepan, and the flour is stirred in to the melted butter. This mixture is cooked until it is a golden colour and just bubbling. Butter is used to provide a fat coating to the flour, enabling it to form a smooth heated product. Butter also contributes to the flavour and colour development of the sauce.

Example: Cheese Ravioli with Butter Sage Sauce

Butter accounts for ~75% of the total content of the sauce. The butter is melted in a saucepan until hot and foamy. Sage leaves are added, cooked for 2 minutes until crisp, and then removed. Spring onions are added and sauted for 30 seconds. Heated melted butter acts as a flavour absorber for savoury ingredients and assists in creating a fried effect in savoury ingredients.

Hint: Cook butter over medium heat, taking care not to burn it. Butter should be light brown with a nutty flavour.

Example: Banana Split with Butterscotch Sauce

Butter accounts for ~23% of the total butterscotch sauce formulation. Butter is combined with brown sugar and sour cream and is simmered on the stovetop until the sugar has dissolved and the sauce is slightly thick. Butter contributes to flavour development in butterscotch sauce.

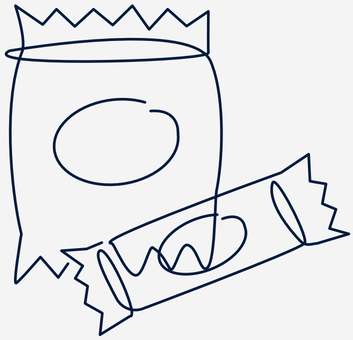
Table 8 Use of milk fat in sauces

Sauces	Milk fat product	Typical usage levels (%)
White sauce	Butter	3
Bernaise sauce	Butter	30
Bechamel sauce	Butter	7
Butter sage sauce	Butter	75
Butterscotch sauce	Butter	23

Dairy products

Recombining

Recombined milk products are defined as the milk products resulting from the combining of milk fat and milk solids non fat, with or without water. This combination must be made to meet the product's specified fat, solids non-fat and total solids levels. Other ingredients used in the formulation of recombined milk products include fresh milk and / or cream, where permitted, and vegetable oils such as coconut or palm oil. The term 'filled' is used when all or some of the milk fat is replaced with vegetable oil. Examples of recombined products include pasteurised fluid milk, sterilised milk, UHT milk, thickened cream, creamers, evaporated milk, and sweetened condensed milk. Several examples and typical levels of milk fat used in recombined products are given in Table 9.



Unsalted butter can be used in the manufacture of recombined milk products as a source of milk fat, but it must be stored under refrigeration and be of highest quality. AMF is the most common source of milk fat for recombination, which can be kept at ambient temperatures.

The milk fat must be added to the recombining formulation at a temperature above its melting point. For example, AMF must be added at above 40°C. Milk fat packed in cans can be melted by immersion in hot water at 80°C for 2-3 hours. Drums of AMF, however, require longer melting times. The drums can be stored in a hot room at 45-50°C for 24-28 hours before use, or in a steam chest or tunnel, which can melt the contents of the drums in about 2 hours. Once melted, the AMF should be transferred to a jacketed holding tank with facilities for maintaining the temperature. Melted AMF should, however, be utilised quickly, otherwise at elevated temperatures milk fat can get oxidised, leading to off flavours in recombined products.

The fat should not be added to the reconstituted milk until the hydration period for the solids-not-fat is complete. Addition of fat at the same time as or before the addition of milk powder should be avoided, as this can lead to processing problems and impaired product quality. An emulsifier is often added to facilitate and improve the emulsification of the milk fat. It is important to thoroughly mix the fat to ensure a uniform distribution. During continuous operation, the melted fat is normally metered into the line followed by thorough mixing in a static or a mechanically operated mixer before entering the homogeniser. The use of homogeniser is critical to ensure the formation of fat globules to stabilise the product.

Table 9 Use of milk fat in recombined products

Recombined product	Milk fat product	Typical usage levels (%)
Recombined Sweetened Condensed Milk (RSCM)	AMF	9
Ice cream	AMF	10
Recombined cream	AMF	35–45
Recombined milk	AMF	1–4

Ice cream and dairy desserts

Milk fat, butter and cream are important ingredients in ice cream, ice cream confections and many dairy dessert applications.

Ice cream is a frozen mixture of a combination of milk components, sweeteners, stabilisers, emulsifiers and flavouring. This blend, called the 'mix', is pasteurised and homogenised before freezing.

During freezing, the mix is agitated vigorously to incorporate air, thus imparting the desirable smoothness and softness of the frozen product.

Formulation of the mix is the most important part of the ice cream manufacturing process, to ensure a mix that is balanced with respect to milk fat, MSNF, sweeteners, flavouring and stabilisers.

Manufacturers generally use milk powders for milk solids, and/or anhydrous milk fat for their milk fat requirements. Milk solids provide the overall body and texture of the ice cream while the milk fat is the major source of flavour and colour of the ice cream or dairy dessert. Fresh or frozen cream can also be used in ice cream manufacture. Several examples and typical levels of milk fat used in ice cream and dairy desserts are given in Table 10.

Functional properties

Milk fat accounts for most of the rich, creamy taste of ice cream, provides body and contributes to the smooth texture.

Butter is used extensively throughout the dairy industry in particulates, and toppings such as toffee bits and caramel swirls, and contributes to their "creamy" flavour.

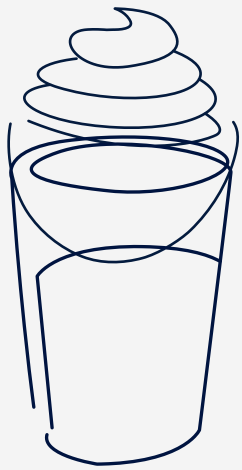
There are a range of classifications for ice cream based on the composition and types of ingredients. The milk fat contents of each category are shown in Table 10. In general, economy ice creams are made with cheaper ingredients, while the super premium products are more likely to be made with fresh concentrated milk and cream.

Conclusions

Milk fat products, such as butter and cream, are versatile food ingredients that are used in a variety of dairy and non-dairy applications. Milk fat products contribute to the flavour of foods, providing buttery or cooked flavour notes on heating or acting as a flavour carrier. Milk fat products also contribute in a functional way, particularly through their unique melting properties, to many foods by adding to the mouthfeel, texture and structure.

Table 10 Use of milk fat in ice cream and dairy desserts

Ice cream and Dairy desserts	Milk fat product	Typical usage levels (%)
Ice cream		
Non-fat ice cream (hard)	AMF/cream	<0.8
Low-fat ice cream (hard)	AMF/cream	2–5
Light ice cream (hard)	AMF/cream	5–6
Reduced-fat ice cream	AMF/cream	7–9
Economy ice cream	AMF/cream	10–12
Regular ice cream	AMF/cream	11–13
Premium ice cream	AMF/cream	12–15
Super premium ice cream	AMF/cream	14–20
Desserts		
Vanilla pudding	Cream (35% fat)	13
Chocolate mousse	Cream (35% fat)	15
Fromage frais	Cream (35% fat)	20
Custard	Butter	6



6.6 Frequently asked questions (FAQ)

A Quality of cream and milk

1. How does lipolysis affect flavour of milk fat products?

There is a fine balance between attractive and undesirable flavour depending on the level of different compounds in specific products. Low levels of fatty acids contribute to the flavour of milk fat products. Off flavours in butter and anhydrous milk fat can be caused by lipolysis before or after manufacture. Off flavours originating before manufacture are mostly due to milk lipase action and result in soapy, bitter and 'back palate' taste sensations. This is characterised by a high FFA content. Lipolysis occurring during storage is due to heat stable bacterial lipase action and results in characteristically sharp, butyric, 'front palate' flavours. This type of lipolysis occurs more readily in butter because of its higher water content.

2. How are off flavours in milk fat minimised?

To minimise off flavours, manufacturers need to handle the milk carefully to ensure that the milk fat globule is not damaged during initial processing of the milk which can lead to lipolysis of the milk fat and the development of off flavours.

There are various factors that can promote lipolysis in raw milk before pasteurisation due to the handling and storage of the milk.

At the farm, the various handling procedures usually involve milking, pumping and bulk storage before pickup in tanker for transport to the dairy factory. Problems can be introduced through excessive air intake at the milking stage, at the claw or teat cups, milk hose and loose line joints. Pipelines that rise, particularly vertical sections connecting one pipe to another at a higher level and excessively long pipelines can contribute to damage to the milk through a constant mixing of milk and foam. If the inlet pipe in the holding tank is too high, excessive splashing and agitation can occur when filling the tank. Addition of fresh warm milk to previously cooled milk may cause thermal activation.

Prolonged storage times can also allow the growth of psychrotrophic bacteria, which grow at refrigeration temperatures and can produce heat-stable lipases. This means that they can survive pasteurisation and continue to be active in manufactured products.

The main source of activation in the factory is from pumping (especially if foaming is also occurring). The same factors apply to the bulk storage tank at the factory as at the farm. To prevent and minimise lipolysis, manufacturers can:

- Avoid excessive agitation, foaming and turbulence
  - check pipes for leaks, avoid long pipelines and/or high-speed pumping
  - avoid excessive stirring
- Pasteurise milk as soon as possible, minimise storage time
- Pasteurise milk before homogenisation (or if not practical, immediately after)
- Chilled storage of milk and cream, preferably 2-4°C
- Store pasteurised milk at appropriate refrigeration temperatures to minimise lipolysis by microbial lipases
- Maintain a high hygiene standard.

B Processing and manufacture of milk fat products

1. What are the different temperature treatments for cooling of cream prior to ageing and churning based on various iodine values?

Before churning, the cream is subjected to temperature treatment which will control the crystallisation of the fat so that the butter will have the desired consistency. The consistency of the butter can be optimised if the temperature treatment is modified to suit the iodine value of the fat. The higher the iodine value, the higher the content of unsaturated fatty acids and the 'softer' the milk fat. The temperature treatment regulates the amount of solid fat to a certain extent – this is the major factor that determines the consistency of butter. Table 11 gives examples of temperature treatments or different iodine values. The first temperature is the value to which the cream is cooled after pasteurisation, the second the heating/souring value and the third the ripening value.

Table 11 Principal temperature programs adjusted to the iodine value

Iodine value	Temperature program (°C)
<28	8–21–20
28–29	8–21–16
30–31	8–20–13
32–34	6–19–12
35–37	6–17–11
38–39	6–15–10
>40	20–8–11

2. What is the role of vacreation in milk fat processing?

Off flavours can be removed from milk and cream by the process of vacreation, where steam is injected into the product and subjected to vacuum which removes unwanted volatile flavours, as well as water vapour.

3. What is the effect of reworking on butter consistency?

The firmness of butter usually increases with time, eventually reaching a maximum after about three weeks or more depending on the temperatures to which it has been subjected to before and after packing. This results from the development of two types of secondary crystal structure:

1 the weak, thrixotropic, association of many small (<1µm) fat crystals to form a three-dimensional structure

2 realignment and stronger bond development between larger fat crystals.

Mechanical reworking of butter causes softening of the butter due to irreversible destruction of the stronger bonds and temporary disruption of the weaker bonds.

Therefore, in practice, butter reworked from bulk 25kg blocks is softer than the same butter put into retail packs directly from the butter maker.

4. What is the effect of head space and dissolved oxygen in AMF drums on oxidation and flavour?

The shelf-life of AMF can be extended at ambient temperature by minimising the oxygen in the package. At the time of packing, oxygen can be present both in the liquid product (dissolved oxygen) and in the headspace gas. The solubility of oxygen in milk fat at 40°C is approximately 38mg/kg for milk fat saturated with air. Dissolved oxygen in AMF is usually reduced to less than 1 mg/kg by the vacuum deaerating step in the manufacturing process. However, subsequent to deaeration, and each subsequent pumping operation or exposure to air in the balance tanks or silos will rapidly increase the oxygen level. The level of dissolved oxygen in the AMF at packing therefore reflects the efficiency of the post-manufacturing handling and filling operations. Sparging with nitrogen gas can help reduce the dissolved oxygen levels in AMF, although there seems to be a lower limit of about 4mg/kg. Minimising the oxygen levels during storage will minimise any oxidation reactions that can lead to off flavour development in the AMF.

C Storage and handling of milk fat products

1. What are the most suitable storage conditions for butter?

Butter must be protected from moisture evaporation and light-induced photo oxidation which can spoil its flavour and appearance. Butter should be stored at a low temperature, in a cool dark place. Butter is best kept refrigerated at 4°C, protected from light and sealed in its original container or wrapping until it is used, as it readily absorbs odours from other foods. Salted butter will keep longer than unsalted butter because the concentration of salt in the aqueous phase is high enough to inhibit growth of many organisms. Always check the use-by date, to ensure natural freshness and quality.

Butter will keep refrigerated for up to eight weeks, but it is best to obtain butter when required rather than storing it. Properly sealed, butter may be kept frozen at –15°C for 4–6 months and at –18 to –23°C for up to 12 months. Butter should be placed in the refrigerator to thaw prior to use.

D Functionality and applications

1. What is the effect of season on milk fat functionality?

In a pasture-based feeding regime, the different seasons result in changes to the grass growth and can influence the milk fat in many ways. When green pasture is available for the cows, the milk fat tends to have a higher concentration of unsaturated fatty acids leading to a 'softer' fat which has a higher iodine value (~36). Regional variations in butter firmness can also exist and the stage of lactation can also affect the textural attributes of butter.

2. Is there a difference in the flavour of milk fat from cows fed on pastures and on concentrates?

Variation in the flavour of milk fat between countries and regions within countries can be attributed to the flavour compounds derived from the diet of the cow. In Australia, the dairy industry is pasture based. Different pasture types can also contribute to variation in milk fat flavour. In colder climates, where pasture growth is not supported, the animals are kept indoors and fed on grain or feed concentrates such as silage. It is known that certain feeds can contribute to off- or 'feed'-flavours in milk, cream and butter.

3. Can I soften or melt butter in the microwave?

The best way to thaw or soften butter is to transfer it from the freezer to the refrigerator or remove it from the refrigerator to let it soften at room temperature. However, butter may be softened or melted in the microwave provided a medium heat power level is used for short intervals at a time and the butter checked in between. If the butter is softened in the microwave and it over melts, it is suggested to use this butter for something else such as flavouring vegetables or as a dip.

4. What types of fresh cream are available and what can they be used for?

Fresh cream can be divided into several categories based on the fat content as shown in Table 12. In all cases, the cream is required to have a standard plate count not exceeding 500,000 micro-organisms per millilitre and have a coliform count not exceeding 100 coliforms per millilitre.

Table 12 Types of fresh cream and suggested uses

Cream type	Milk fat %	Suggestions for use
Rich, Double, Pure, Pure rich, Thick or Double thick cream	45–60	• Dollop or spoon. It will hold its shape. • Accompaniment to dessert, puddings and soups. • Stir into hot dishes for richness.
Cream, Pure (pouring or thin), Thickened, Thick or Whipping	35	• Whip and add to sauces, soups, vegetable gratins, quiches, and custards. Pour over desserts. Add to cocktails. • It has a light airy texture when whipped, so is ideal for cake fillings, mousses, ice creams and cheesecakes. • Pure cream is commonly used in reduction and pasta sauces. • Substitute for milk and butter in scone-making.
Lite, Lite Thick (thickened), or Light	18	• Pourable • Add to sauces, soups, drinks, and desserts. • Not suitable for whipping.

E Others

1. Do butter and milk fat ingredients contain *trans* fat?

Yes, but the level of *trans* fat in dairy foods and dairy ingredients is naturally very low at around 4% of the total fat content, including CLA. Milk fat is more saturated than many vegetable fats. Therefore, it is naturally more stable against oxidation, better able to crystallise and does not require hydrogenation – a process that can lead to the creation of unfavourable *trans* fatty acids. Milk fat is not completely free of *trans* fatty acids as small amounts of these molecules are naturally formed in milk due to as a result of hydrogenation by microbes in the cow's stomach.

In product formulations using dairy ingredients, total *trans* fat will depend on the percentage of dairy ingredients in the formula, serving size and the *trans* fat contribution from all ingredients.

2. What is CLA?

Conjugated linoleic acid (CLA) is a collective term used to describe one or more positional and geometric forms of the essential fatty acid linoleic acid. CLA is naturally present in cow's milk and beef and other ruminant meats. Milk fat, infat, in particular, is the richest natural dietary source of CLA in the cis-9, trans-11 (c9, t11) configuration. Emerging research indicates that milk-derived CLA is highly bioactive and might hold anti-cancer properties as well as offer potential cardiovascular health benefits.

A variety of factors, such as the cow's diet, can influence the CLA content of milk fat. Because the CLA content of dairy products is related to their fat content, CLA levels are greater in higher fat than in lower fat products.

6.7 Glossary

Emulsion

An emulsion is a suspension of droplets of one liquid in another. Milk is an emulsion of fat-in-water, butter an emulsion of water-in-fat.

Fat globule

Fat globules are the droplets of fat in milk. The droplets are separated from the aqueous phase by a milk fat globule membrane that surrounds and contains the fat.

Fatty acid

A fatty acid molecule is composed of a hydrocarbon chain and a carboxyl group. Three fatty acids attached to a glycerol backbone comprise a triacylglycerol – the main fat component in milk.

Free fat

Free fat is fat which is easily extractible (fat not contained within fat globules) from milk or cream by a solvent under standard conditions of time, temperature and agitation.

Lipolysis

Lipolysis is the reaction catalysed by lipase enzymes where fatty acids are cleaved from the triglycerides resulting in free fatty acids and leads to the development of off flavours in the product.

Oxidation

Oxidation is a breakdown reaction of the milk fat that occurs at the double bonds of the unsaturated fatty acids in the fat. Oxidation can lead to a metallic off flavour in milk fat products.

Phase inversion

When milk and cream are turned to butter, there is a phase inversion from an oil-in-water emulsion to a water-in-oil emulsion.

Triacylglycerols

Triacylglycerols are the main fat components in milk and are comprised of three fatty acids attached to a glycerol backbone.

6.8 References and further reading

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07 High Value Functional Dairy Ingredients

Content

7.1 Introduction

Milk has been a source of nutrition for centuries but recent advances in analytical and biochemical techniques have helped in identification of several bioactive components from milk and verification of their bioactivities. Although many of the bioactive components from milk remain unexploited as commercial ingredients, ongoing developments in new processing technologies such as membrane filtration, ion exchange chromatography and nano- or micro-encapsulation have stimulated the manufacture, commercialisation and applications of some of the biologically active components from milk. The growth in functional foods and nutraceuticals offer new opportunities for bioactive ingredients from milk.

Milk contains high value functional dairy ingredients both in the lipid and in the skim part. These bioactive components originate from the milk lipids, proteins, and carbohydrate (mainly lactose) and include:

- Milk fat globule membrane (MFGM). Milk phospholipids.
- Bioactive peptides.
- Growth factors.
- Immunoglobulins.
- α-lactalbumin (α-La).
- Lactoferrin (LF).
- Glycomacropeptide (GMP).
- Milk oligosaccharides.

Although the milk phospholipids have been commercially available for several years, other components listed above are under various stages of development. By far, skim milk and whey are the major bioactive-rich streams of milk and a range of bioactive ingredients from these streams have been commercialised. Further research and development, no doubt, is likely to lead to commercialisation of more functional ingredients in future. This chapter highlights biological functionality and applications of several high value functional dairy ingredients from milk and provides a list of frequently asked questions to help users of these ingredients.

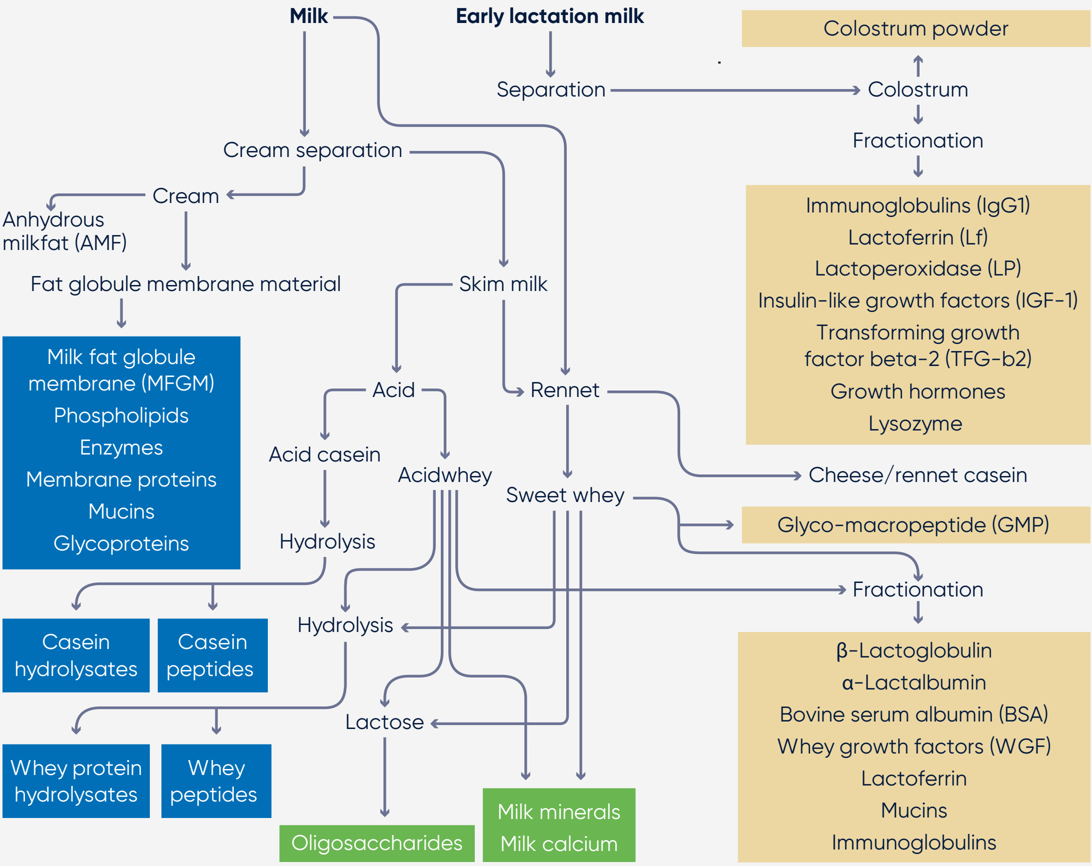
Figure 1 shows some of the high value functional ingredients identified from milk and summarises general processing steps for their commercial manufacture. One of the foremost bioactive-rich fluids produced by the cow is the colostrum. Colostrum provides life-supporting immune and growth factors that ensure the health and vitality of the newborn calf. Surplus colostrum is commercially utilised as a rich source of bioactive ingredients, including immunoglobulins, lactoferrin, lactoperoxidase, lysozyme and several growth factors.

In order to fractionate, isolate and concentrate bioactive components from milk, the first step is the separation of fresh milk into cream and skim milk. The cream part contains almost all the fat globules and the associated fat globule membrane that is a rich source of several bioactive components (see Figure 1). The skim part is rich in protein. Bovine milk contains around 3.5% protein, which consists of about 80% casein and 20% whey proteins.

The caseins further consist of α-, β- and κ- caseins. The whey proteins include β-lactoglobulin (β-Lg), α-lactalbumin (α-La), immunoglobulins and bovine serum albumin. Skim milk is usually treated with acid or rennet to separate casein from whey proteins; both casein and whey streams then become raw materials for isolation of functional bioactive components. Although many biologically active peptide segments have been identified in casein (identified as casokinins), the current commercial product range is limited to casein hydrolysates and phosphopeptides. During cheese manufacture, rennet acts on part of κ-casein to set the milk and this releases the glycomacropeptide (GMP) in whey.

The GMP can be separated and concentrated for use as a functional ingredient. In the dairy industry, whey from cheese manufacture remains the most abundant source of whey-based bioactive ingredients. Several bioactive ingredients have been commercialised from whey as shown in Figure 1. Among these are ingredients enriched in whole proteins (e.g. β-lactoglobulin, α-lactalbumin, lactoferrin and lactoperoxidase), hydrolysed forms of proteins (e.g. whey protein hydrolysates with varying degrees of hydrolysis), and milk minerals. Dairy manufacturers are actively researching and developing new physiological or bioactive ingredients from milk that no doubt will be available in the future.

Figure 1 High value functional (bioactive) ingredients from milk*



Some of the ingredients may not yet be available commercially.

Table 1 summarises the main biological functions of bioactive ingredients from milk.

Table 1 Biological function of bioactive ingredients from milk

Bioactive ingredient	Potential biological function	Potential food applications
Colostrum	• Immune factors • Growth factors • Anti-microbial properties	• Sports formulation • Calf feeding
Immunoglobulins	• Antibacterial and immune enhancing	• Infant formula • Health care products
Lactoferrin	• Antimicrobial activity • Antiviral activity • Anti-tumour activity • Anti-inflammatory activity • Immunomodulating activity • Iron binding ability responsible for many functions such as bacteriostatic effect, cell growth promotion, antioxidation and iron delivery and absorption	• Infant formula • Sports nutrition • Meat preservation • Adult nutritional powders and drinks
Lactoperoxidase	• Preservation effect • Bacteriostatic effect against Gram +ve bacteria and bactericidal effect against Gram –ve bacteria, e.g. *Pseudomonads, Coliforms, Salmonella, Listeria*	• Food preservation in general, meat products
Casein and whey protein hydrolysate	• Reduced allergenicity • Increased protein absorption • Increased peptide bioactivity • Lowering blood pressure	• Infant and enteral formulation • Geriatric products, sports beverages • Weight control diets
Casein and whey peptides	• Fast absorption • Reduced allergenicity • Blood pressure reduction	• Infant and enteral formulation • Isotonic beverage • Sports nutrition
Caseinophosphopeptide (CPP)	• Mineral carrier, helps in re-mineralisation and mineral absorption • Protection against dental caries • Antibacterial	• High mineral beverages • Chewing gum • Breakfast cereals
Glycomacropeptide (GMP) or Caseinomacropeptide (CMP)	• Satiety, low phenylalanine • Prevention of dental cavities • Controlling blood clotting • Antibacterial and antiviral properties	• Phenylketonuria diets • Sports nutrition • Infant formula • Weight control formula
Micellar casein	• Slow release of amino acids • Rich source of protein and calcium	• Sports nutrition • Weight loss products
Osteopontins	• Immune functions	• Infant formula
α-lactalbumin	• Sleep enhancement	• Drinks and beverages
Milk minerals and milk calcium	• Bone and teeth health and osteoporosis, hypertension benefits	• Mineral fortification of beverages, breakfast cereals

7.2 Colostrum

Colostrum is the first milk produced by a cow after the birth of its calf. Colostrum is a rich source of antibodies, growth factors and nutrients for the suckling neonate and may provide passive immunity to the newborn against various infectious microorganisms, particularly those that affect the gastrointestinal tract. It may also have other health benefits.

A comparison of the composition of colostrum obtained during the first three milkings of a cow with normal cow milk is shown in Table 2. As seen in the Table 2, the composition of colostrum rapidly changes with the increase in number of milkings after birth of the calf. The first milking colostrum has the highest amounts of protein and bioactive ingredients such as immunoglobulins and is normally fed to the calf. This is particularly important for the defence of the newborn calf as a newborn calf is born without antibodies in the blood that are critical for the proper function of the immune system. Colostrum differs considerably from normal milk. Colostrum contains over ten times the amount of immunoglobulins present in normal milk (Table 3). Immunoglobulins are very heat-sensitive proteins, which makes the processing of colostrum into a food ingredient with long shelf life a challenging operation.

Colostrum is also a rich source of growth factors as shown in Table 4. Growth factors are key regulators of a variety of cellular functions and are involved in the control of tissue growth and repair. Extensive research has identified several applications for their use in clinical medicine and biotechnology. The most important of these is likely to be a therapeutic potential in wound healing.

A general scheme for manufacture of functional ingredients from colostrum is shown in Figure 2. Manufacture of colostrum powder or protein concentrate requires stringent quality control during collection, transport, processing, handling and storage so that the bioactivities of components are retained.

Table 2 Composition of colostrum[1]

Component	Milking number after birth of calf			Normal milk
	1	2	3	
Specific gravity	1.056	1.040	1.035	1.032
Total solids, %	23.9	17.9	14.1	12.9
Protein, %	14.0	8.4	5.1	3.1
Casein, %	4.8	4.3	3.8	2.5
IgG, mg/ml	48	25	15	0.6
Fat, %	6.7	5.4	3.9	3.7
Lactose, %	2.7	3.9	4.4	5.0
Vitamin A, µg/L	2950	1900	1130	340
Vitamin D, IU, g fat	0.9–1.8	0.4		
Riboflavin, µg/L	4.8	2.7	1.9	1.5
Choline, mg/ml	0.70	0.34	0.23	0.13

Table 3 Immunoglobulins found in bovine colostrum and normal milk[2]

Immunoglobulin	Colostrum (g/L)	Milk (g/L)
IgG1	52–87	0.31–0.4
IgG2	1.6–2.1	0.03–0.08
IgA	3.7–6.1	0.03–0.06
IgM	3.2–6.2	0.04–0.06

Table 4 Concentration of growth factors in colostrum and normal milk[2]

Growth factors	Colostrum (µ/L)	Milk (µg/L)
IGF-1	50–2000	<10
IGF-2	200–600	<10
TGF-β1	n.d.	4.3
TGF-β2	n.d.	n.d.
EGF	n.d.	<2

IGF – insulin-like growth factors
TGF – transforming growth factor
EGF – epidermal growth factor
** n.d. – not determined*

1 Foley & Otterby (1978)
2 Pakkanen & Aalto (1997)

Colostrum obtained from the first few milkings is generally pooled, and either frozen or transported chilled to the dairy processing facility. After separation of colostrum cream (which can be fed to the calf), the skim colostrum can be concentrated and dried into colostrum powder. For removal of casein, skim colostrum is usually treated with rennet or acid, and the casein-free whey is used for development of colostrum whey powder or colostrum whey protein concentrate. Colostrum whey protein concentrate is particularly valuable as it is rich in bioactive protein components and contains low levels of lactose. Commercial drying of colostrum is either carried out by freeze-drying or by spray drying under mild temperatures to preserve its bioactivity.

Bovine colostrum is marketed in several forms. Commercial colostrum products are available with immunoglobulin contents ranging from 16 to 50%. Composition of a colostrum product with 22% IgG is shown in Table 5.

Figure 2 Processing schemes for manufacture of colostrum based ingredients

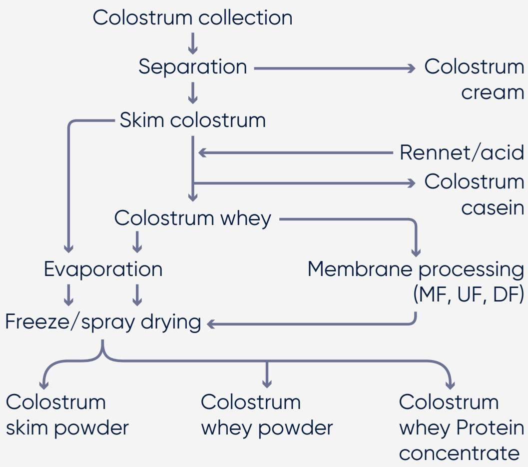


Table 5 Composition of a commercial colostrum product with 22% IgG

Component	Amount
Moisture (%)	5
Protein (%)	75
IgG (%)	22
Ash (%)	6
Lactose (%)	10
Fat (%)	2
Lactoferrin (%)	0.3
Calcium (%)	1.5

Colostrum: Functionality and applications

Colostrum products can provide several physiologically functional properties. The benefits of colostrum for humans include boosting the immune system and promoting cell repair are continually being researched and discovered. Major benefits and applications of colostrum include[3]:

- Source of growth factors
- Source of antimicrobial components
- Immune-enhancing properties and intestinal benefits
- Sports and performance applications

Source of growth factors

In addition to being a rich source of essential nutrients such as amino acids, carbohydrate, lipids and minerals, colostrum contains a range of growth factors that can stimulate healthy development of cells and tissues. Growth factors from colostrum and whey have been commercially available for some time. Growth factors present in colostrum include insulin-like growth factors 1 and 2 (IGF-1 and IGF-2), transforming growth factors – β1 and β2 (TGF-β1 and TGF-β2) and epidermal growth factor (EGF). Some of these factors are also present in regular milk but in very small amounts (100-1000 times less than colostrum).

3 Pakkanen & Aalto (1997)

The IGFs stimulate the immune system, promote cell repair and growth, and influence how the body uses fat, protein and sugar. The IGFs acting as endocrine, autocrine and paracrine hormones enhance cellular glucose uptake stimulating synthesis of proteins, DNA, RNA and lipids. The amino acid sequence of bovine IGF-1 is identical to that of human IGF-1 and bovine IGF-2 differs from human IGF-2 by only three amino acid residues. Both IGF-1 and IGF-2 are heat-stable proteins that help in growth and differentiation of cells.

Antimicrobial components

Colostrum is a rich source of antimicrobial components that can help in protection against infections. Antimicrobial components present in colostrum include lactoferrin, lactoperoxidase, lysozyme and immunoglobulins. Each of these components is available commercially in purified forms and discussed in detail in the latter part of this chapter. Antibodies from colostrum in oral immunotherapy have aided treatment of various human infections, including those caused by antibiotic resistant bacteria.

Immune-enhancing properties and intestinal benefits

One of the main reasons for hospital admission of infants and young children is infectious diarrhoea, usually caused by a rotavirus infection. Infants can also acquire rotavirus in hospital neonatal and paediatric wards; the infection can also be transmitted to adult members of the family. Colostrum has been successfully tried out in the protection against rotavirus and diarrhoea[4]. It has been suggested that infant formulas could be fortified with colostral immunoglobulins[5]. Colostrum may help protect the gastrointestinal tract against stomach cancers[6] and ulcers[7]. Colostrum has also been shown to prevent gut damage induced by non-steroidal anti-inflammatory drug (NSAIDS). NSAIDS are given for the treatment of pain and are a common cause of gastritis.

Sports and performance applications

Colostrum appears to aid strength and speed in athletes, as well as increase insulin, which has anabolic effects. Studies have shown that supplementation with bovine colostrum (20 g/d) in combination with exercise training for 8 weeks may increase bone-free lean body mass in active men and women[8].

Colostrum has been shown to enhance serum IGF-1, IgG, hormone and saliva IgA during training of athletes[9]. In clinical trials, IGF-1 is known to have strong anabolic effects on muscle tissue, as it can mimic most of the actions of growth hormones. IGF-I is of benefit to athletes, body builders and people concerned about higher weight because it can help burn fat and encourage lean muscle tissue.

7.3 Glycomacropeptide (GMP)

Glycomacropeptide (GMP) is a hydrophilic peptide (amino acid residue 102 to 169) of κ-casein that provides stability to casein micelles in milk. When rennet acts on κ-casein during the setting of milk for cheese manufacture, GMP is released into the whey. GMP makes up about 15% to 20% of the whey proteins. Recent advances in fractionation have allowed separation of GMP from cheese whey into commercial GMP-enriched ingredients. In whey at low pH, GMP is highly negatively charged while whey proteins are positively charged. This makes it easy for an ion exchange process to isolate GMP from whey. When whey at pH 3 is passed through a cation exchanger, the GMP is not adsorbed by the cation exchanger and can be concentrated and desalted by ultrafiltration. Alternatively, GMP from whey at pH less than 4 can be bound to an anion exchanger while the rest of the whey proteins pass through the column. Pure GMP can then be eluted from

4 Davidson *et al* (1989)
5 Seung *et al* (1995)
6 Masuda *et al* (2000)
7 Playford *et al* (2000)
8 Antonio *et al* (2001)
9 Mero *et al* (1997)

the ion exchanger using a buffer and thereafter concentrated using membrane systems.

GMP is unique because it is a glycoprotein (protein containing carbohydrate) and, thus, has an oligosaccharide chain attached to it. It also is unique because it contains none of amino acids phenylalanine, tryptophan or tyrosine. GMP has high levels of the branched-chain amino acids, leucine, isoleucine and valine. This composition of GMP gives it some unique characteristics that can be utilized in a variety of important applications. A small proportion of human population has phenylketonuria (PKU), meaning they are unable to digest phenylalanine. GMP is one of the few amino-acid sources PKU patients can tolerate because the pure GMP does not contain phenylalanine.

Composition of a commercial GMP product is shown in Table 6.

Table 6 Composition of a commercial GMP

Component	Amount
Moisture, %	5
Protein, %	80
GMP (% of total protein)	90
Sialic acid, %	4

GMP: Functionality and applications

Published research has linked GMP with many important physiological functions, including promotion of probiotic bifidobacterial growth; suppression of gastric secretions; inhibition of bacterial and viral adhesion; modulation of immune-system responses; and binding of cholera and E. coli enterotoxins. In simpler terms, GMP offers potential benefits to consumers relevant to intestinal health, appetite control, reduced dental caries, enhanced immunity and protection against diarrhoea.

Some of the bioactive properties of GMP are:

- Anti-inflammatory[10]
- Toxin binding[11]
- Inhibition of bacterial and viral adhesion[12]
- Immune modulation and protection against diarrhoea[13]
- Prebiotic effect[14]
- Important source of amino acids for population suffering from phenylketonuria (PKU)

Suggested applications of GMP are:

- Dental care products such as toothpaste and mouthwash for prevention of dental caries and remineralisation
- Supplements and diets for population suffering from PKU
- Prebiotic for probiotic supplements and foods
- Sports nutrition products as source of branched chain amino acids
- High protein diets for weight control

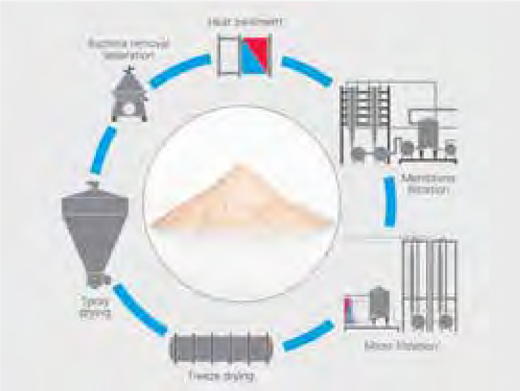
7.4 Lactoferrin (LF)

Lactoferrin (LF) is an iron-binding glycoprotein present in colostrum, milk and whey. LF exists as a single peptide chain with a molecular weight of 77,000. It is folded into two globular units with each unit able to bind 1.4 mg of iron per gram of protein. Bovine LF is somewhat similar in structure to the human form, having approximately 70% of the same amino acids. The iron-binding ability of LF is responsible for many biological functions such as bacteriostatic effect, growth-promoting effect on certain cell lines, and prevention of lipid peroxidation and promotion of iron absorption in the body.

Lactoferrin is one of the few proteins in whey that is positively charged at pH 7.0 (isoelectric point of approximately pH 7.9) while most other proteins are negatively charged. This feature of LF has been exploited in commercial isolation of LF. Using cation based resins and selective salt solutions, LF can be separated from other positively charged proteins attached to the resin.

10 Daddaoua *et al.* (2005)
11 Kawasaki *et al.* (1992)
12 Nesser *et al.* (1988)
13 Otani *et al.* (1995)
14 Azuma *et al.* (1985)

Further concentration of LF is carried out using ultrafiltration and spray drying. The diagram below highlights some of the processing methods for LF manufacture.



Processing plants for milk lactoferrin powder ***(gea.com)***

In its purest form, LF powder is pink in colour. Commercially, LF is available in a range of protein concentrations. In milk and whey, the concentration of LF is very low, therefore the cost of separation and manufacture is high. Table 7 shows the composition of a commercial LF powder.

Table 7 Composition of a commercial lactoferrin product

Component	Amount
Moisture (%)	5
Protein (%)	95
Lactoferrin (% of total protein)	90
Iron (%)	13
Ash (%)	1
Fat (%)	<1
Lactose (%)	<1

Lactoferrin: Functionality and applications

Lactoferrin can provide several physiological, functional and bioactive properties, which are mainly derived from its ability to bind iron. Each molecule of LF can bind two atoms of iron.

The main bioactive properties of LF include antibacterial, antiviral, antioxidant, immune modulation, and ability to bind iron and make it unavailable for microorganisms.

Antibacterial and anti-viral properties

Lactoferrin inhibits the growth of pathogenic bacteria and fungi, due to its ability to bind large quantities of iron. Lactoferrin binds iron very strongly, thus rendering this essential nutrient unavailable to support microbial growth. Lactoferrin also disrupts bacterial digestion of carbohydrates, further limiting their growth. In addition, the action of pepsin in the stomach converts LF into lactoferricin, which has broad-spectrum activity against pathogenic bacteria and yeast. Lactoferrin has the ability to bind to parasites and the outer membrane of Gram-negative bacteria, making the cell wall more permeable and thus improving the efficiency of antibiotics.

Furthermore, segments of the LF molecule can exert a direct bactericidal effect on certain strains of bacteria. It is also thought to inhibit the attachment of bacteria to the gut wall, therefore reducing the probability of infection. Anti-viral effects of bovine LF against several types of viruses have been reported. Lactoferrin appears to achieve this by inhibiting virus absorption and its penetration into cells.

Antioxidant properties

Lactoferrin can be used as a natural antioxidant and may reduce the susceptibility to ageing processes and disease. Lactoferrin provides protection against oxidative damage by scavenging excess iron, which catalyses the undesired formation of free radicals from hydrogen peroxide. These are produced due to microbial respiration, thus allowing the cell's own peroxidase to harmlessly break down the hydrogen peroxide.

Immune modulation

Lactoferrin contributes to the defence against pathogens by activation of cells involved in the anti-inflammatory response during microbial infection, thus enhancing self-immunity.

Iron transport and absorption

Lactoferrin is an excellent carrier of iron and increases the bioavailability of iron.

Commercial LF is suitable for applications in health supplements, functional foods and drinks, infant formulas, cosmetics and oral care products. Examples of potential markets for LF are supplements for the elderly or immune-compromised patients, supplements for recovery from gastrointestinal infections, products used to stimulate the body's immune system to help deal with toxic environments, disorders or treatments, and prophylactic products for travellers' diarrhoea. Lactoferrin can be used in several food applications such as

- Sports nutritional formulations
- Infant formula
- Yoghurt
- Meat applications
- Chewing tablets or gums
- Antioxidant in cosmetics

Lactoferrin can be added in the range 10–100 mg per 100 g of product. This broad application range requires knowledge on effective incorporation of this bioactive component based on the prediction of its properties during processing, storage and consumer use.

7.5 Lactoperoxidase (LP)

Lactoperoxidase [EC 1.11.1.7[15]] is an enzyme present in colostrum, whey and milk, with a molecular weight of approximately 77.5 kDa. Bovine colostrum and milk contain about 11-45 mg/L and 13-30 mg/L LP respectively[16]. In whey, LP constitutes approximately 0.5% of whey proteins[17]. The biological significance of LP is its involvement in the natural host defence system against invading microorganisms.

Lactoperoxidase inactivates or kills a wide spectrum of microorganisms through an enzymatic action. This reaction involves two cofactors, hydrogen peroxide and thiocyanate ions, which together with LP constitute the lactoperoxidase system (LP system). Activation of the enzyme results in the formation of hypothiocyanite ions, which are responsible for the antimicrobial action. The mechanism of the LP system can be described by the following reaction:

$$Glucose + H_2O + O_2 \xrightarrow{Glucose\ oxidase} H_2O_2 + Glucuronate \xrightarrow{LP + SCN^-} HOSCN / OSCN^-$$

The reaction of the LP system relies on the production of short-lived intermediary oxidation products of the thiocyanate ion (OSCN-) that reacts with bacterial cytoplasmic membranes, as well as impairs the function of metabolic enzymes. As addition of H2O2 is not permitted in certain countries, in situ development of H2O2 is carried out by the addition of glucose oxidase (a permitted additive). The source of thiocyanate ion can be either naturally present (as in the case of animal tissues and plant),or added as sodium or potassium thiocyanate.

Commercially, LP is isolated from either skim milk or whey using an ion-exchange process like that used for isolation of LF. The basic principle for commercial manufacture is that LP has an isoelectric pH of 9.0-9.5 which means that it is positively charged at the normal pH of cheese whey (6.0 – 6.2) while the rest of the proteins are negatively charged. This difference in pH is used to adsorb LP to resins on an anion exchange column that is subsequently separated from other proteins. The LP from the resin is eluted using a buffer, concentrated and freeze dried. Gross composition of a commercial LP product is shown in Table 8.

15 Enzyme Commission Number
16 Korhonen (1977)
17 de Wit & van Hooydonk (1996)

Table 8 Composition of a commercial lactoperoxidase product

Component	Amount
Moisture (%)	6.8
Protein (%)	91
LP (% of protein)	83
LP activity (ABTS method) U/mg protein	270
Ash (%)	2

Lactoperoxidase: Functionality and applications

Lactoperoxidase when used in the form of an LP system has a broad spectrum of antibacterial activity, having a bacteriostatic effect against Gram-positive bacteria and a bactericidal effect against Gram-negative microorganisms, *e.g. Pseudomonads, Coliform, Salmonella and Listeria*[18]. The following are the examples of potential applications of LP:

- Improved yield of aquaculture by using the LP system to kill fish pathogens[19]
- Application of lactoperoxidase together with LP system activating ingredients (thiocyanate and hydrogen peroxide) in toothpaste formulations to protect against oral streptococci[20]. Activation of salivary peroxidase antimicrobial system in toothpaste and mouth rinse reduces acid formation by oral microorganisms and clinical studies have shown that plaque accumulation, gingivitis and early carie lesions and aphthous lesions may all be reduced by appropriate applications of the applied enzyme preparations[21].
- Promising results have been obtained when activating components are included in calf feed with the aim of activating the LP system in the intestinal tract[22]
- Using the LP system to protect contamination of *Campylobacter jejuni* in poultry during slaughter[23]
- Lactoperoxidase can be used improve the shelf life in meat products by creating conditions that allow activation of the LP system
- Lactoperoxidase can be used successfully for controlling lactose fermentation and acidity development during storage of yoghurt[24]
- Application of the LP system for preservation of cosmetics showed a broad-spectrum antimicrobial activity against bacteria yeasts and moulds[25]

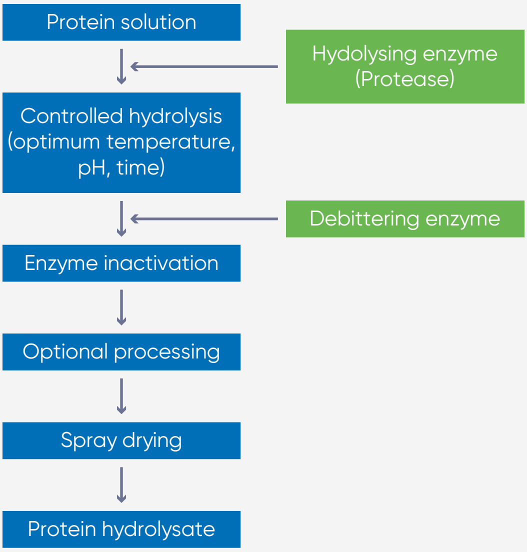
7.6 Casein and whey protein hydrolysates

The enzymatic hydrolysis of milk proteins yields protein hydrolysates with unique functional and nutritional properties. Both casein and whey proteins can be hydrolysed to produce protein hydrolysates with various degrees of hydrolysis. During enzymatic hydrolysis, casein and whey proteins are broken down into peptides of different sizes, and free amino acids. Specific enzymes are used that allow a good control over the size and functionality of peptides formed during hydrolysis. Enzymatic protein hydrolysates containing short chain peptides with characteristic amino acid profiles and defined molecular size are used in specific formulations such as those used for feeding hospitalised patients.

A general process for manufacture of protein hydrolysates is shown in Figure 3.

18 Reiter & Harnulv (1984)
19 Kussendrager & van Hooydonk (2000)
20 Reiter & Harnulv (1984)
21 Hoogendoorn (1985)
22 Reiter *et al* (1981)
23 Borch *et al* (1989)
24 Nakada *et al* (1996)
25 Guthrie (1992)

Figure 3 A general process for manufacture of milk protein hydrolysate



For the manufacture of protein hydrolysates, milk proteins (casein, caseinate, milk protein concentrate, lactalbumin, whey protein concentrate, or whey protein isolate) are first dispersed and solubilised in water and the pH and temperature are adjusted to the desired levels (generally targeting the optimum temperature for the enzyme). An appropriate enzyme is then added to the protein solution (substrate) at a certain enzyme: substrate ratio that optimises the enzymatic reaction. Under controlled conditions, the enzyme cleaves the peptides bonds and produces the desired level of protein hydrolysis. The hydrolysed protein is optionally processed through steps such as clarification, flavour reduction, concentration, and finally spray dried.

Enzymatic hydrolysis of protein causes several changes in protein structure that affect the functional properties of protein. These changes include:

- Decrease in molecular weight due to breakdown of long polypeptides into smaller peptides, and increase in the number of peptides
- Decrease in the pH when hydrolysis is carried out at neutral to basic pH due to the release of H^+
- Increase in pH when hydrolysis is carried out at acidic pH due to the consumption of H^+
- Increase in the solubility due to increase in NH_3^+ and COO- contents of proteins
- Increase in the number of hydrophobic residues due to destruction of the aggregated (globular) structure of protein

There are several variables that need to be carefully controlled during the manufacture of high quality protein hydrolysate. The first consideration is the selection of appropriate substrate, i.e. the protein. Generally, for whey protein hydrolysates, whey protein concentrate or whey protein isolate is used, as these result in hydrolysates which are of high quality and have bland flavour. Casein is used as a substrate for casein hydrolysates. Next, selection of suitable enzyme is important. Enzyme must be approved food-grade type, and added at optimum level (enzyme/substrate ratio) required for hydrolysis. Hydrolysis of protein results in a decrease in the pH of the protein solution. Therefore regular pH adjustment is needed during manufacture. Generally, sodium hydroxide is used to adjust pH but if low-sodium hydrolysate is desired, potassium hydroxide can be used for pH adjustment. Throughout the process, pH, time and temperature are monitored and controlled which helps in producing high quality, nutritional and functional protein hydrolysates.

An important parameter for quality is the degree of hydrolysis (DH) where the higher value reflects higher level of hydrolysis. Hydrolysates should be selected based on flavour, degree of hydrolysis, bioactivity, and nutritional composition.

Hydrolysis of milk proteins leads to the formation of hydrophobic bitter peptides and the bitter taste of protein hydrolysates is a major barrier to their use in food and health care products. The intensity of the bitterness is proportional to the number of hydrophobic amino acids in the hydrolysate. The presence of a proline residue in the centre of the peptide also contributes to the bitterness. The peptidases that can cleave hydrophobic amino acids and proline are valuable in debittering protein hydrolysates. Aminopeptidases from lactic acid bacteria are available under the trade name Debitrase™.

Carboxypeptidase A has a high specificity for hydrophobic amino acids and hence has a great potential for debittering protein hydrolysates. A combination of an endo-protease for the primary hydrolysis and an aminopeptidase for the secondary hydrolysis is required for the manufacture of a functional hydrolysate with reduced bitterness.

Commercial milk protein hydrolysates are available in a range of degrees of hydrolysis and molecular weight profiles. Table 9 shows approximate composition and functional properties of commercial hydrolysates.

Table 9 Approximate composition and potential functionality and applications of milk protein hydrolysates

	Whey protein or casein hydrolysate			
Degree of hydrolysis (%)	<5	6–10	11–20	>20
Protein (%)	80–92	80–92	80–92	80–92
Amino nitrogen (%)	1–2	1–3	1–4	3–10
pH, 5% solids	6.0–7.6	6.0–7.6	6.0–7.6	6.0–7.6
Fat (%)	0.1–3.5	0.1–3.5	0.1–1.0	0.1–1.0
Lactose (%)	0.1–3.0	0.1–3.0	0.1–1.0	0.1–1.0
Ash (%)	2.0–4.0	3.0–4.0	3.0–4.0	3.0–5.0
Major differences	Improved physical functionality (solubility, emulsification, foaming, etc.)	High levels of medium chain peptides, high solubility and heat stability	High levels of short to medium chain peptides, reduced protein allergy, high heat stability, low lactose and low fat, reduced allergenicity	High levels of di- and tri-peptides and free amino acids; high heat stability, low lactose and low fat, reduced allergenicity
Potential food applications	Dry and liquid beverages, infant formula, sports nutritional products	High protein beverage powders, powdered diet supplements, infant, sports and enteral nutritional formulations	Hypoallergenic infant, sports and enteral formulations, high protein formulations	Medical and clinical nutritional formulations, hypoallergenic infant and sports nutritional formulations, lactose-free formulations

Protein hydrolysates: Functionality and applications

Milk protein hydrolysates can be used for the following bioactive or physiological functions:

- Reduced allergenicity and antigenicity
- Increased protein absorption
- Release of bioactive peptides

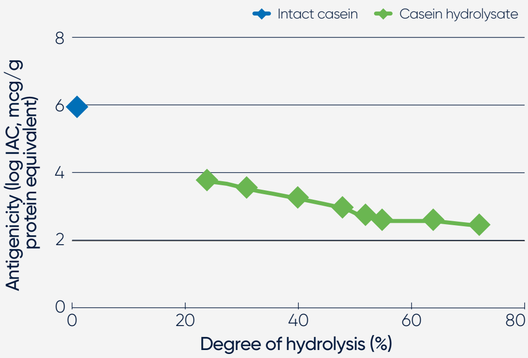
Reduced allergenicity

Due to the differences in the protein composition of human and cow milk, feeding of cow milk to human newborn babies can cause allergic reactions. Hydrolysis of cow milk proteins into smaller peptides reduces the risk of allergenicity and allows the use of hydrolysate as a substitute for human milk protein in infant formula especially for babies that are intolerant to intact milk proteins. Milk protein hydrolysates are also suitable for replacement of intact proteins in adult nutritional formulations where reduced allergenicity is needed. The antigenicity of a protein, i.e. its ability to induce an allergic reaction, is related to the size of protein, amino acid sequence, and presence of secondary and tertiary structures. The antigenicity of hydrolysates can be measured by an enzyme-linked immunosorbent (ELISA) inhibition assay that measures the amount of immunologically active protein. Intact casein shows a high value for immunologically active casein (IAC), at 106 µg/g protein equivalent (Figure 3). Increasing the degree of hydrolysis can decrease this value from 106 to 103 µg/g or below, as seen for casein hydrolysate in Figure 4.

Food applications that can benefit from reduced allergenicity are infant formula, adult nutritional formulations, isotonic sports formulations, enteral formulations and medical nutritional formulations.

26 Mahmoud *et al* (1992)

Figure 4 Allergenicity of casein and casein hydrolysate[26]



Increased protein absorption

Depending on the degree of hydrolysis, type of enzyme and conditions during hydrolysis, a range of peptides can be obtained from milk proteins. The decrease in the peptide size generally leads to an increase in absorption of peptides. Milk protein hydrolysates containing mostly di- and tripeptides are absorbed more rapidly than free form amino acids and much more rapidly than intact proteins. This is desirable for athletes who want to maximise the amino acid delivery to muscles, and to the patients with impaired absorption system.

Release of bioactive peptides

Hydrolysis of milk proteins may produce biologically active peptides that are usually buried inside the aggregated structures of protein molecules. Milk protein hydrolysates contain several biologically active peptides such as antihypertensive peptides. The antihypertensive effect of several peptides has been related to the inhibition of the angiotensin-converting enzyme (ACE). ACE activity results in blood pressure increase via conversion of angiotensin I to angiotensin II, which is a vasoconstrictive peptide, and via degradation of bradykinin, which is a vasodilative peptide. Inhibition of ACE, e.g. by peptides in milk protein hydrolysates, results in a decrease in blood pressure.

Milk-derived peptides

Milk protein peptides are made by hydrolysis of milk proteins. Research has shown that they have many physiological benefits including helping with control of blood pressure by working with the body's natural mechanism for controlling blood pressure. Dairy peptides only lower blood pressure when it is above normal and are intended for use by people who have been given diet and lifestyle advice to control their blood pressure. They are not intended as a replacement for blood pressure medication. They are found naturally in some cheeses such as Dutch Gouda and mature Cheddar, but the levels are too low to be useful.

Research studies have identified several bioactive peptides from milk proteins, however, only a handful companies have commercialised milk-derived peptides. One of the leading companies in this area is DMV International (**http://www.dmv-international.com**). Another company, Calpis has been selling milk peptides under the brand name Ameal that are available as food supplements. AmealPeptide™ are special dairy peptides that are added to some dairy drinks, such as Flora Pro Active blood pressure daily dose drink, which when taken daily can help to control blood pressure as part of a healthy diet.

One of the main hurdles in commercialisation of milk-derived peptides remains the high cost of extraction and the inability to make health claims under most regulatory environments. More innovation and commercialisation of milk peptides is anticipated soon as companies look for value-added, high return dairy ingredients and health claims regulations are simplified.

7.7 Milk minerals

Calcium and phosphorus are the major minerals required for the growth and development of bones and teeth. Calcium deficiency is far too common in diet, and awareness of this deficiency has led to calcium fortification of a range of food products including breakfast cereals and fruit juices. Although consumers consider milk and dairy products to be the richest sources of calcium, many have limited their consumption to reduce fat in their diets, or because of lactose intolerance. Commercial milk mineral complex is obtained from cheese whey after removal of proteins as protein concentrates, and lactose, as lactose powder. Milk minerals are a rich source of calcium used for calcium fortification of food and beverage products. A typical composition of a commercial milk mineral product (milk calcium) with 24% calcium is shown in Table 10.

Table 10 Typical compositions of milk minerals with 24% calcium

Component	Amount per 100 g
Moisture (free & bound) (g)	10.0
Protein (g)	5.0
Fat (g)	1.0
Lactose (g)	5.0
Ash (g)	78.0
Sodium (g)	0.5
Potassium (g)	0.15
Calcium (g)	24.0
Magnesium (g)	0.8
Phosphorus (g)	13.7
Phosphorus as phosphates (g)	39.0
Chloride (g)	0.20
Iron (mg)	11.0
Copper (mg)	0.1
Manganese (mg)	1.0
Zinc (mg)	48
Iodine (ug)	20

Milk minerals: Functionality and applications

Calcium in milk minerals is a highly bioavailable calcium phosphate which is a natural milk calcium complex. Dietary calcium has been linked to osteoporosis and bodily functions such as regulation of cell function, nerve conduction, muscle contraction and blood coagulation. Milk minerals are rich in calcium and milk calcium has been suggested to have the following bioactive functions:

- Prevention of osteoporosis and growth of healthy bones and teeth[27, 28]
- Control of blood pressure and cardiovascular disease[29, 30]
- Lowering the effect on hypertension[31]
- Prevention of colon cancer[32]
- Control of weight gain and obesity[33, 34]

Suggested applications of milk minerals include:

- Dairy products such as recombined milk, flavoured milk, yoghurt and cheese
- Nutritional and functional foods such as sports and adult nutritional beverages, weight loss products and sports bars
- Bakery products such as breads and cakes
- Confectionery products
- Breakfast cereals
- Convenience foods such as soups, sauces and frozen desserts
- Food supplements such as capsules and tablets

27 Cadogan *et al.* (1997)
28 Murphy *et al.* (1994)
29 McCarron & Reusser (1999)
30 Miller *et al.* (2000)
31 Hatton & McCarron (1994)
32 Holt (1999)
33 Zemel *et al.* (2000)
34 Davies *et al.* (2000)

Milk calcium

Several dairy companies are currently offering milk calcium made from either whey or milk permeate after ultrafiltration. Milk calcium is becoming an increasingly important source of calcium supplementation in the food industry. Recognised for its numerous health benefits, dietary calcium has proven to have positive effects on osteoporosis, healthy bones and teeth, hypertension and even certain cancers. The gap between calcium intake and recommended daily intake (RDI) is much wider than previously thought. Milk calcium is generally available as milk minerals with approximately 24% calcium. It has an advantage over other sources of calcium as it is considered natural, has a neutral taste and bland odour. Milk calcium helps manufacturers design products with a "clean label" and natural image. Some calcium suppliers offer different granulations for varied applications. Major applications of milk calcium include fortification of beverages and drinks.

One of the major applications of dairy calcium is now in weight control products. Success in this market could be very profitable for the dairy industry, as this market is likely to grow considerably soon.

Alpha iactalbumin

Some dairy companies have isolated α-lactalbumin from cheese whey using an ion-exchange technology and developed ingredients rich in α-lactalbumin. Davisco Foods (**daviscofoods.com**) in US has been marketing tryptophan-rich α-lactalbumin based on its ability to improve sleep and early morning performance by increased alertness.

A study carried out by Markus *et al* (2005)[35] showed a 130% increase in plasma tryptophan after the evening intake of a α-lactalbumin–enriched standard diet as compared with a placebo diet.

This was accompanied by reduced sleepiness and higher task-related brain activity the following morning, which suggests improved alertness due to better sleep.

Micellar casein

High concentrations of casein in micellar form can help create new opportunities for dairy proteins that exploit colloidal casein with naturally high calcium content. Kerry Ingredients has recently launched micellar casein under the brand name Micellnor™ that is specifically developed for use in sports nutrition and weight loss applications. According to Kerry, Micellnor™ generates a positive nitrogen balance in the body and promotes satiety. Slow amino acid release promotes muscle growth and recovery, thus preventing muscle breakdown. The slow release principle ensures that casein coagulates and aggregates in the stomach. This results in slow and prolonged digestion of proteins. Kerry Ingredients Micellnor™ is claimed as a native micellar casein product, produced from skim milk using a combination of membrane filtration technologies.

35 *Markus, CM, Lisa M Jonkman, Jan HCM Lammers, Nicolaas EP Deutz, Marielle H Messer, and Nienke Rigtering (2005). Evening intake of a-lactalbumin increases plasma tryptophan availability and improves morning alertness and brain measures of attention. Am J Clin Nutr 2005; 81:1026 –33.*

7.8 Milk Protein Concentrates (MPC) – overview of manufacture and composition

Milk protein concentrate (MPC) products refer to spray dried concentrated milk protein products that contain higher levels of casein and whey proteins and much lower levels of lactose compared with skim milk powder.

The generic term MPC refers to milk protein concentrate manufactured by:

- Blending of casein (caseinate) and whey protein (whey powder or WPC),
- Co-precipitation of casein and whey protein, or
- Ultrafiltration of skim milk to increase protein concentration followed by spray drying.

MPC products made by the three methods show considerably different functional properties and are suitable for a range of food applications (see Table 11). The blending of proteins is carried out either in a dry or a liquid form to obtain MPC with specific protein, lactose, and mineral profile. When MPC is made by dry blending proteins (e.g. caseinate and WPC), the product has less homogeneous functionality than the products made by co-precipitation or ultrafiltration. In the co-precipitation process, skim milk is heated (80-85°C at pH 6.0-6.4) in the presence or absence of added calcium, followed by acidification which results in casein-whey protein interaction and dissociation of casein micelles. The proteins are resolubilised by adjusting the pH to 7.0.

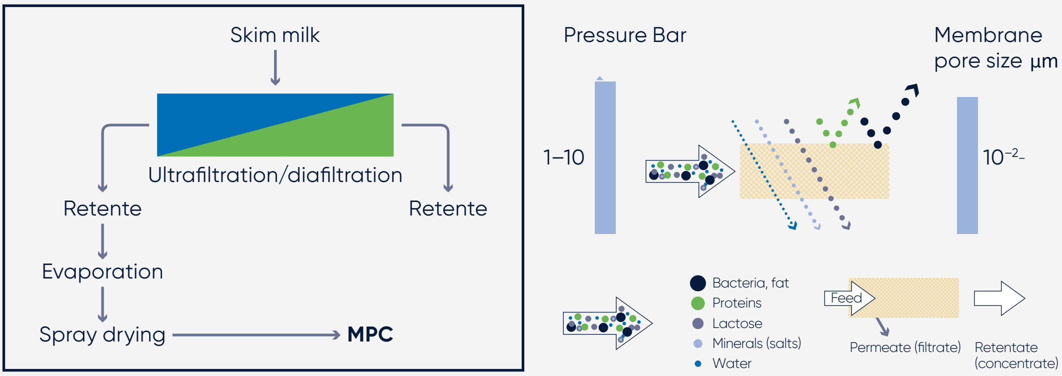
In Australia, MPC generally refers to the product manufactured by ultrafiltration (UF).

The process of UF involves use of semi-permeable membranes with molecular weight cut off of around 10,000 Daltons to concentrate both casein and whey proteins (Figure 5). The production of MPC with protein content above 65% generally requires an additional step of diafiltration which is used to wash out excess lactose and minerals. Diafiltration involves dilution of retentate with water followed by removal of that water as permeate via UF which flushes out more lactose and soluble minerals in the permeate.

Table 11 Comparison of manufacturing methods of MPC

	MPC by blending	MPC by co-precipitation	MPC by ultrafiltration
Starting Material	Casein (e.g. caseinate) and whey products (e.g. WPC)	Skim milk	Skim milk
Process	Dry or wet blending	Heat precipitation of low pH skim milk with or without calcium and resolubilisation to neutral pH	Ultrafiltration with or without diafiltration
Casein/WP ratio	Variable	80:20	80:20
State of casein micelle	Micelle dissociated to casein aggregates	Micelle dissociated	Mostly native micellar casein
State of whey proteins	Mostly undenatured	Denatured	Mostly undenatured
Casein whey protein interaction	No interactions	Casein whey protein interactions through disulphide bonds	Little or no interaction between casein and whey protein
Calcium concentration	Low	Medium for hi-calcium co-precipitate	Medium to high

Figure 5 Simplified process diagram for milk protein concentrate



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Commercially, MPC is often classified by the percentage of protein present, i.e. MPC 56 is MPC with 56% protein. Typical compositions of commercial milk protein concentrates are shown in Table 12.

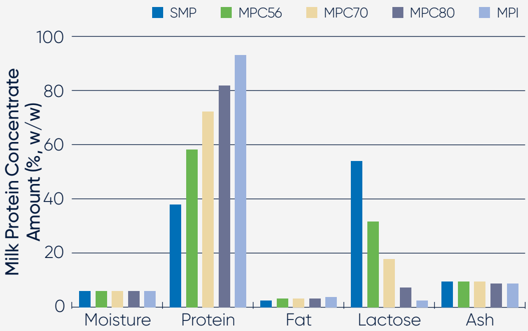
Table 12 Typical compositions of milk protein concentrates

	Amount per 100 g				
Attribute	SMP	MPC56	MPC70	MPC80	MPI
Moisture (g)	4.0	4.0	4.0	4.0	4.0
Protein (g)	36	56	70	80	90
Fat (g)	0.8	1.2	1.3	1.7	2.5
Lactose (g)	52	30	16	5.5	0.9
Ash (g)	8	7.6	7.5	7.3	7.1
Sodium (mg)	450	400	200	120	30
Potassium (mg)	1640	1000	800	380	200
Calcium (mg)	1250	2000	2100	2200	2200
Phosphorus (mg)	1050	1200	1400	1400	1400
Chloride (mg)	600	550	350	80	50

A comparison of the gross composition of MPCs is given in Figure 6. As seen in Figure 6, with increase in protein concentration, there is a corresponding decrease in lactose concentration. Although the total amount of minerals does not change significantly, the type of minerals changes as the protein concentration increases.

There is a gradual increase in the amount of colloidal minerals (due to the increase in the casein micelle concentration) and a decrease in the water soluble minerals such as chloride and potassium.

Figure 6 Comparison of major components of MPC



Functional properties and applications of MPC

MPCs are valuable protein ingredients that are suitable for a range of food applications. Appendix 1 summarises the selection criteria for milk protein concentrates based on functionality and applications.

Solubility

The solubility of MPCs depends on the protein concentration, temperature, and the amount of shear applied during mixing. As the protein concentration of MPC increases, the solubility is slightly reduced but this can be easily overcome by dissolving MPC at high temperature, allowing more time for the protein to stabilise, and adjusting the mixing conditions. Homogenisation of high protein MPC greatly improves the solubility. High protein MPCs, with improved solubility are also commercially available.

Good solubility of MPCs is important for their application in dry and liquid nutritional beverages (such as infant and enteral formulations), dairy products (such as recombined milk, ice cream, yoghurt and cheese) and other dry mixes (such as soups and gravies). Due to the presence of casein micelles and their ability to rennet, MPCs are preferred for fortification of cheese milk. Good solubility at room temperature is an important attribute for using MPC for cheese milk extension. Poorly soluble MPCs may result in a defect called "nugget" formation if not processed properly.

Under normal mixing conditions, MPC56 provides an excellent ingredient for extending milk solids but high protein MPCs with improved cold-water solubility can also be used.

Water binding and viscosity

MPCs have high water binding capacities due to their high protein levels. For protein concentrates with high solubility, the increase in protein content also increases the viscosity of the protein dispersion. Water binding and viscosity properties of MPC are useful in several food products including meat emulsions, soups and gravies.

Gelation and structure formation

Fortification of cheese milk (cheese milk extension) is an important application for MPC. The presence of casein micelles in MPC is considered particularly useful during renneting as the casein micelles behave like casein in cheese milk and thus help in rapid cheese curd formation. The gelation related functionality of MPC is useful in enhancing the firmness of rennet gel during the manufacture of cheese. Good dispersibility and solubility remains an important criterion for use of MPC in cheese milk extension because the casein micelles in MPC need to be rennetted by the chymosin enzyme. If the MPC has poor solubility, undesirable textural attributes, such as "nugget" formation is noticed in the cheese. Such cheese does not ripen well. Preferred MPCs for cheese milk extension are MPC56 and MPC70, as these generally have desired functional properties such as casein micelle hydration, solubility and rennet gel formation.

Heat stability

Dispersions made from MPCs are very heat stable and formulations containing MPC can be retorted (121°C for 16 min) or UHT (148°C for 3 s) treated. High heat stability of MPCs makes them particularly useful for manufacture of liquid nutritional beverages such as infant and enteral formulations. For nutritional formulations, MPCs with low or no lactose are generally preferred.

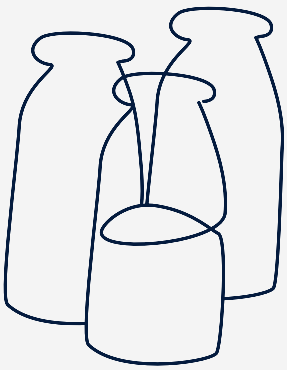
Examples of commercial products that can benefit from high heat stability of MPCs are recombined UHT milk, and infant and enteral formulations manufactured using UHT or retort.

Emulsifying properties

Milk proteins in MPC have excellent emulsifying properties that aid in the formation of oil-water emulsions which are important for products such as enteral formula and nutritional beverages. In low-lactose or lactose-free, protein-based enteral and other nutritional beverages, MPC85 or MPI can be successfully used. Such formulations have good heat stability and emulsion stability when subjected to high heat treatment such as UHT or retort sterilisation. Recommended food application using emulsifying properties of MPCs are recombined dairy products, infant formulation, and nutritional beverages needing oil-water emulsification.

Foaming and whipping properties

MPCs have excellent foaming and whipping properties derived from the presence of casein micelles and whey proteins in the ratio like that present in milk. MPCs can be successfully used for foam and foam stabilisation in the manufacture of products such as ice cream, whipped topping, and angel cakes.



MPC products: Applications and usage level

Usage levels of MPCs in food applications will depend on several factors such as type of application, desired compositional, nutritional and functionality requirements and intended processing conditions. Table 13 shows applications and usage levels of MPC products.

Table 13 MPC products – applications and recommended usage levels

Application	MPC56	MPC70	MPC80	MPI
Dairy				
Recombined milks (including chocolate milk)	4–6	4–6	3–5	2–4
Cheese milk extension	0.8–1.0	0.7–0.9	0.6–0.8	0.5–0.7
Ice creams	1–2	1–2	0.5–1.5	0.5–1.5
Yoghurts	2–5	2–5	1–3	1–3
Processed cheeses	2–5	2–5	2–4	1–3
Bakery & confectionery				
Breads	2–3	1–3	1–2	1–2
Cakes	3–5	2–5	1–3	1–3
Biscuits	3–5	1–3	1–2	1–2
Chocolates	2–3	1–2	1–2	1–2
Desserts	2–3	2–3	1–2	1–2
Meat products				
Sausages	2–4	2–3	1–2	1–2
Surimi	2–5	2–4	1–2	1–2
Convenience				
Sauces	2–4	2–3	1–2	1–2
Soups/gravies	1–4	1–4	1–2	1–2
Salad dressings	1–2	1–2	–	–
Nutritional products				
Infant formulae (liquid)	3–5	2–4	1–2	1–2
Enteral formulae (liquid)	–	3–6	2–5	2–4
Sports drinks	–	2–8	1–6	1–6
Sports bars	2–8	2–8	1–6	1–6
Dry mixes (including dry nutritional beverages)	15–30	15–30	8–15	4–10

7.9 Frequently asked questions (FAQ)

Colostrum

1. What is colostrum and how is it different from normal milk?

Colostrum is the first milk produced by the cow during the first 24-36 hours after calving and serves as the first natural food for a newborn calf. Colostrum is not only a source of nutrients such as fat, protein, carbohydrate, vitamins and minerals; it also contains several biologically active components that are present in minute quantities in normal milk. The most important bioactive components of colostrum are growth factors and antimicrobial factors that provide help in preventing infections.

2. Which calves could benefit from supplementation of diet with colostrum?

Colostrum supplementation is advised for calves for which colostrum from their mother is not available. Calves that are too weak to stand and suckle immediately after birth could benefit from high amounts of immunoglobulins and other growth factors from colostrum.

Glycomacropeptides (GMPs)

1. Why is GMP promoted as a "weight control" ingredient?

Research has shown that GMP stimulates synthesis and release of the hormone cholecystokinin (CCK) in the duodenum. The two important physical events triggered by CCK during digestion are the release of the pancreatic enzymes and the contraction and emptying of the gall bladder/hepatic bile duct. Pancreatic enzymes are critical for the complete digestion of fats, proteins and carbohydrates and therefore the full nutritional realisation of food. CCK has the effect of slowing the overall digestive process by slowing intestinal contractions, thus giving the digestive enzymes more time to work on their respective substrates. This results in more complete absorption of a given digestive loading. In fact, there is interest in GMP as an appetite suppressant for inclusion with other foods. The reason is by slowing digestion one perceives the "full" feeling longer (satiety effect) following a meal, possibly discouraging between- meal snacking. This process is likely to have an effect as a "weight control" agent in diet.

2. What is PKU and why is GMP suitable for PKU patients?

Phenylketonuria (PKU) is a rare, metabolic disorder that is inherited from ancestors. People with PKU cannot utilise the essential amino acid phenylalanine and its derivatives due to the absence of the enzyme needed for utilisation of phenylalanine. Consequently, a phenylketonuria person consuming a normal diet would accumulate high levels of phenylalanine, which may cause toxicity to the central nervous system and possible brain damage. Such persons are recommended special low-phenylalanine diets that provide adequate protein. High quality glycomacropeptide (GMP) is an ideal ingredient for phenylketonurics, as it contains negligible levels of phenylalanine.

Lactoferrin (LF)

1. How much LF can be added in food formulations?

The addition of LF to food products is generally based on the desired level of iron. The desired level of iron could vary from as little as 1 mg/100 mL for infant formula to as high as 7 mg/100 mL for a sports formulation.

2. How can LF be used in improving shelf life of meat products?

In 2002, the USDA approved the use of activated LF on fresh beef. Activated LF or lactoferricin, is a pepsin hydrolysate of LF. Lactoferricin has enhanced antimicrobial action in comparison to LF. This activated form has been shown to protect fresh beef against E. coli 0157:H7, Salmonella, Campylobacter and more than 30 types of other pathogenic bacteria. The activated LF prevents pathogenic bacteria from attaching to the surface of the meat and prevents their growth.

3. What is the best method for LF addition to acidified beverages such as drinking yogurt and sports drinks?

One of the important properties of LF is its suitability for low pH applications. Lactoferrin is stable at low pH and can be added to drinking yoghurt after preheat treatment, or after fermentation, or through mixing with the fruit preparation. In fruit yoghurt, LF can be added after the heat treatment of milk together with the starter culture or with the fruit preparation.

4. What are the main bioactive properties of LF?

The main bioactive properties of LF are derived from its ability to bind iron. These properties include:

- *Improved bioavailability of iron:* LF carries iron efficiently and helps in absorption of iron in the body
- *Antioxidant properties:* LF can be used as a natural antioxidant that can prevent oxidative damage to body tissues by controlling the production of free radicals
- *Antibacterial property:* LF binds and depletes iron in the environment, which limits the growth of bacteria. Action of pepsin in stomach converts LF into lactoferricin that has broad applications against pathogenic bacteria and yeasts. Furthermore, there are reports suggesting that LF interferes directly with bacterial cell surface thereby killing sensitive organisms
- *Antiviral properties:* Potentially, LF can inhibit the absorption of viruses to mammalian cells thereby preventing viral infection of cells
- *Immunomodulatory properties:* During microbial infection, LF provides anti-inflammatory activity and support.

5. What are the major applications of LF?

Potential food applications of Australian LF include functional foods, beverages, sports formulations, infant formulations, health supplements and animal feed. In food applications, LF can provide several health benefits such as antiviral and antibacterial activity, immune enhancement and antioxidation activity. Lactoferrin can also be used in cosmetics and oral care products, exploiting the antibacterial and antiviral benefits.

- Sports and infant formulations
- Chewing gum
- Mouthwash and toothpaste
- Veterinary and feed specialties
- Natural preservative in foods

Lactoferrin can be added in the range 10-100 mg per 100 g of product. This broad application range requires knowledge on effective incorporation of this bioactive component based on the prediction of its biological activity during processing, storage and use.

6. How does heat treatment such as pasteurisation affect the activity of LF?

Lactoferrin is heat sensitive as this affects its biological activity. However, formulation containing LF can be pasteurised at normal pasteurisation temperature i.e. 72°C for 16 s with less than 5% loss of bioactivity. Although pasteurisation causes minimal reduction in the activity, excessive heat treatment during processing can reduce its biological activity.

Lactoperoxidase (LP)

1. How do I use LP for preservation of meat?

Lactoperoxidase provides an anti-bacterial, preservative effect when used in combination with thiocyanate ion (SCN-) and hydrogen peroxide (H2O2). In combination, three ingredients form a system called LP system. The resultant product of the oxidation reaction is hypothiocyanite ion (OSCN-) that inhibits bacterial metabolism via the oxidation of essential sulphydryl groups in proteins.

The preservative effect of the LP System involves use of three ingredients:

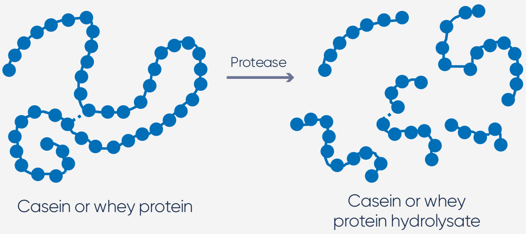
- LP at enzyme concentration of 1-20 mg/kg of meat
- Sodium or potassium thiocyanate ion at a concentration of 5-40 mg/kg meat (as thiocyanate ion)
- A source of hydrogen peroxide (H2O2) (in situ production using glucose oxidase which is an approved processing aid in some countries) at a concentration of 5-50 mg/kg meat.

Protein hydrolysates

1. What is enzymatic hydrolysis of milk proteins and how is it carried out?

Enzymatic hydrolysis involves breakdown of protein molecules into smaller peptides and amino acids through the action of a protease or a peptidase as seen below.

Figure 7 Enzymatic hydrolysis of milk protein



For manufacture of whey protein hydrolysate, a dispersion of whey protein concentrate (WPC) or whey protein isolate (WPI) is adjusted to temperature and pH which match the optimum conditions of the hydrolysing enzyme. The enzyme is then added and allowed to react with protein for a specified time. Sometimes more than one enzyme is added to optimise the hydrolysis for flavour and optimum size of peptide. After completion of hydrolysis the enzyme is deactivated, usually via heat treatment, and the milk protein hydrolysate is pasteurised. Subsequent treatments of the hydrolysate may include filtration, clarification, concentration and spray drying to make hydrolysate powders.

2. What are the benefits of protein hydrolysates and peptides over whole protein?

There are three main benefits of using milk protein hydrolysates and peptides over whole protein:

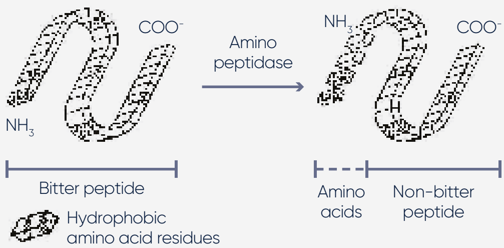
- The digestibility of proteins is improved which helps people with impaired digestive functions by providing essential amino acids in digestible form.
- The allergenicity associated with whole protein is reduced, which is particularly beneficial for infants or adults who are allergic to dairy proteins.
- The overall absorption of amino acids is improved, as the amino acids are already digested in hydrolysates and peptides. This is of particular interest to sports people who are at risk of negative nitrogen balance and need to get amino acids which absorb faster.

3. Why do some protein hydrolysates taste bitter, and how is bitterness reduced in commercial hydrolysates?

A major barrier in the wide acceptance of protein hydrolysates is the unpleasant bitter flavour of some products. Bitterness results from oligopeptides, which are formed by endoproteinases during the hydrolysis of native protein. The bitter taste develops after a certain degree of hydrolysis, when the peptides have molecular weight between 1,000 and 5,000 Daltons and high content of hydrophobic amino acids (leucine, isoleucine, proline, valine, phenylalanine, tyrosine and tryptophan). Almost all peptides containing these amino acids tend to be bitter, with intensity proportional to the number of hydrophobic amino acids and the size of the peptide. Depending on their share in the total protein, one can predict the tendency to bitter peptide formation during hydrolysis. As caseins contain more hydrophobic amino acids than whey proteins, hydrolysates from casein result in bitterness even at a low degree of hydrolysis.

Commercially, protein hydrolysates with little or no bitterness have been manufactured. Methods tried for removing bitterness include adsorption to active carbon, binding to ion exchange resins, plastein reaction or masking, but most have been discarded for technical or economic reasons. More success has been achieved with exopeptidases that attack the protein molecule only at the N- (aminopeptidases) or C-terminal end (carboxypeptidase) and split off small peptide fragments or amino acids. Aminopeptidases such as Debitrase™, remove single or pairs of amino acids from the N-terminal of a peptide chain rendering the peptides free from bitterness (see the Figure below).

Figure 8 Debittering effect of an aminopeptidase[36]



During hydrolysis, letting proteinase and aminopeptidase act at the same time can reduce bitterness. In this case, the process is conducted beyond the degree of hydrolysis at which the bitter point would have been reached with proteinase alone. In addition, a two-step process can be used to reduce the bitterness in the hydrolysate. In the two-step process, the conventional proteinase is allowed to act in the first step at which the bitter point is exceeded. In the second step, the aminopeptidases are given the opportunity to break down the bitter peptides. Although proteinases with natural exopeptidase activities already shift the point of unpleasant bitterness very noticeably, the pure aminopeptidases will shift that point much further and further reduce bitterness to very low levels

4. What can be done to improve the emulsifying properties of protein hydrolysate?

As the process of hydrolysis breaks down the large macromolecules of protein into smaller polypeptides, the amphiphilicity of protein is reduced thereby reducing the ability to emulsify fat. Stable emulsions such as infant and adult nutritional formulations with protein hydrolysate, can be manufactured by appropriate manipulation of emulsifying conditions and by using suitable emulsifiers. Often a combination of the two is required to make stable emulsions that can withstand high temperature treatment.

5. What is ACE-I activity and how can protein hydrolysate and peptides help in hypertension?

Angiotensin converting enzyme (ACE) is a key enzyme involved in the regulation of blood pressure. The ACE inhibitors (ACE-I) work by blocking (inhibiting) the enzyme that converts the inactive form of angiotensin (angiotensin I) in the blood to its active form (angiotensin II). Angiotensin-II is a very potent vasoconstrictor and leads to high blood pressure (also called hypertension). Hypertension is the most important cause of human deaths in affluent countries. Hypertension affects over 80 per cent of diabetics and is one of the primary risk markers for metabolic syndrome. Protein ingredients, such as hydrolysates and peptides with ACE-I activities, help in lowering hypertension and risk of related diseases.

6. What is the importance of branched chain amino acids (BCAAs), and which protein products provide high amounts of BCAAs?

The branched chain amino acids (BCAAs) are leucine, isoleucine and valine. BCAAs are considered essential amino acids because human beings cannot survive unless these amino acids are present in the diet. These amino acids are particularly useful for athletes and sports people in general. BCAAs are needed for the maintenance of muscle tissue and appear to preserve muscle stores of glycogen (a storage form of carbohydrate that can be converted into energy).

36 Pawlett D and Bruce G (1996)

BCAAs also help prevent muscle protein breakdown during exercise.

During sustained exercise, muscle BCAAs are used for energy and NH3 production. The subsequent increase of free tryptophan to BCAA ratio is thought to increase the tryptophan availability for serotonin synthesis. This can cause sleep and could increase the mental effort necessary to maintain athletic activity. BCAA supplementation before and during exercise may therefore delay fatigue and improve athletic performance. Research suggests that regular supplementation with BCAA can prevent central fatigue by preventing tryptophan from entering the brain. However, more research is needed to support such findings further. Whey protein products originating from acid whey contain higher amounts of BCAAs than those from cheese whey.

Milk minerals

1. What are the advantages of using milk calcium over commercial calcium salts such as calcium carbonate and calcium phosphate?

There are several sources of calcium available in the market including those from non-dairy sources. Milk calcium is a 100% natural source of calcium derived from milk. In addition to calcium, milk calcium may contain protein and other nutrients such as minerals that are not available from non-dairy calcium salts. The flavour of milk calcium is superior to other calcium salts. The absorption of dairy calcium is considered superior to other sources since it is present with other minerals such as phosphorus, which are essential for bone metabolism. Milk calcium contains a calcium: phosphorus ratio of approximately 1.7:1 that is considered optimal for bone absorption (optimal range 0.2-2.0).

2. Is the milk calcium more bioavailable than other calcium salts?

Several clinical studies have been carried out on bioavailability of dietary milk calcium. While milk calcium is bioavailable, studies have not found it significantly higher than the bioavailability of calcium from other sources. Bioavailability of calcium is influenced by the several factors including the level of calcium intake, vitamin D status, phytates, oxalates, caffeine, lipids, phosphopeptides, proteins, lactose and phosphorus. A review on calcium and bone health showed a positive effect of dairy calcium on bone health and the prevention of osteoporosis[37]. The flavour of milk calcium is generally superior to other calcium salts.

3. How can we avoid sedimentation of milk minerals in liquid beverages such as a nutritional beverage?

Two strategies can be used to optimise the use of milk minerals in liquid beverages:

- Using micronised milk minerals and controlling viscosity. The sedimentation of particles in a beverage is governed by the movement of particles and can be roughly predicted by the Stokes Law, according to which the rate of movement of particles is directly proportional to the diameter of particles and the density difference between the particle and the surrounding medium, and inversely proportional to the viscosity of the liquid. Thus, by reducing size (by micronisation) and increasing viscosity (using a stabiliser), the rate of separation of milk minerals can be reduced.
- Using appropriate hydrocolloid stabilisers that create a weak three-dimensional network and a yield stress in the formulation. The yield stress needs to be just sufficient to hold the minerals, as too much yield stress may impart an undesirable appearance (gel-like structure) to the beverage.

37 Kun *et al*. (2001)

Milk Protein Concentrates (MPCs)

1. What are the advantages of using MPC over SMP?

MPCs contain both casein and whey proteins almost in the same proportion as present in skim milk (*i.e.* 80% casein and 20% whey proteins). Therefore, proteins in MPC have similar functional properties to those in SMP. MPCs can be used to replace SMP for recombined milk type applications where the products requires low lactose, as MPCs contain considerably lower amounts of lactose than SMP. Depending on the product being manufactured, formulations using MPC are sometimes better suited and more cost effective than using SMP.

2. What are the differences between MPC and caseinates - sodium and calcium? Can MPC be used to replace caseinates in food applications?

The major differences between MPC and caseinates are in the state of the casein and the level of whey proteins. The caseins in MPC are present in the form of casein micelles whereas in sodium caseinate, caseins are in "random coil" aggregates. In calcium caseinate they are present as calcium-linked large aggregates (sometime called artificial micelles). MPC also contains whey proteins in the same proportion as present in milk, whereas caseinates contain no whey proteins. In most applications caseinates can be replaced by MPCs.

3. What are the main applications of MPC?

Due to the relatively unaltered structure of the protein components, these products are increasingly expanding into the dairy and nutritional foods. MPCs can be used as replacement ingredients for SMP, caseinates or whey protein concentrates (WPCs). Compared with skim milk powders, MPCs have less lactose and higher proportions of protein, and casein: whey protein ratio virtually identical to SMP. Milk protein concentrates are particularly suited for use in recombined white cheeses, cream cheese spreads, and fresh cheeses such as fromage frais and labneh. In recombined cheeses, the use of MPC 56 also eliminates the need for whey drainage and disposal as carried out in the traditional cheese making process, due to the high protein and low lactose composition of the product. Thus, these products can be manufactured on existing recombining equipment without the need for specialised cheese making equipment. Water usage at the reconstitution stage is also reduced. MPCs are also suitable for nutritional drinks or special diet formulations (e.g. enteral formulations) where elevated protein levels are desirable.

4. What factors influence the functionality of MPCs in cheese application?

The main factors affecting the functionality of MPC in cheese milk are the solubility and hydration of MPC. Poor solubility of MPC in cheese milk can lead to the formation of dry, gel-like particles in the cheese matrix. Therefore, it is important that MPCs with high solubility are chosen for this application. Adequate hydration of casein micelles from MPC allows the micelles to take part in the rennet-induced gelation and cheese structure formation. Solubility of MPC at room temperature can be improved by heating or homogenisation of MPC dispersions and allowing more time for hydration and stabilisation of the proteins.

7.10 Glossary

ACE - I

Angiotensin converting enzyme (ACE) is a key enzyme involved in the regulation of blood pressure. The ACE inhibitors (ACE-I) work by blocking (inhibiting) the enzyme that converts the inactive form of angiotensin (angiotensin I) in the blood to its active form (angiotensin II). Angiotensin-II is very potent vasoconstrictor and leads to high blood pressure (also called hypertension). Hypertension is the most important cause of human deaths in affluent countries.

Antimicrobial components

Antimicrobials are biologically active components that protect against bacterial infections and enhance immunity. Antimicrobial components of milk include growth factors, lactoferrin, lactoperoxidase and lysozyme.

Antioxidant

An antioxidant is a chemical that prevents the oxidation of other chemicals. In biological systems, the normal processes of oxidation (plus a minor contribution from ionising radiation) produce highly reactive free radicals. The free radicals can readily react with and damage other molecules and body cells.

Bioactivity

The physiological functional role of a food component is called bioactivity. Examples of bioactivity include anti-hypertensive activity of peptides from milk, and antibacterial and immune enhancing properties of lactoferrin.

Casein hydrolysate

Peptides of casein obtained by enzymatic hydrolysis of casein or caseinate

Colostrum

Colostrum is the first milk produced by a cow after the birth of a calf. Colostrum is a rich source of antibodies, growth factors and nutrients for the suckling neonate, and may provide passive immunity to the newborn against various infectious microorganisms, particularly those that affect the gastrointestinal tract.

ELISA

ELISA, enzyme-linked immunosorbent assay is a sensitive laboratory method used to detect the presence of antigens or antibodies of interest in a wide variety of biological samples. An ELIZA method can be used to measure the antigenicity of milk proteins and hydrolysates.

Functional food

Functional foods refer to foods and food components that provide health benefits beyond basic nutrition. Functional components may be naturally present (e.g. broccoli) or obtained from dietary supplements (e.g. vitamins and minerals) or fortified in foods (e.g. health drinks).

Growth factors

Growth factors are bioactive proteins present in colostrum, milk and whey. Growth factors are key regulators of a variety of cellular functions and are involved in the control of tissue growth and repair. Extensive research has identified several applications for their use in clinical medicine and biotechnology. Commonly identified growth factors are insulin-like growth factors-1 and 2 (IGF-1 and IGF-2), transforming growth factors – β1 and β2 (TGF-β1 and TGF-β2) and epidermal growth factor (EGF).

Hydrolysis

Enzymatic hydrolysis involves breakdown of protein molecules into smaller peptides and amino acids through the action of a protease or a peptidase. Hydrolysis of protein improves its functional properties, improves its digestibility and releases bioactive peptides.

Lactoferrin

Lactoferrin is an iron-binding glycoprotein (carbohydrate containing protein) present in colostrum, milk and whey. The iron-binding ability of LF is responsible for many biological functions such as bacteriostatic effect, growth-promoting effect on certain cell lines, prevention of lipid peroxidation and promotion of iron absorption in the body.

Lactoperoxidase

Lactoperoxidase [EC 1.11.1.7] is an enzyme present in colostrum and milk, with a molecular weight of approximately 77.5 kDa. Bovine colostrum and milk contain about 11-45 mg/L and 13-30 mg/L LP respectively. The biological significance of LP is its involvement in the natural host defence system against invading microorganisms.

Membrane filtration

Membrane filtration refers to the processes of separation of proteins, carbohydrates and minerals using semi permeable membrane fractionation of proteins using polymers and ceramic filters. The separation is based on molecular weight or molecular size. Membrane filtration is generally a cross-flow pressure-driven process. Four major membrane filtration processes are: reverse osmosis, nanofiltration, ultrafiltration and microfiltration. WPC and MPC are generally manufactured using the ultrafiltration process.

MPC

Milk protein concentrates generally refer to protein powders obtained by ultrafiltration of skim milk. MPC contains caseins and whey proteins in almost similar ratio to that present in skim milk, i.e. 80% casein and 20% whey proteins. As in SMP, the caseins in MPC are present as casein micelles. The protein content in MPC varies from 56 to 85%.

MPI

Milk protein isolate – refers to milk protein concentrate with protein content of more than 90%.

Milk minerals

Milk minerals are obtained from cheese whey after removal of proteins and lactose. Milk minerals are a rich source of calcium and used for calcium fortification of food and beverage products.

Peptide

Peptides refer to segments present in protein molecules formed by joining amino acid residues. The link between one amino acid residue and the next is an amide bond, and is sometimes referred to as a peptide bond.

Permeate

The low molecular weight "materials" or "components" passing through membrane filters during the manufacture of WPC and MPC is known as permeate. Permeate from Ultrafiltration mostly contains all the lactose and minerals. After removal of lactose by crystallisation, permeate forms the basis for the manufacture of milk minerals and milk calcium powders.

Physical functional properties

Physical functional properties refer to attributes that contribute to physical properties such as viscosity, gelation, foaming and emulsification in water (aqueous functionality) or in food products (food system functionality).

Physiological functional properties

Physiological functional properties refer to the biological activity or bioactivity of proteins.

PKU

Phenylketonuria (PKU) is a rare, inherited metabolic disorder. People with PKU cannot utilise the essential amino acid phenylalanine and its derivatives due to the absence of the enzyme needed for utilisation of phenylalanine. Consequently, a phenylketonuria person consuming a normal diet would accumulate high levels of phenylalanine, which may cause toxicity to the central nervous system and possible brain damage.

Prebiotic

Prebiotics refer to ingredients that promote the growth of probiotic bacteria. Examples of prebiotics are oligosaccharides such as fructo-oligosaccharides or inulin.

Probiotic

Probiotic refers to a substance containing beneficial live microorganisms that claim to be beneficial to humans and animals, e.g. by restoring the balance of microflora in the digestive tract. Examples of probiotic bacteria are acidophilus and Bifidobacteria.

Retentate

During the process of membrane filtration, the concentrated material retained by the membrane is termed as the retentate.

Solubility

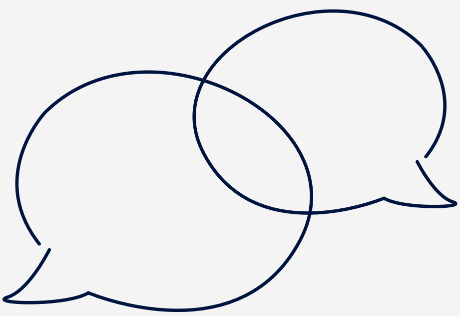
Solubility of protein powders refers to the ability of the particles to uptake water and solubilise. Solubility of proteins relates to surface hydrophobic (protein-protein) and hydrophilic (protein-solvent) interactions with water. Among all the functional properties, solubility is the most important.

Viscosity

Viscosity refers to the resistance of a solution to flow and visually it refers to the thickness of the solution. Viscosity of protein solutions is largely dependent on the concentration and status of proteins. Viscosity is important in providing physical stability of dispersions and emulsions and contributes to the mouthfeel of food products.

Whey protein hydrolysate

Peptides of whey proteins obtained by enzymatic hydrolysis of whey proteins.



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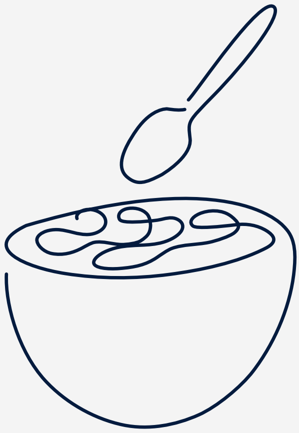

Appendix 1 Selection of milk protein concentrate based on functional properties and food applications

	Functional property	Flavour enhancement	Nutrition enhancement	High protein	Low lactose	Dispersibility	Solubility at 20°C
Milk protein product	MPC56	♦	♦			♦	♦
	MPC70	♦	♦	♦		♦	♦
	MPC80		♦	♦	♦	♦	
	MPI		♦	♦	♦	♦	
Dairy	Recombined milk	■	■	■	■	■	■
	Cheese milk extension			■			■
	Ice cream	■	■	■		■	■
	Yoghurt		■	■		■	
	Processed cheese	■		■	■		
Bakery & confectionary	Bread	■	■	■	■		
	Cake	■	■	■	■		
	Biscuits	■	■	■	■		
	Desserts	■	■	■	■		
Meat products	Chopped meat	■	■	■			
	Sausage	■	■	■			
	Surimi	■	■	■			
Convenience	Sauce	■	■	■		■	
	Soup/gravy	■	■	■		■	
	Salad dressing	■	■	■		■	
Nutritional products	Infant formula		■	■	■	■	■
	Enteral formula		■	■	■	■	■
	Nutritional beverages		■	■	■	■	■
	Sports bar	■	■	■	■		

Solubility at 45°C	Solubility at 65°C	Water binding	Fat binding	Viscosity	Heat stability	Emulsification	Foaming
♦	♦	♦			♦	♦	♦
♦	♦	♦	♦	♦	♦	♦	♦
♦	♦	♦	♦	♦	♦	♦	♦
♦	♦	♦	♦	♦	♦	♦	♦
■	■				■	■	
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08 Whey Products

Content

8.1 Introduction

Whey products are now well-established dairy ingredients marketed for their nutritional, physical, physiological and functional properties. Due to the availability of a diversified range of whey-based dairy ingredients, the selection of a suitable ingredient has now become a challenge. This requires considerable interaction between the manufacturer and the user of the ingredient. Good understanding of physico-chemical properties of ingredient components and processing conditions used during the manufacture of ingredients can provide helpful guidelines in identifying relevant functionality. However, this alone does not guarantee an optimum functional performance of whey products in a food application.

Optimisation of the functional performance in a food system also requires additional knowledge of the constituent ingredients of food applications and potential interactions with the components of the dairy ingredient. If dairy ingredients are selected simply based on the type of powder or a perceived functionality, there may be inconsistent functional performance in food products. This chapter simplifies some of the issues in relation to understanding the functionality and applications of whey products.

8.2 Whey products – overview of manufacture and Quality

Whey is the by product from cheese or casein manufacture which is largely casein free and fat free. In the past, manufacturers focusing on the cheese and casein products found it difficult to utilise the whey. Some manufacturers simply dumped the whey creating environmental pollution, while others either fed it to pigs or sprayed it on farmlands. Although manufacturers knew that whey was a rich source of nutrients, they simply did not have the technology or the knowledge to cost-effectively extract nutrients from whey. Since the availability of membrane processes such as Ultrafiltration in the 1970s, manufacturers have established new methods for manufacture of a range of dried whey products and demonstrated their significant health and nutritional benefits.

Whey – types, composition and processing

The source of the whey is one of the most important factors affecting the composition, processing, and functionality of whey products. In the dairy industry, there are two types of whey available:

- Sweet whey (pH 6.00-6.50)
- Acid whey (pH 4.50-4.70)

Sweet whey is obtained during the manufacture of cheese (such as Cheddar and Mozzarella) and rennet casein, while acid whey is obtained during the manufacture of acid casein (mineral, lactic acid casein) or some fresh cheese varieties such as cream cheese and cottage cheese). More recently, due to the growth of Greek yoghurt in the US, there has been a significant growth in availability of acid whey from Greek yoghurt. The major differences between sweet and acid whey are in pH and mineral levels. (Table 1). The pH of the sweet whey is considerably higher than that of the acid whey. The acid whey contains higher amounts of minerals than sweet whey as the acidification moves colloidal calcium phosphate and other minerals from the casein micelle into the whey. The compositional differences between sweet and acid whey significantly influence the functionality of whey products manufactured from different whey types.

Table 1 Composition: Sweet Whey Vs Acid Whey

Constituent	Sweet whey	Acid whey
Total solids (%)	6.6	6.5
Water (%)	93.5	93.5
Fat (%)	0.04	0.04
Protein (%)	0.60	0.60
Lactose (%)	4.80	4.90
pH	6.2	4.6
Lactic acid (%)	0.05	0.40
Ash (total minerals) (%)	0.50	0.78
Calcium (%)	0.04	0.12
Phosphorus (%)	0.04	0.06
Sodium (%)	0.05	0.05
Potassium (%)	0.16	0.16
Chloride (%)	0.11	0.11

Whey processing

Whey is a rich source of functional and nutritional components and thus can be processed into a range of whey products. Figures 1- 3 show typical processing protocols for whey for the manufacture of whey products. Typically, whey is clarified to remove casein and cheese curd particles, and thereafter the bulk of the fat is removed as whey cream using centrifugal separation. Microfiltration (MF) can be used to further decrease the fat content as fat adversely influences the functional properties of whey protein products. However, MF can add extra costs to the processing so manufacturers use MF only if necessary. Once clarified and separated whey is pasteurised at 72 °C for 15 seconds and subsequently converted to a range of whey products with varying protein, lactose and mineral concentrations. Process-induced modifications, such as preheating and drying conditions and salt levels are manipulated to develop ingredients with functionalities tailored to specific food applications. Further modifications during drying, such as agglomeration and lecithination, are also commonly used to improve handling and dispersibility of dry whey products.

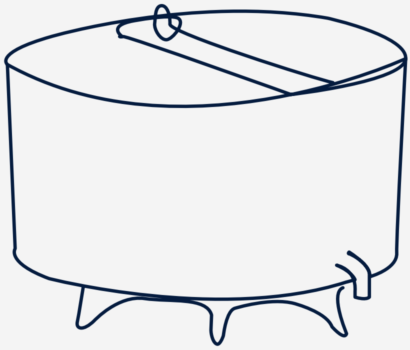


Figure 1 Typical processing of whey during manufacture of whey products

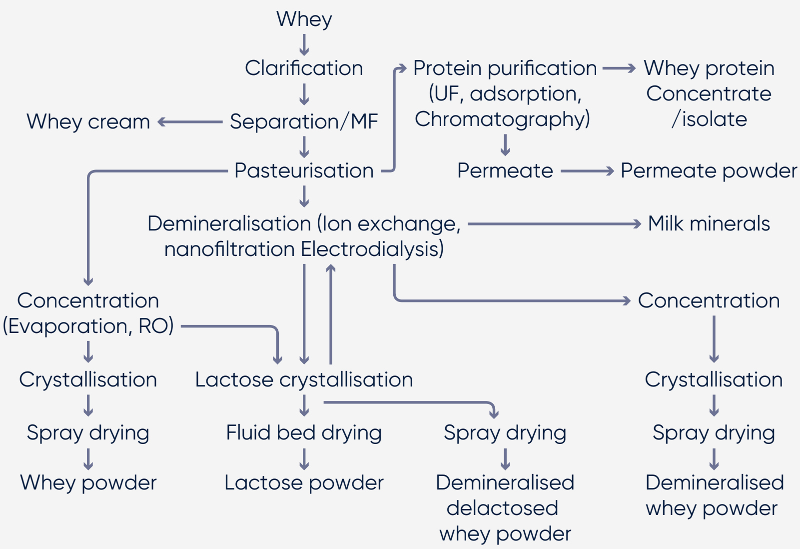
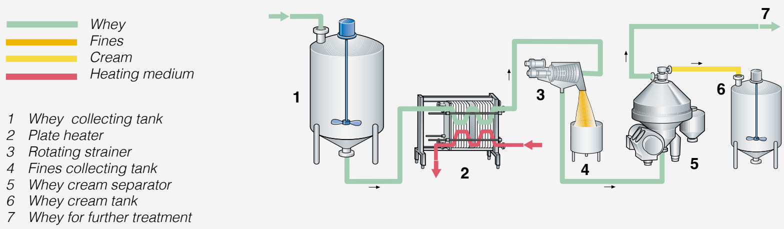
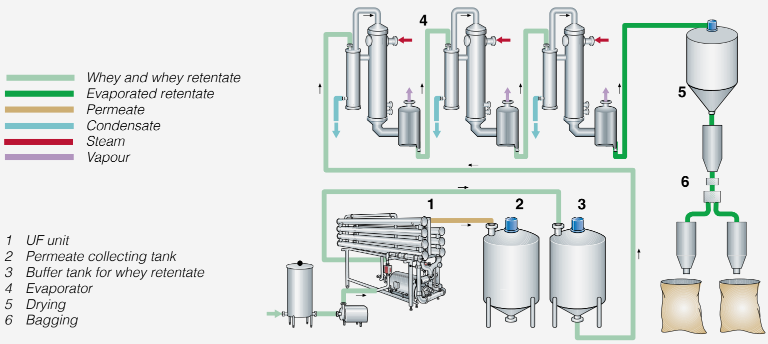


Figure 2 Whey fines and fat separation



Dairy Processing Handbook

Figure 3 Production of a dried whey product using Ultrafiltration (UF)



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Whey protein ingredients

For nutritional and functional reasons, protein is one of the most valuable components in whey and thus a range of protein rich products are manufactured from whey. Table 2 shows the approximate composition of major whey protein products. Generally, for each whey protein product, several variations are available depending on the desired functionality in a food system. For example, WPC80 is available as high heat stable, high gelling, or high emulsifying types. Similarly, demineralised whey with 90% demineralisation (D-90) is widely used as a source of whey proteins in the manufacture of infant formula.

Figure 4 compares the major constituents of whey protein products. As protein concentration increases, there is a corresponding decrease in lactose and ash (minerals) levels. The fat content of WPC generally increases as the protein content increases.

This is because the process of ultrafiltration used for protein concentration also retains the fat in whey. However, in WPI, the fat content is extremely low because the additional step of microfiltration (MF) is used to remove fat. Alternately, proteins are separated by chromatography and concentrated so fat is virtually excluded from the product.

Figure 4 Comparison of Major Constituents of Whey Protein Products

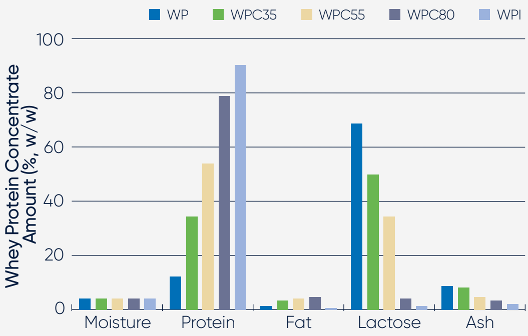


Table 2 Approximate Compositions of Whey Protein Products

	Amount per 100 g				
Attribute	**Whey powder**	**Demineralised whey powder (40% demineralisation)**	**Demineralised whey powder (90% demineralisation)**	**WPC35**	**WPC55**
Moisture (g)	4.0	4.0	4.0	4.0	4.0
Protein (g)	12.0	12.5	18.5	35	55
Fat (g)	1.5	1.0	1.0	3.0	4.0
Lactose (g)	70.0	77.5	82.5	51	35
Ash (g)	8.5	6.0	1.0	8.0	4.5
Sodium (mg)	780	425	12.0	430	500
Potassium (mg)	1470	680	250	1720	500
Calcium (mg)	420	180	4.0	1180	450
Phosphorus (mg)	930	550	14.0	500	350
Chloride (mg)	360	210	50	220	400

Table 2 (continued)

Attribute	**Whey powder**	**WPC80**	**WPI Chromatography**	**WPI Microfiltration**
Moisture (g)	4.0	4.0	4.0	4.0
Protein (g)	12.0	80	90	90
Fat (g)	1.5	5	0.5	0.2
Lactose (g)	70.0	4	1	0.5
Ash (g)	8.5	3.2	3.7	1.6
Sodium (mg)	780	130	700	230
Potassium (mg)	1470	480	1100	590
Calcium (mg)	420	400	150	490
Phosphorus (mg)	930	270	300	240
Chloride (mg)	360	290	50	50

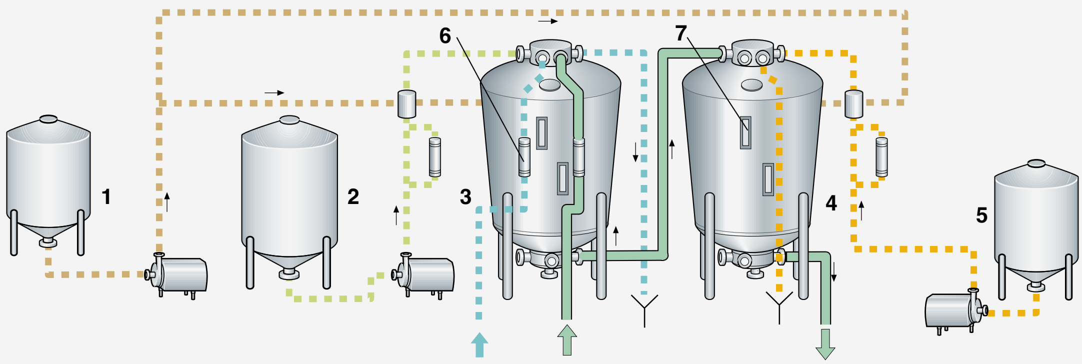
Whey powders

The simplest and cheapest of the whey products are the whey powders which are manufactured by spray drying of concentrated and crystallised whey. As whey contains relatively high salt content on a dry weight basis (8-12%), its use as an ingredient in human food is limited. However, if it is demineralised to reduce the salt, its uses can be greatly increased, especially as an ingredient in infant formula. Using the processes of ion-exchange, electrodialysis and nanofiltration, the whey can be partially demineralised (25-30%) or highly demineralised (90-95%) depending on the end use.

Typically, demineralised whey powders have 40%, 70% or 90% demineralisation (see Table 2). Demineralisation at 90% is typically carried out by a combination of Nanofiltration and ion-exchange. The latter process involves the use of resin beads in fixed columns to adsorb minerals from the whey solution in exchange for other ionic species. The process involves cation exchange and anion exchange in separate columns. A process overview is shown in Figure 5.

Other whey products include delactosed whey powder which is made from liquid delactosed whey. This delactosed whey is a by-product from the manufacture of lactose from whey or from whey permeate.

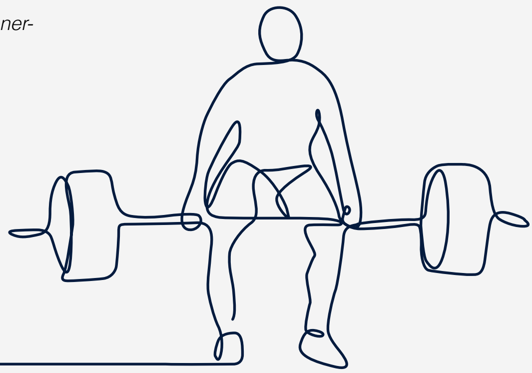
Figure 5 Demineralisation of cheese whey by Ion-Exchange



1 Disinfection tank
2 HCl tank
3 Cation tank
4 Anion tank
5 NaOH tank
6 Flow meter
7 Sight glass

Whey
HCl
Service water
NaOH
Disinfectant

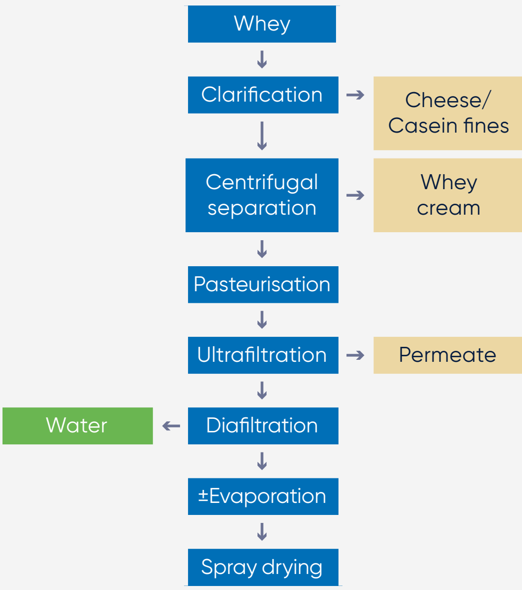
The dotted lines are used in the regenerative and sanitation phases.



Whey protein concentrate

Whey protein concentrates (WPCs) are preferred over whey powders in protein-enriching applications. WPCs contain proteins at 35 - 80% levels and correspondingly reduced amounts of lactose and minerals. WPCs are manufactured either by ultrafiltration, diafiltration or by ion exchange chromatography. A simple process flow diagram for manufacture of WPC is shown in Figures 3 & 6.

Figure 6 Major steps used in the manufacture of WPC



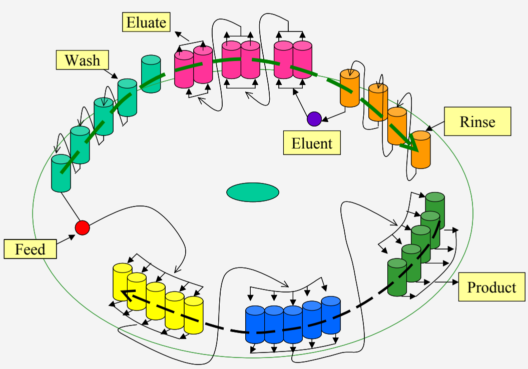
Ultrafiltration uses semi-permeable membranes to separate whey components based on selective molecular weight and structure. The applied pressure forces the water and the smaller molecules (minerals and lactose) through the membrane (permeate) while retaining whey protein molecules (retentate).

For 80% WPC, the retentate is diluted with water (termed as diafiltration) and further concentrated through ultrafiltration. The diafiltration step removes excess lactose and minerals which helps in raising the protein levels.

Whey protein isolate

When protein content of WPC is above 90%, the products are generally known as whey protein isolates (WPIs). Whey protein isolate is commonly manufactured by either (a) ion exchange followed by concentration and spray drying, or (b) microfiltration followed by ultrafiltration and spray drying. In the manufacture of WPI by ion exchange, the pH of clarified whey is lowered to 3.0-3.5 and passed through ion exchange resins where most of the proteins are adsorbed which are subsequently eluted and the pH is readjusted. The protein solution is then concentrated by evaporation, ultrafiltration or reverse osmosis and spray dried. The ion exchange process is generally carried out using a batch process. Recently, a similar but continuous ion exchange chromatographic separation process has been adopted by some companies[1]. Continuous chromatographic method allows separation of component of mixtures down to the molecular level. A simple flow diagram for a continuous ion exchange (ISEP) chromatography is shown in Figure 7.

Figure 7 A simple flow diagram for continuous ion exchange chromatography (ISEP)[2]



1 tsk-g.co.jp/en/tech/equip/ion.html
2 From Calgon Carbon Corporation

In the process, whey passes through a vertical column filled with a solid sorbent and depending on the degree of attraction between the separating molecules and the sorbent, molecules migrate at different rates and are physically separated and collected.

In the microfiltration process, whey is pressure driven through ceramic membranes or polymeric filters where these act as molecular sieves. This is followed by ultrafiltration and spray drying. Microfiltration is a continuous membrane process which removes virtually all the fat in whey based on the much larger size of fat molecules compared with proteins and carbohydrates.

The major difference between the ion exchange and the microfiltration processes is that the WPI produced using the ion exchange method does not contain glycomacropeptide (GMP) originally present in sweet whey. Other differences are in the levels of individual proteins and mineral contents (see Table 2).

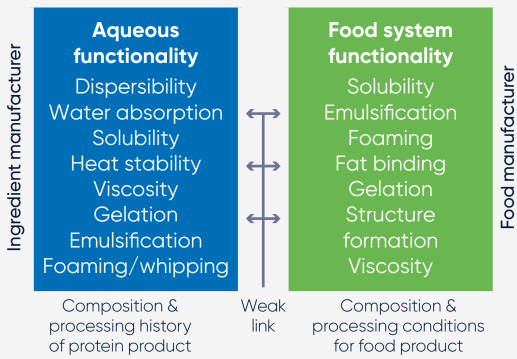
Factors for selection of whey protein products for applications

Whey protein products are suitable for a range of food applications. The selection of a suitable protein product is based on a number of factors such as price, availability, nutrition and functionality of the product. A major factor is the composition of the product especially the levels of protein, lactose or minerals. Another important factor is the desired nutritional or functional performance in the final product.

8.3 Functional properties and applications of whey protein products

Functional properties are those physico-chemical properties that determine the performance of the whey product in water (aqueous functionality) or in food systems (food system functionality). Functional properties of whey proteins are governed by intrinsic factors such as amino acid composition, protein structure, level of denaturation, aggregation and the surface charge. Other factors such as whey composition, processing conditions, temperature, pH and ionic strength also play important roles in determining the functionality of protein ingredients. Figure 8 summarises the relationship between "aqueous functionality" and "food system functionality".

Figure 8 Relationship between functional properties of whey protein products in water ("aqueous functionality") and in food products ("food system functionality")



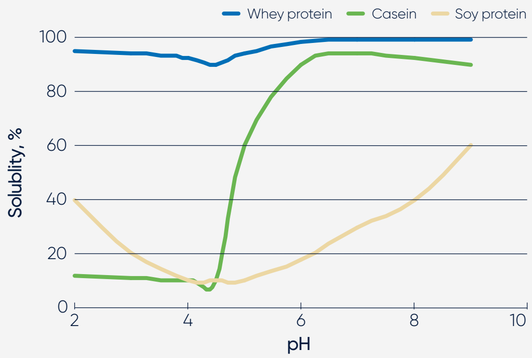
Functional properties in water ("aqueous functionality") primarily reveal the effects of the source of protein, processing history, composition of protein ingredients and quality. On the other hand, similar properties when measured in food products reveal additional influences of the composition and processing conditions of the food product.

The link between the aqueous functionality and the food system functionality is generally weak as the food products contain many ingredients and processing parameters that modify the functional properties of whey proteins. It is well recognised that the results of functionality testing in aqueous systems do not necessarily predict the functional behaviour of the protein in commercial food systems. Due to the complexity of food applications and the costs involved, it is difficult for manufacturers to test protein ingredients in real food systems. To bridge this functionality gap, model food systems containing essential ingredients of the final food product are used to evaluate functionality. Testing of protein ingredients in model foods systems helps in prediction of their performance in the final food product and thus help with ingredient selection. Appendix 1 summarises the selection criteria for whey protein products based on functionality and food application.

Solubility

Whey protein products are highly soluble at room temperature and at low ionic strength. One of the major advantages of whey protein products over casein products is their solubility at the entire pH range for food products (Figure 9). This is partly due to the small molecular size of whey proteins and the presence of a range of proteins with varying isoelectric pH values (isoelectric pH varying from 4.5 to 5.5). Heating whey proteins above their denaturation temperature causes aggregation of proteins with little or no effect on the solubility (as the aggregates are too small to sediment at low gravitational forces) especially at low protein levels. Heating of whey proteins at high protein concentrations leads to aggregation or gelation of proteins.

Figure 9 Solubility of whey, casein and soy proteins at different pH values



Solubility is important in dry and instant beverages such as powdered nutritional beverages and powdered soups. Good solubility of whey protein products is also useful when mixed with other ingredients in the formation of liquid beverages and emulsions, such as recombined milk and infant formula. In general, well-manufactured whey protein products have excellent solubility in water.

Water binding and viscosity

Proteins bind water through their hydrophilic amino acids and their location in the protein structure determines the water binding ability of the protein. Whey proteins have high water binding ability and this can enhance viscosity of the food system. Viscosity is an important functional property of whey proteins that which provides mouthfeel and stability to liquid and semi-solid food systems. Viscosity of whey proteins decreases as the temperature of protein solution increases from room temperature to around 60°C. The viscosity of whey protein solution starts increasing as the temperature of heating increases above the denaturation temperature of whey proteins (approximately 78°C). This is due to the increased water binding due to the unfolding of protein molecules.

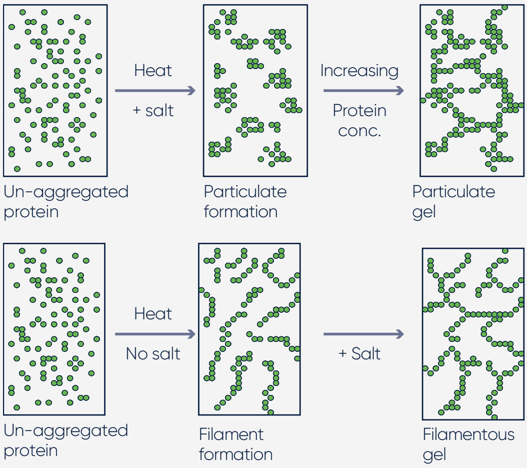
The increase in viscosity is also dependent on concentration and pH. For example, at low pH and at low protein concentration the increase in viscosity is limited.

The viscosity related functionality of whey proteins is important in semi-solid foods such as soups, gravies, sauces and salad dressings. Although all whey protein products are suitable for viscosity development, protein products with high protein contents such as WPC 55 and WPC 80 are recommended.

Gelation and structure formation

Heat-induced, non-reversible gelation or gel formation is an important property of whey proteins for applications such as meat binding. Gelation properties of whey proteins are dependent on protein concentration, pH and ionic strength (e.g. the salt level) (Figure 10).

Figure 10 Development of protein gels[3]



At low protein concentrations (4-6% protein), whey proteins produce soft and clear gels. Increasing the protein concentration increases the gel strength and the turbidity of the gel. At low pH, whey proteins produce weak and turbid gels. Increasing the pH to neutral level increases the gel strength, elasticity,

3 Based on Bryant and McClements (1998)

and transparency of the gel. It is also important to select WPCs with little or no fat as the presence of fat adversely affects the gel formation and clarity of the whey protein gel. A texture analyser such as TAXT Plus from Stable Micro Systems can be used to measure the gelling properties of whey proteins.

Food products that can benefit from the gelation and structure building properties of whey proteins are meat products such as ham, surimi, and sausage and dairy products such as yoghurt and processed cheese. In yoghurt, whey proteins are especially useful in improving viscosity, gel strength and preventing defects such as liquid separation. Preheating of milk for yoghurt manufacture denatures whey proteins and leads to casein-whey protein interactions and when casein gels due to the reduction in pH to around 4.6 when yoghurt sets, whey proteins help in strengthening the gel network and binding the free water.

Other food products where the gelation properties are useful include dairy desserts and pasta products. Optimum results for gelation and structure building are obtained when high protein products such as WPC80 and WPI are used in the formulation. Heating beyond the denaturation temperature of whey protein is needed to accomplish the desired gel structure.

Emulsifying properties

Whey proteins are amphiphilic in nature meaning that they can anchor at the oil-water interface thereby lowering the interfacial tension and providing stability to the interface. This surface-active property of whey proteins allows them to form emulsions where the proteins adsorb at the oil-water interface and envelop the oil droplets providing them stability against oxidation, coalescence, and oiling off. Further rearrangement and unfolding of protein structure at the interface can enhance the emulsifying ability of whey proteins. Excessive heat induced denaturation and aggregation of whey proteins results in lowering the emulsifying properties.

Two commonly used methods for assessing emulsifying properties of whey proteins are emulsifying capacity and emulsion stability. The amount of oil that can be used to make a visibly stable emulsion is termed as emulsifying capacity while the time that the emulsion remains stable is known as the emulsion stability.

Food products that require emulsification of oil include beverages such as infant and enteral formula, convenience foods such as salad dressing and mayonnaise, and dairy products such as recombined milk, ice cream, and yoghurt. For manufacture of recombined milk products, whey protein products are often reconstituted (solubilised) in water at room temperature rather than at high temperatures. Whey protein products suitable for emulsifying properties are WPC35, WPC55, WPC80 and WPI.

Foaming and whipping properties

The amphiphilic nature of whey proteins is also responsible for their high foaming and whipping properties. The foaming and whipping ability of whey proteins are improved by increasing protein content and impaired by the presence of fat. Heating of WPC generally enhances the foam stability of proteins as heating unfolds the hydrophobic sites in the protein structure. Other factors that affect the foaming and whipping properties of whey proteins are the pH and the ionic strength. Low pH and high ionic strength impair the foaming properties while slight denaturation improves the foaming properties. The foaming properties of WPCs can be measured by whipping a fixed amount of protein solution and measuring the volume expansion (foaming capacity) and time until the foam collapses (foam stability).

High foaming and whipping properties of whey proteins allows them to replace egg white in certain food applications such as cakes. Other foaming applications of whey proteins include ice cream and whipped topping.

Coating and film formation

The ability of whey proteins to form a transparent, bland, and flexible film allows them to be used as barriers against oxygen, moisture, aroma, and oil transport between two or more food products or between the food product and the atmosphere. Current demands for long shelf life foods and desire to recycle the packaging have led to increased demand for biofilms produced by whey proteins. Food applications that could benefit from coating properties of whey proteins are nuts, fruits and cakes. High protein products such as WPC80 and WPI are suitable for coating and film formation.

Binding and adhesion properties

Whey proteins provide adhesion properties to meat products, batters, and fish products resulting in homogeneous products. Binding and adhesion properties are enhanced by heat-induced gelation of whey proteins. In bakery products such as bagels, whey proteins can provide surface glazing and binding of seeds thereby enhancing the appearance. Recommended whey protein ingredients are WPC55, WPC80, and WPI.

Browning properties

Browning is an important property in baked goods and caramel products. Whey protein products, due to the presence of lactose, have excellent Maillard type browning characteristics. Whey protein products such as whey powder, demineralised whey powder, WPC35 and WPC55 are suitable ingredients for browning applications.

Stability at low pH

Whey proteins have an advantage over casein protein at an acidic pH such as low-pH beverages. At low pH, caseins tend to precipitate while whey proteins remain soluble and functional. Major applications of low-pH beverages are sports drinks and isotonic beverages. High protein WPCs and WPI are suitable for low pH applications. WPI is recommended for use where the clarity of the beverage is important. It is important to select whey protein product free from fat as the presence of fat can cause cloudiness in beverages.

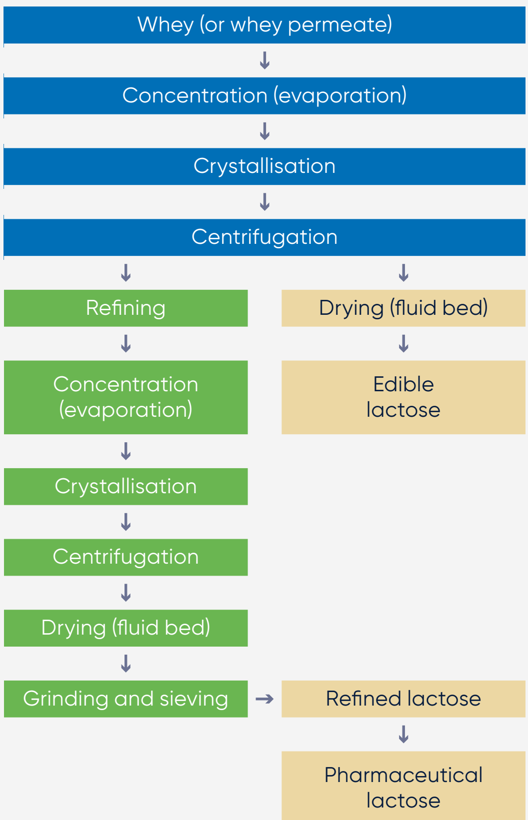
8.4 Lactose – composition, types, manufacture and uses

Lactose, also known as milk sugar, is a unique carbohydrate present in mammalian milk (humans and cows). Cheese or acid whey is a rich source of lactose, forming almost 70% of weight on solids basis. There are two basic methods for removal of lactose from whey:

- Removal from concentrated whey without removal of proteins
- Removal from concentrated whey from which the protein has been removed by ion exchange or ultrafiltration

A simple process for manufacture of lactose is shown in Figure 11.

Figure 11 A process flow diagram for manufacture of lactose from whey or whey permeate



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Clarified cheese whey or permeate from whey after Ultrafiltration is concentrated by two-stage evaporation from approximately 6% solids to 30% solids in the first stage and from 30 to 60% solids in the second stage. The concentrated whey or whey permeate is slowly cooled to approximately 12-15°C, seeded (as optional step) with very fine lactose crystals. During this process, lactose crystallises from the solutions to form alpha lactose, which is decanted (centrifuged) to yield raw lactose and mother liquor. The raw lactose is washed further, decanted and dried to produce creamy edible lactose. This is further refined by decolourising, recrystallising, grinding and sieving to produce refined or pharmaceutical grade lactose with defined specifications and particle size distribution. Different grades of lactose and their applications are shown in Table 5.

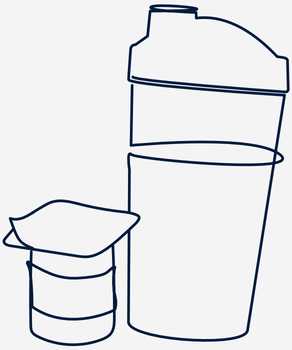
Table 5 Grades of Lactose and Applications[4]

	Edible	Refined edible	US Pharmacopeia
Powder appearance	Yellow	White	White
Appearance of solution	Slight yellow/turbid	Colourless opaque	Clear, colourless, odourless
Acidity (pH)	4.5–7.0	4.0–6.5	4.0–6.5
Specific rotation	54.2–55.1	–	54.8–55.5
Lactose (%) Minimum	99.0	99.5	99.7
Protein (%)	<0.5	<0.3	–
Free moisture (%)	<0.5	<0.5	–
Applications	Confectionery, bakery, meat and dairy products, dry beverages, fermentation	Infant foods, Adult nutritional products	Tablet wet granulation, direct compression, capsules, inhalation products

Typical composition of a commercial edible grade lactose powder is shown in Table 6

Table 6 Typical Composition of a Commercial Edible Grade Lactose Powder

Component	Amount per 100 g
Moisture (free) (g)	0.20
Protein (g)	0.20
Lactose (alpha monohydrate) (g)	99.0
Ash (g)	0.50



4 Rajah & Blenford (1988)

Lactose properties and applications

Crystal forms

The two isomeric forms of lactose, i.e., alpha and beta, exist in crystalline forms in equilibrium in solution. Usually, alpha lactose crystallises as a monohydrate where the crystals are very hard and non-hygroscopic, while anhydrous beta lactose crystallises into fine crystals. Lactose can also exist in an amorphous, glassy form as a mixture of alpha and beta lactose. It is important to understand the relative proportion of crystalline and amorphous forms of lactose in commercial lactose and milk powders, as these may influence the functional properties of powders.

Solubility

Compared to other sugars, lactose has a low solubility and the solutions can be supersaturated easily. For example, at 30°C, only 20 g of alpha lactose can be dissolved in water compared with 69 g of sucrose before super saturation. The beta form of lactose is considerably more soluble than the alpha form.

Sweetness

Lactose has a clean sweet taste without any aftertaste noticed with a few artificial sweeteners. The intensity of sweetness of lactose is only 30% that of sucrose. The sweetness of lactose is dependent on the concentration and temperature of solution, higher the concentration or the temperature, higher the sweetness. Lactose can also be combined with other sugars resulting in a synergistic effect and higher sweetness.

Moisture sorption

Moisture sorption characteristics of lactose affect its stability and quality. In combination with water activity it may affect many chemical reactions. Commercial lactose powders may contain up to 20% amorphous lactose and water activity of around 0.3. When high level of amorphous lactose is present, it leads to increase in moisture absorption and can result in defects such as caking.

Browning

Lactose and lactose-containing powders, such as whey powder, are commonly used for their browning properties and development of a characteristic flavour. The browning reaction in lactose-containing products is induced by either (a) caramelisation or (b) Maillard reactions. The caramelisation occurs at high temperatures (150-175°C) and consists of a succession of dehydration, condensation and polymerisation reactions. The resulting water-insoluble compounds are called melanines that appear brown in colour. The Maillard reactions are induced when proteins or amino groups are present in the powder. The Maillard reactions can occur at low temperatures (such as the storage temperature of lactose) and result in condensation of lactose and amino groups into a series of re-arrangements and finally into insoluble melanines.

Applications

Lactose is widely used in the food industry - infant formula, bakery, confectionery, meat and dairy. In the pharmaceutical industry, lactose’s bland flavour makes it ideal for use in tablet granulation and compression, capsules, inhalation and injectable products. Lactose being a reducing sugar helps in providing controlled browning in food products such as bakery and confectionery goods giving them a characteristic golden colour.

Several new products have been derived from lactose, which offer a range of opportunities for lactose. These include hydrolysed lactose with improved solubility, lactitol (sugar alcohol of lactose) as sugar substitute for bakery and confectionery products, lactulose (isomerisation of glucose moiety) for medical and infant formulations, lactobionic acid as acidifying and complexing agent for metal ions and fermented lactose products such as alcohol, lactic, propionic and citric acid.

8.5 Whey products – applications and usage levels

Usage levels of whey products in food applications will depend on several factors such as type of food application, desired nutritional and functionality requirements, and intended processing conditions. Table 7 below is provided as a guideline only.

Table 7 Whey products – applications and recommended usage levels

Application	Ingredient usage level (% w/w)						
	WP	DWP	WPC 35	WPC 55	WPC 80	WPI	Lactose
Dairy							
Recombined milks (including chocolate milk)	2–4	2–4	2–3	2–3	1–2	1–2	3–6
Ice creams	2–3	2–3	1–3	1–2	1–2	0.5–2	2–6
Yoghurts	2–5	2–5	2–5	2–4	1–3	1–3	2–4
Processed cheeses	3–6	3–6	1–3	1–3	1–2	0.5–2	–
Bakery & confectionery							
Breads	3–6	3–6	2–5	2–3	1–2	1–2	2–4
Cakes	2–4	1–5	4–6	3–5	2–4	2–6	8–10
Biscuits	3–6	3–6	3–5	3–5	2–4	1–3	4–6
Chocolates	1–5	1–5	1–5	2–3	1–2	1–2	3–7
Desserts	2–5	2–5	1–4	1–4	1–3	1–2	–
Meat products							
Sausages	3–5	3–5	3–5	2–5	2–4	1–3	–
Surimi	3–5	3–5	3–5	2–5	2–4	1–3	–
Convenience							
Sauces	2–5	3–6	5–8	5–8	2–4	2–4	–
Soups/gravies	2–5	3–6	2–5	2–4	1–3	1–2	–
Salad dressings	2–6	2–6	2–5	2–4	2–3	2–3	–
Nutritional products							
Infant formulae (liquid)	6–8	6–8	4–6	3–5	2–4	1.5–3	–
Enteral formulae (liquid)	–	–	–	–	1–2	0.5–2	–
Sports drinks	–	–	–	–	4–20	2–15	4–7
Sports bars	2–5	2–5	2–8	2–15	2–20	2–20	–
Dry mixes (including dry nutritional beverages)	40–60	40–60	30–50	30–50	20–30	15–20	15–40

WP – whey powder, DWP – 40% demineralised whey powder

8.6 Frequently asked questions (FAQ)

Composition and manufacturing

1. What are the different whey proteins present in milk?

Milk contains approximately 3.5% protein and whey proteins represent approximately 20% of the total proteins in milk or 0.7% in milk. The major whey proteins are β-lactoglobulin (50%), α-lactalbumin (20%), bovine serum albumin (6%), immunoglobulins (11%), and other proteins such as lactoferrin, proteose peptone (13%).

2. What are the major nutritional benefits of whey proteins?

Whey proteins have several nutritional benefits such as:

- Having one of the highest protein efficiency ratios of 3.5 compared with other major proteins: Casein 2.5, Soy 1.8 and Wheat 0.75
- Being slow to digest, they provide quality peptides and amino acids in the intestine
- Having high levels of essential amino acids compared with other sources of protein
- Being rich in sulphur-containing amino acids like cysteine which enhances immune function and antioxidant status
- Being rich in branched chain amino acids, leucine, isoleucine and valine, which prevent the degradation of muscle cells during heavy exercise.

3. What are the major differences between WPI manufactured via membrane process such as Microfiltration / Ultrafiltration and ion exchange and chromatography?

Although the gross composition of WPI manufactured by membrane processing is similar to that manufactured by the ion exchange and chromatography, there are minor differences. During the ion exchange process, protein molecules are removed from liquid whey through chemical binding to the resin in the columns. The bound protein is removed from the resin by pH adjustment and buffer and subsequently concentrated via ultrafiltration.
The ion exchange process results in slight chemical modifications to the protein, where some calcium is replaced by sodium during the binding with and release from the resin. Most of the whey proteins are captured with this process except glycomacropeptide (GMP).

In the microfiltration process, particulate materials such as residual fat, microbial debris and denatured protein, are removed via a MF membrane before concentration of proteins using the ultrafiltration process. The MF process produces WPI that is different from the ion exchange WPI in that there is no chemical modification to the protein and GMPs are retained in the WPI. If no pH adjustment is used and the process is carried out under mild temperatures, the WPI is almost completely free of denaturation. Physical functional properties of WPI from MF can be optimised via controlled denaturation of whey proteins and manipulation of ionic strength.

4. How do I know which WPC is appropriate for my food application?

Commercially, WPC are powders with protein concentrations ranging from 35 to 80%. These powders have significantly different compositions especially regarding levels of protein, lactose, fat and minerals. If WPC is added to food on a solids basis, there will be large differences in the formulation and functionality due to the differences in protein content. Appendix 1 can be used as a general guide for selecting a suitable WPC, but protein content and functionality should be the key factors for selecting the WPC for each application. For example, if gel formation was the key requirement, WPC with high levels of protein would be suitable.

Functional properties

1. What are the major functional properties of whey proteins?

In addition to the high nutritional value, whey proteins have excellent water binding, gelation, whipping and foaming properties. In the native form, whey proteins have globular structures that are formed through the intra-molecular disulphide bonds. Heating whey proteins above their denaturation temperatures, the globular structures unfold and the functional properties such as water binding improve. Whey proteins have good emulsion forming properties and excellent emulsion stabilising properties.

2. What is the difference in functional properties of WPC manufactured from sweet whey and acid whey?

Sweet whey is at higher pH of 6.0-6.5 and contains considerably lower levels of minerals such as calcium than the levels in acid whey which is at pH of 4.5-4.7. This difference in mineral levels impacts functional properties of WPCs. WPC from acid whey may have poor heat stability due to higher calcium levels but can provide better gelation properties. In contrast, WPC from sweet whey has higher heat stability than that from acid whey but has poorer gelling properties. It should be noted that this "rule of thumb" might not apply if WPCs of similar compositions are obtained by suitable processing of the whey.

3. Whey proteins are soluble in the entire pH range of food products while caseins tend to precipitate near its isoelectric point of pH 4.6, why?

Whey proteins contain a range of proteins such as β-lactoglobulin, α-lactalbumin, bovine serum albumin, immunoglobulins, and lactoferrin with varying molecular size and isoelectric pH. The proteins in whey have smaller molecular size (10-20 nm) compared with casein micelles (e.g. 30-300 nm) and contain more uniform electric charge distribution than casein proteins. The combination of these properties allows whey proteins to show high solubility over a wide pH range.

4. What is the caking problem in whey powders and how can it be minimised?

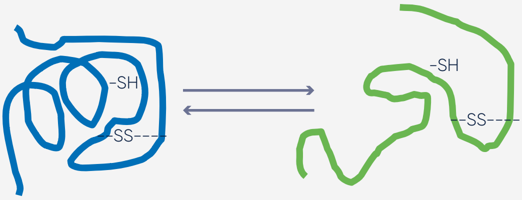
The caking defect in whey powder is largely related to the hygroscopic and crystallisation properties of lactose. If the lactose crystallisation process during manufacture is not handled properly, the lactose attracts moisture from the environment and forms a cake which can harden over time through the linking of the cake structure throughout the package. Actions that minimise the risk of caking are:

- Maximum crystallisation of the lactose after evaporation and controlled crystallisation of the concentrate through cooling prior to spray drying
- Formation of small, uniformly sized crystals during the crystallisation step
- Controlled crystallisation during gentle drying in the fluid bed
- Use of packaging that prevents up-take of moisture from the environment
- Storage of whey powder under clean, dry and cool conditions.

5. What is denaturation of whey proteins and what is its significance?

Denaturation of whey proteins refers to the unfolding of the native configuration of protein. Denaturation can be defined as modification of the secondary, tertiary, or quaternary structure of the protein molecule, excluding breakage of covalent bonds. Denaturation is therefore a process by which hydrogen bonds, hydrophobic interactions, and salt linkages are broken when the protein unfolds. Such a change may be induced by change in environmental conditions such as heating above a certain temperature, alteration in pH, ionic strength, radiation, high pressure or shearing. Depending on the extent of the change, the denaturation can be reversible or irreversible. Denaturation of whey proteins results in loss of its biological activity and change in functional properties. In whey proteins, buried sulphydryl groups (-SH groups) are exposed during the denaturation and become active sites for interaction with other sulphydryl groups leading to aggregation of proteins. Pre-denaturation helps in improving the heat stability of whey proteins and therefore manufacture of commercial heat-stable WPCs sometimes require preheating during manufacture. Controlled denaturation of whey proteins improves functional properties such as emulsification, gelling and foaming.

However, extensive denaturation can lead to aggregation, insolubilisation or gelation of whey proteins that can adversely influence the functional properties.



Native Denatured

Applications of whey products

1. What are the major food applications of whey powder?

Whey powders are manufactured by evaporation, crystallisation and spray and drying of sweet or acid. Whey powders contain relatively low levels of proteins (10-12%) and high levels of lactose (74-76%). Whey powders are very cost-effective nutritional ingredients suitable for a range of bakery, confectionery, and convenience food products. Demineralised whey powders are suitable in applications requiring low salt levels such as yoghurt. There are mainly three levels of demineralisation, 40%, 70% and 90%. Demineralised whey powder with 90% demineralisation is preferred for infant formulations as it contains low levels of minerals.

2. What are the major applications of different WPCs?

WPCs contain protein levels from 35% to 85%. WPCs are versatile food ingredients and applications range from nutritional fortification to targeted functionality such as water binding and gel formation. In most commercial WPCs, the whey proteins are in the undenatured state, which means by heating during application, high quality gels can be formed. For example, low levels of WPC 80 added to yoghurt can reduce the water leakage defect due to WPC 80 having high water binding capacity. WPC is suitable for many food applications such as infant formula, bakery, confectionery, and nutritional products.

Health, sports and nutritional products generally require WPC with high protein and low lactose levels.

3. What are the advantages or disadvantages of using whey proteins over other proteins in food applications?

One of the major advantages of whey proteins over caseins is the solubility over the entire pH range. Caseins tend to precipitate near the isoelectric point of 4.6 whereas whey proteins remain soluble at wide pH range. Therefore, for applications such as fruit juice and acidic beverages, whey proteins are better suited than caseins. On the other hand, a major disadvantage of whey proteins is their poor heat stability. Heating whey proteins above the denaturation temperature causes unfolding (denaturation) of the protein structure and disulphide bond-mediated aggregation that may be followed by protein gelation. However, appropriate manipulation of processing conditions can overcome the poor heat stability of whey proteins. The main factors influencing heat stability are protein concentration, temperature, pH and ionic strength. Whey proteins are more susceptible to heat-induced aggregation and visible precipitation at high protein concentrations, (pH 4.5-5.5) high ionic strength (such as calcium concentration), and high temperature (above 80°C).

Compared with proteins from other sources such as soy and other plant proteins, whey proteins are nutritionally superior. They provide many functional properties that are difficult to achieve using plant proteins. One of the measures of protein quality is the measurement of biological value (BV). BV measures the amount of protein (or more precisely - the nitrogen) retained in the human body per gram of protein absorbed. Comparison for BV is generally made with the BV of an egg that has a BV of 100. The table below compares the BV of protein from various sources.

Protein	Biological value
WPI	159
WPC	104
Egg	100
Fish	83
Beef	80
Chicken	79
Casein	77
Soy	74
Wheat	54
Pulses	49

Another major advantage of whey proteins is that they provide the highest value of branched chain amino acids (leucine, isoleucine and valine), which are important for muscle building and recovery.

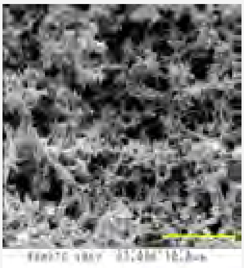
4. What is heat-induced gelation of whey proteins and what factors influence this property?

Heat-induced gelation of whey protein refers to the property of forming a gel on heating which contributes towards the structure and texture of food. The heat-mediated gelation of protein-water systems has been described as a two-stage process. In the first stage, the denaturation of the native protein occurs while in the second stage protein-protein interaction occurs resulting in a three-dimensional protein network that forms the final gel structure. The strength and texture of whey protein gels are influenced by intrinsic factors such as the composition and concentration of the proteins and by extrinsic factors such as heating temperature, pH, ionic strength and the presence of other food components, for example, lipids, sugars, starches, etc. Heating above protein denaturation temperature results in unfolding of the protein and activation off sulphydryl groups. This leads to the formation of new intermolecular disulphide bonds which facilitate formation of orderly gel structure. The macrostructure of protein gels is largely dependent on the protein concentration and at any given temperature, a minimum critical concentration is needed for formation of the gel network. The ionic strength and the pH influence the gelation reactions by affecting the balance of polar and non-polar residues and interaction between protein-protein residues. Protein-protein interactions are generally favoured where the net change of protein is minimum, i.e. pH values near the isoelectric point. High ionic strength tends to reduce electrostatic repulsion between proteins due to the shielding of ionisable groups by mobile salt ions. Combination of protein concentration, temperature, pH and ionic strength is used to control the heat-induced gelation of whey proteins. When the pH is near the isoelectric point and the ionic strength is low, randomly aggregate gels are formed by hydrophobic interaction. When pH is away from the isoelectric point and at low ionic strength, electrostatic-repulsive forces hinder the formation of random aggregates and hence linear polymers are formed.

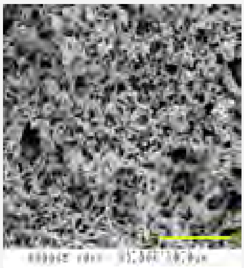
5. What are the benefits of using whey proteins in yoghurt?

Whey proteins are used mainly to improve the texture of yoghurt. In set yoghurt, whey proteins can improve water binding and reduce syneresis during transport and storage. In stirred style yoghurt, whey proteins improve viscosity and mouthfeel. Whey proteins (e.g. WPC 80) are added to the yoghurt milk before the heat treatment to allow their denaturation and their interaction with casein micelles. The recommended levels of fortification are 2 to 4%. Overall, the addition of WPC to yoghurt improves its texture and water binding properties. A comparison of yoghurt with 12% total solids and 4.2% protein with or without WPC is shown in the figure below. It is obvious that the addition of WPC resulted in a fine stranded structure, and reduced the void volume that could lead to whey separation.

Figure Effect of addition of WPC on microstructure of yoghurt[5]



All skim milk solids, 12% TS, 4.2% protein



60% skim milk solids, +40% WPC40

6. How do we ensure heat stability of whey proteins in the manufacture of UHT milk?

One of the challenges using WPCs is the inadequate heat stability of whey proteins. When whey proteins are heated above the denaturation temperature (approximately 78°C), unfolding of the globular structures occurs. Depending on the temperature, protein concentration, pH and ionic strength, high temperature heating, such as UHT, can lead to the formation of insoluble protein precipitates. The key factors to control during the manufacture of UHT milk are the pH and the availability of free calcium ions. Too low pH can enhance the protein instability while too high free (ionic) calcium can lead to aggregation of whey proteins and ultimately precipitation of protein. These defects can be largely overcome by selecting a WPC with low calcium, and using phosphate salts to bind free calcium in the UHT formulation. Heat stable WPCs are commercially available and can be satisfactorily used in UHT applications.

7. Which types of beverage applications are suitable for WPC and WPI?

WPC or WPI can be used as a source of proteins in most beverages such as sports formulations, infant nutrition, enteral formula, fruit juice, drinks and soy beverages.

In soy beverages such as soymilk, whey proteins can provide sulphur-containing amino acids which are lacking in soy proteins. Whey proteins also enhance the flavour of soy beverages. WPC or WPI is suitable for both acidic and neutral pH beverages. Careful selection of WPC or WPI is important when the beverage needs to be heated at high temperatures. In such cases heat stable WPC should be used.

8. Which types of whey protein ingredients are suitable for clear beverages?

The cloudiness in beverages may be due to the colloidal particles of whey proteins. The most suitable whey protein product for clear beverages is WPI which has little or no fat content. Clear WPI powders are commercially available. WPIs with undenatured protein and low lipid contents are suitable for both neutral pH and low pH beverages.

9. What are the advantages of using WPC in sports nutrition?

Whey proteins contain the highest concentration of branched chain amino acids (BCAAs), leucine, isoleucine and valine. BCAAs provide suitable nutrition for athletes seeking optimal lean muscle mass. BCAAs are also considered essential amino acids for humans. For athletes, BCAAs are needed for the maintenance of muscle tissue and to preserve muscle stores of glycogen, which is stored in muscle as a source of energy, BCAAs also help prevent muscle protein breakdown during exercise.

During sustained exercise, muscle BCAAs are used for energy and NH3 production. The subsequent increase of free tryptophan to BCAA ratio is thought to increase the tryptophan availability for serotonin synthesis. This can cause sleep and could increase the mental effort necessary to maintain athletic activity.

5 Puvanenthiran *et al* (2002) Structure and visco-elastic properties of set yoghurt with altered casein to whey protein ratios. International Dairy Journal 12, 383-391.

BCAA supplementation before and during exercise may therefore delay fatigue and improve athletic performance. Research suggests that regular supplementation with branched chain amino acids can prevent central fatigue by preventing tryptophan from entering the brain. Whey protein products originating from acid whey contain higher levels of BCAAs than those manufactured from cheese whey.

10. What are the major functional properties of lactose in food applications?

Lactose can provide the following applications in food products:

- Reduction in the overall sweetness of the product since the sweetness of lactose is only 30% that of sucrose
- Can be used as a carrier of flavour and enhancement of flavour in food products
- Source of nutrition and energy, especially in infant formulae which contain nearly 50% lactose
- Browning and characteristic golden crust in bakery products and caramelisation in confectionery products
- Source of fermentable sugar for yoghurt and other fermented products.

8.7 Glossary

Cheese milk extension

Cheese milk extension refers to boosting solids and increasing the cheese yield by the addition of protein powders. MPC56 and 70 are generally preferred for cheese milk extension as the casein micelles in these powders easily form cheese curd.

Denaturation

Denaturation refers to the changes in the conformation of the native state of whey proteins. In the native state and under specified temperature, pH and ionic strength whey proteins have certain conformation (e.g. secondary and tertiary structures) and biological activity. Alterations in the environmental conditions, such as heating, change in pH or ionic strength leads to the unfolding of the protein structure. This state is called the denatured state which influences functionality.

Dispersibility

Dispersibility refers to the ability of a powder to disperse into individual particles upon coming into contact with water or a liquid food product.

Dispersibility of protein powders can be enhanced by agglomeration during spray drying, and further enhancement by coating the agglomerates with lecithin (instantising).

Emulsion

An emulsion refers to dispersion or suspension of two immiscible liquids such as oil and water. Food emulsions can be oil-in-water such as milk or water-in-oil such as butter. An emulsion is intrinsically unstable due to the difference in the surface tension of the dispersed (e.g. oil) and the continuous phase (e.g. water). Milk proteins can form stable emulsions due to their ability to adsorb at the oil-water interface and reduce the interfacial tension.

Emulsification

The process of formation of an emulsion is termed as emulsification. Emulsification is usually carried out by mechanical means such as a homogenisation.

Emulsifying capacity

Emulsifying capacity refers to the maximum amount of oil that can be emulsified in an aqueous dispersion containing a fixed amount of protein before the inversion or breakdown of emulsion.

Emulsion stability

Emulsion stability refers to the amount of oil separation from an emulsion measured over a fixed time of storage after emulsion formation.

Foaming ability

Foaming ability refers to the maximum amount of foam that can be made by whipping a fixed amount of protein before the breakdown of the foam. To form a foam efficiently, proteins need to unfold and adsorb rapidly at the interface.

Foam stability

The maximum time the foam stays stable is interpreted as foam stability.

Gelation

Gelation is the ability of protein powders to develop a three-dimensional network. Heating, pH or ionic strength, can induce gelation in WPC.

GMP

Glycomacropeptide – also known as caseinomacropeptide (CMP) or caseino-glycomacropeptide (CGMP) – hydrophilic peptide fraction of kappa casein released in whey after the action of rennet on casein micelle.

Heat stability

The ability of protein products to withstand high temperature heat treatment is referred to as the heat stability. MPCs are very heat stable can be heated for more than an hour at 121°C. WPCs containing native whey proteins are less heat stable but their heat stability can be controlled by controlling protein concentration, pH and ionic strength during heating.

Hydration and water binding

Hydration and water binding or water uptake of proteins are interchangeable terms used in the food industry. Hydration generally refers to ability of protein powder to absorb and bind water.

Membrane filtration

Membrane filtration refers to pressure driven processes using a semi permeable membrane for separating molecules such as protein, fat, sugars and salts based on their molecular size. Four major membrane filtration processes are: reverse osmosis, nanofiltration, ultrafiltration and microfiltration. WPC and MPC are generally manufactured using the ultrafiltration process.

Permeate

The low molecular weight components passing through membrane filters is known as permeate. Ultrafiltration permeate mostly contains most of the lactose and minerals.

Physical functional properties

Physical functional properties refer to properties such as viscosity, gelation, foaming and emulsification.

Physiological functional properties

Physiological functional properties refer to the biological activity or bioactivity.

Retentate

During the process of membrane filtration, the concentrated protein material retained by the membrane is termed as retentate.

Solubility

Solubility of protein powders refers to the ability of the particles to uptake water and dissolve in it with gentle agitation.

Viscosity

Viscosity refers to the resistance of a solution to flow and visually it refers to the thickness of the solution. Viscosity of protein solutions is related to the concentration of proteins and the availability of hydrophilic amino acids. Viscosity is important in providing physical stability of dispersions and emulsions and contributes to the mouthfeel of food products.

WPC

Whey protein concentrate – refers to whey protein powders manufactured by concentrating whey proteins by membrane processing (such as ultrafiltration) or ion exchange chromatography. WPCs are differentiated based on their protein contents 35% to 85%.

WPI

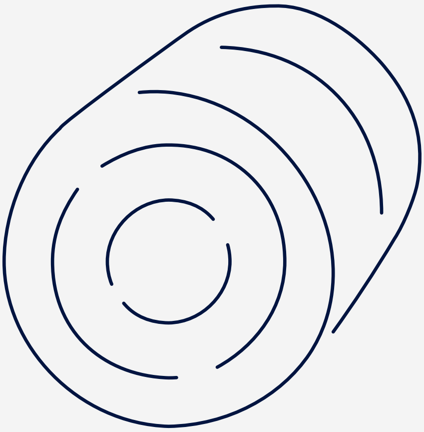
Whey protein isolate – refers to a whey protein concentrate with protein content over 90%. WPI is relatively free from lactose and a valuable ingredient for sports drinks, infant nutrition, functional foods and nutraceuticals.

Whey

The yellowish green liquid obtained as by product during manufacture of cheese, rennet casein and acid casein. Whey obtained during the manufacture of Cheddar or Mozzarella cheese or rennet casein is termed as sweet whey due to its pH 6.0-6.5 while that obtained during the manufacture of acid casein, cream cheese or cottage cheese is called acid whey because its pH is around 4.6. Whey contains whey proteins, lactose, minerals and low levels of fat.

Whey proteins

The proteins present in whey are known as whey proteins or serum proteins. The major whey proteins are β-lactoglobulin and α-lactalbumin, together representing nearly 70% of the total whey protein. Other whey proteins are bovine serum albumin, lactoferrin and proteose peptone.



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Appendix 1: Functional properties of whey products for dairy, bakery and confectionery applications

Functional property	Whey protein product					
	WP	DWP	WPC 35	WPC 55	WPC 80	WPI
Bulking agent	♦	♦	♦			
Flavour enhancement	♦	♦	♦	♦		
Nutrition enhancement			♦	♦	♦	♦
High protein				♦	♦	♦
Low lactose					♦	♦
Low minerals					♦	♦
Dispersibility	♦	♦	♦	♦	♦	♦
Solubility	♦	♦	♦	♦	♦	♦
Clarity						♦
Water binding			♦	♦	♦	♦
Fat binding				♦	♦	♦
Viscosity				♦	♦	♦
Gelation					♦	♦
Heat stability		♦	♦	♦	♦	♦
Low pH stability	♦	♦	♦	♦	♦	♦
Emulsification			♦	♦	♦	♦
Foaming			♦	♦	♦	♦
Whipping			♦	♦	♦	♦
Film formation				♦	♦	♦
Crystallisation	♦	♦				
Browning	♦	♦	♦	♦		
Adhesion				♦	♦	♦

WP – whey powder

DWP – demineralised whey powder

Dairy				Bakery & confectionary			
Recombined milk	Ice cream	Yoghurt	Processed cheese	Bread	Cake	Biscuits	Chocolate
■	■	■		■	■	■	■
■	■	■	■	■	■	■	■
■	■	■	■	■	■	■	
■	■	■	■				
■	■	■	■				
	■	■	■	■	■	■	
			■		■	■	
		■	■	■	■	■	
		■	■	■	■		
■			■				
		■	■				
■	■	■	■				
	■						
					■		
					■		
							■
				■	■		

Appendix 2: Functional properties of whey products for meat, convenience and nutritional applications

Functional property	Whey protein product						Meat products			
	WP	DWP	WPC 35	WPC 55	WPC 80	WPI	Desserts	Chopped meat	Sausage	Surimi
Bulking agent	♦	♦	♦							
Flavour enhancement	♦	♦	♦	♦			■			
Nutrition enhancement			♦	♦	♦	♦	■	■	■	■
High protein				♦	♦	♦	■	■	■	■
Low lactose					♦	♦				
Low minerals					♦	♦				
Dispersibility	♦	♦	♦	♦	♦	♦				
Solubility	♦	♦	♦	♦	♦	♦	■			
Clarity						♦				
Water binding			♦	♦	♦	♦	■	■	■	■
Fat binding				♦	♦	♦	■	■	■	■
Viscosity				♦	♦	♦	■	■	■	■
Gelation					♦	♦	■	■	■	■
Heat stability		♦	♦	♦	♦	♦	■			
Low pH stability	♦	♦	♦	♦	♦	♦				
Emulsification			♦	♦	♦	♦	■	■	■	■
Foaming			♦	♦	♦	♦				
Whipping			♦	♦	♦	♦	■			
Film formation				♦	♦	♦				
Crystallisation	♦	♦								
Browning	♦	♦	♦	♦			■			
Adhesion				♦	♦	♦		■	■	

WP – whey powder

DWP – demineralised whey powder

Convenience			Nutritional products				Dry mixes
Sauce	Soup/gravy	Salad dressing	Infant formula	Enteral formula	Sports drink	Sports bar	
							■
■	■	■	■				■
■	■	■	■	■			■
		■	■	■	■	■	■
				■	■	■	■
				■			■
■	■	■	■	■			■
■	■	■	■	■			■
					■		
■	■	■					
						■	
■	■	■					■
	■		■	■			
■		■			■		
■	■	■	■	■			
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09 Frozen Milk and Frozen Cream

Content

9.1 Introduction

Frozen Milk products refer to those milk products that have been concentrated, rapidly chilled and frozen. These products can then be stored frozen for extended periods of time (typical shelf life of 18 months) and thawed prior to use. Frozen Milk products include Frozen Skim Milk Concentrate (0.5% fat) and Frozen Whole Milk Concentrate (approximately 15% fat). Frozen milk products can be used to replace fresh milk and extended shelf life (ESL) milk products as well as be used as an ingredient in a range of food applications including ice cream, yoghurts, bakery and confectionery.

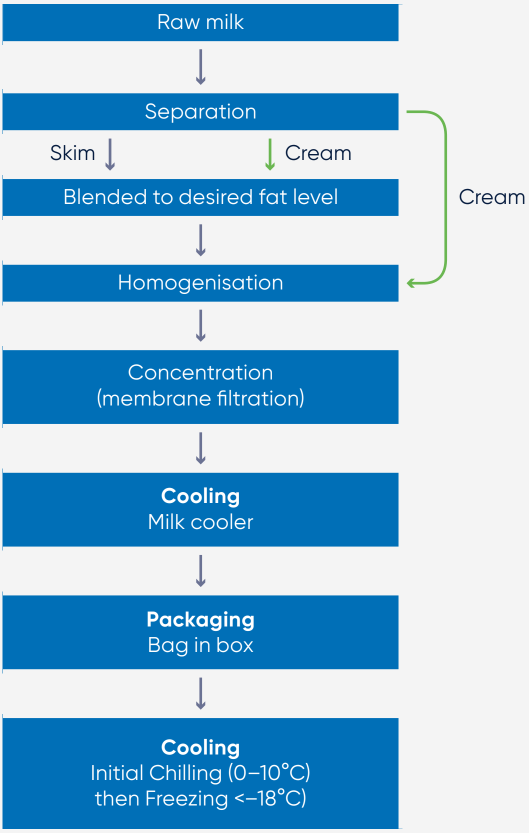
Frozen Cream products use fresh cream that is rapidly chilled and frozen in a way similar to frozen milks. Frozen Cream products include Frozen Cream (approximately 30 - 50% fat) and High Fat Frozen Cream (55 - 75% fat) with both products typically having shelf life of around 18 months. Frozen cream that is intended to be used in fresh cream applications requires additional care in thawing and usage. Frozen Cream that is used as an ingredient can be used in recombined milks, butter and ice cream. Like frozen milk, the thawing of frozen cream is important for its end use functionality and quality.

Table 1 Categories of frozen milks and creams with fat and milk solids levels

Product	Fat level (approx)	Milk Solids
Frozen skim milk concentrate	0.5%	Up to 70%
Frozen whole milk concentrate	15%	Up to 70%
Frozen cream	30 – 50%	Up to 70%
Frozen high fat cream	55 – 70%	Up to 70%

9.2 Overview of manufacturing principles

Figure 1 Summary of processing steps for Manufacture of Frozen Milk and Frozen Cream



For frozen skim milk products, the separated raw milk (skim portion) is pasteurised and concentrated without the addition of cream. For frozen whole milk products cream is added to the skim prior to pasteurisation.

Figure 1 describes the process steps involved in more detail for the production of frozen milk and frozen cream. The key process steps include:

Separation – separating the raw milk into cream and skim milk portions.

Homogenisation – the cream fat globules are reduced in size to allow them to be evenly dispersed throughout the milk.

Blending – the skim and cream portions are mixed to the desired fat and protein levels.

Pasteurisation – typically ESL temperatures of around 125 – 130°C for 2–4 seconds are used to kill pathogenic organisms and inactive proteolytic and lipolytic enzymes which can cause the milk to spoil. For frozen cream products a vacreation or de-aeration step may be incorporated to reduce volatile flavours.

Concentration – the total solids in the milk is concentrated, typically through a reverse osmosis RO process to reduce the amount of water in the product which reduces storage and transport costs. Concentration levels are generally in the range 45–70% milk solids.

Cooling – the concentrated milk is then cooled through a milk cooling system in preparation for packing.

Packing – the product is typically packed in a bag in box system (see Figure 2 below).

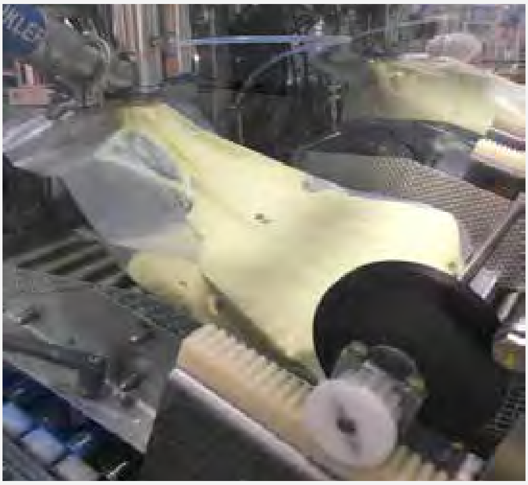
Cooling and freezing:

Frozen milk – single cartons or whole pallets can be cooled initially to chilled temperatures (0–4°C) and then blast frozen quickly to <18°C where the product is kept until dispatch.

Frozen cream – single cartons or whole pallets can be cooled initially to 6–8°C through a wide gap plate cooler then blast frozen quickly to <18°C.

Higher fat frozen cream – single cartons or whole pallets can be cooled initially to 10°C then frozen to <18°C within 4 hours.

Figure 2 Milk concentrate milk being filled in bag



9.3 Thawing of frozen milk & frozen cream

Production of frozen cream is a two stage process, which includes the manufacture of cream followed by the freezing process.

Cream production

Cream for butter manufacture is generally around 40% butterfat while a variety of other fat levels from 30% - 48% are common for table cream. In all cases, the cream should be fresh and of good quality. Pasteurisation methods depend on the customer's specification with some preferring a slightly nutty taste historically associated with vacreation and the reduction of volatile flavours, while others prefer standard plate pasteurisation with a small de-aeration step.

Frozen cream

Cream intended purely for ingredient use where the retention of the fat emulsion is not important, may be frozen without any special precautions. In other cases where it is required that the properties of the thawed product closely resemble those of natural cream, fast freezing to prevent damage to the milk fat globule membrane (MFGM) is essential.

Fresh cream flavour and maintenance of most of the cream emulsion at fat levels of 30 to 48% is readily achievable by cooling quickly to 6 to 8 degrees in a wide gap plate cooler then packaging and blast freezing quickly. Cream for further processing can be stored for periods of 6-10 months at temperatures below –18°C if handled properly.

High fat frozen cream

Most of the demand for butterfat in the form of high fat frozen cream is in the export arena, as it is expensive to transport water. Depending on the import regulations of the customer and country exported to, these fat levels can range from 55% - 75% with stipulations on functionality, flavour and texture on thawing.

The fat content of cream will affect the freezing process, from the pre-cooling stage through to the thawing stage. As the fat content increases to 70% it becomes more difficult to maintain this emulsion to the point where retention of 80% of the emulsion is a practical maximum without the use of stabilisers or emulsifiers.

The higher the fat content of the cream:

- the harder it is to maintain the emulsion
- the thicker the consistency and higher the viscosity of the cream
- the longer the cream will take to cool and freeze.

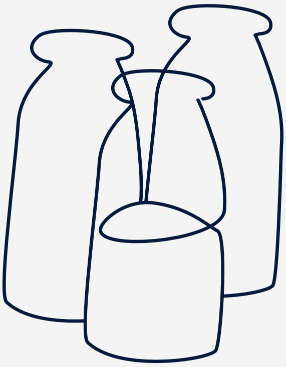
Cream with a higher fat content will thicken considerably at low temperatures and therefore, it should not be chilled below 10°C and should be frozen within 4 hours of cooling otherwise the viscosity will prevent consistent freezing during filling.

For a high fat cream product, this precooling is usually conducted in a scraped surface heat exchanger (SSHE). The SSHE consists of a jacketed cylinder with a rotating dasher holding rows of scraper blades. The product gets pumped through the cylinder whilst the cooling medium is circulated between the cylinder and the jacket. SSHE is designed to continuously remove product from the heat transfer cylinder wall.

This is essential for the successful cooling of products that have large particulates, high viscosity, or those which crystallise during cooling. The scraper blades prevent any build-up on the cylinder wall and optimise thermal exchange and run time.

The subsequent increase in viscosity associated with high fat cream then requires a second cooling stage using scraped surface heat exchange as is represented in Figure 1.

Depending on the functionality required, low-pressure homogenisation could be used as a means of controlling the viscosity of the cream, while minimising clusters of the fat globules and maximising the contact of available protein over the surface of the fat globules. Homogenisation also decreases the average size of the fat globules depending on the pressures used so that quick freezing can result in smaller average crystal sizes.



Frozen cream quality

Freezing is a preservation technique that works by slowing down the enzymatic and chemical reactions that can take place, thus inhibiting spoilage micro-organisms and pathogens. Freezing changes the physical state of a substance by changing water into ice when energy is removed in the form of cooling below freezing temperature. Usually, the temperature is further reduced to -18°C for storage.

Water in the form of ice is unavailable for the growth of micro-organisms. When water freezes, it expands by 9% in volume while forming ice crystals that vary in size depending on the rate of freezing – slow freezing gives large crystals, fast freezing yields smaller crystals. In the case of frozen cream, large crystals may damage the fat globule membrane resulting in the loss of emulsion stability and the formation of free fat on thawing.

It is important to realise that successful freezing will only retain the inherent quality present initially in the product and will not improve quality characteristics, thus quality level prior to freezing is extremely important.

Frozen cream functionality

Frozen cream is used in several applications where fresh cream is required. The main uses for frozen cream rely on its flavour, functionality and fat content. From a consumer perspective, the purpose of freezing cream is to increase convenience, increase shelf life and, if properly processed, frozen cream can be of a quality equal to that of the fresh cream .

When using this cream, customers have a variety of functional requirements, from basic butterfat supply for recombining, through to good whipping properties for cake toppings. Cream intended for ingredient use is suitable for reprocessing into cream soups, recombined milk, butter or ice cream.

There are many factors which influence the manufacture of frozen cream, including:

Price – relative to other fat sources or fresh cream and taking into consideration cost of storage.

Flavour – major reason for use, however, may be used in applications where flavour is not critical.

Convenience – in terms of addition to process, ease of handling or to have a consistent ready supply available in frozen storage; and

Storage – need to have facilities available to handle the transport and storage of frozen cream (-18°C).

Pasteurised cream functional properties

The basic functional attributes of cream include:

Flavour – The unique natural flavour of cream adds richness to many foods and enhances other flavours in food products. Due to the narrow melting range of the milk fat in cream, cream provides a quick release of flavours.

Texture – Cream adds a rich, smooth viscosity and mouthfeel to many food products such as soups and sauces, primarily due to the milk fat and the fat-protein network created during homogenisation.

Fat-soluble ingredient carrier – The milk fat in cream acts as a carrier of fat-soluble vitamins and aids in the even distribution of other fat-soluble ingredients.

Emulsification – The natural proteins present in cream act as emulsifiers and aid in emulsification, aeration, foaming and overrun to give products such as whipped cream and ice cream a smooth and stable texture.

Browning – Cream contributes to the browning of cooked foods through the Maillard browning reaction between proteins and lactose found in cream. The Maillard reaction also contributes to brown flavours in cooked food products containing cream.

Whitening colour – Cream adds a whitening effect in products such as coffee. The colouring power of cream depends on the suspension of particles within the cream. Large particles in cream such as fat globules and casein, reflect and scatter light creating a whitening effect.

9.4 Thawing of frozen milk & frozen cream

Thawing

When using frozen cream, the thawing process is controlled by the end user and is usually the result of available facilities. The major factors are thawing time, which is a function of temperature differential, mechanical energy and time. Different combinations can have differing effects on the flavour, functionality and microbiological quality of the thawed cream. The functionality requirement in the end product will determine whether slow or fast thawing is the better option. This area is normally developed between supplier and customer depending on the intended use of the cream and economies of scale.

The thawing of Frozen Milks and Frozen Creams is critical to controlling the product's quality and functionality. Thawing is a reversal of the physical processes used for freezing. Fat melts at higher temperatures than temperatures at which it solidifies. The production of liquid cream generally requires a temperature above 35°C for the fat to be emulsified and blended. The thawing technique used will depend on the intended application and whether or not retention of the emulsion is required.

Instant thawing

In this case, the Frozen Cream can be broken up mechanically while being heated and melted on a continuous basis. This limits the possibility of microbiological growth but can cause major phase separation as the water phase is in the form of ice crystals, which can mechanically shear the fat globule structure, while not allowing sufficient time for the protein to re-hydrate. This method is suitable in applications where homogenisation is an essential part of the process. Homogenisation results in formation of fat globules. In some cases, microwave technology can be incorporated as the heat source.

Slow thawing

Slow thawing introduces a number of difficulties and requires much more rigorous controls as it can take up to a week depending on the end use.

Optimum temperature during thawing is <5°C for three main reasons:

- To minimise bacterial growth in the external layers as these thaw first and remain at the thawing temperature for the duration of thawing.
- To maximise re-absorption of the water phase by the protein, 2–10% whey off can normally be expected, depending on the processing and freezing methods used. This is normally recovered when processed.
- Higher temperatures, such as 20°C can bring on severe rancidity within 24 hours, as there is insufficient protein to protect all the triglycerides from hydrolysis by lipase enzymes.
- Experience has shown that this method results in maximising protein hydration over time, which helps maximise retention of the cream emulsion.

9.5 Applications of frozen milk & frozen cream

Frozen milks

Frozen Milk products offer numerous advantages. These include:

- Alternatives to dry products such as Skim Milk powder (SMP) and Whole Milk powder.
- Reduced 'powder' flavours associated with milk powders.
- Improved functionality over milk powders, especially solubility.
- Critical where fresh flavour is required.
- Long shelf life ingredient – storage and supply.

Frozen Milks can be used as a replacement for fresh milk. Following careful thawing of frozen product, it needs to be recombined from its concentrated state to the required fat and protein levels. The recombination process usually uses water to dilute the concentrated Frozen Milks which are then heat treated. Heat treatments can involve fresh milk pasteurisation or ESL treatments to produce plain and flavoured drinking milk products.

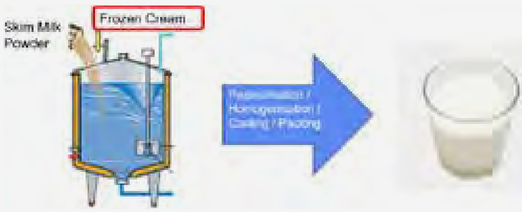
As an ingredient, frozen milks can also be used concentrated or recombined in the manufacture of ice cream, yoghurt and yoghurt drinks, as well as in a range of bakery and confectionery applications.

Frozen cream

Once thawed correctly, frozen cream can provide many of the functional and flavour attributes of fresh cream.

Frozen Cream that has been thawed quickly may show signs of significant phase separation. This product is more suitable as an Ingredient where it is generally further processed via a homogenisation step as in the case of the manufacture of ice cream, butter, cream soups and recombined milks (Figure 3).

Figure 3 Use of Frozen Cream in Recombined Milk



Frozen Cream that has been thawed slowly will contain less phase separation and is better suited to foodservice applications where the appearance, functionality and flavour of the product is more desired. Applications in this area include cream fillers in cakes and bakery, as well as in whipping creams and whipping toppings. Additionally, Frozen Cream can also be used in savoury ingredient applications where fresh cream would normally be used such as potato and pasta bakes, quiches, and numerous bakery applications such as in cakes, biscuits, pies and bread.

9.6 Frequently asked questions (FAQ)

Frozen milk and frozen cream

1. How should frozen cream be thawed?

Thawing is a reversal of the physical processes used for freezing. Fat melts at higher temperatures than those at which it solidifies. The production of liquid cream generally requires a temperature above 35°C for the fat to be emulsified and blended. The thawing technique used will depend on the intended application and whether retention of the emulsion is required.

Instant thawing

In this case, the frozen cream can be broken up mechanically while being heated and melted on a continuous basis. This limits the possibility of microbiological growth but can cause major phase separation as the water phase is in the form of ice crystals, which mechanically shear the fat structure, while not allowing sufficient time for the protein to re-hydrate. This method is suitable in applications where homogenisation is an essential part of the process. In some cases, microwave technology can be incorporated as the heat source.

Slow thawing

Slow thawing introduces several difficulties and requires much more rigorous controls as it can take up to a week depending on the end use.

Optimum temperature during thawing is < 5°C for three main reasons:

- To minimise bacterial growth in the external layers as these thaw first and remain at the thawing temperature for the duration of thawing.
- To maximise re-absorption of the water phase by the protein. Around 2 to 10% whey off can normally be expected, depending on the processing and freezing methods used. This is normally recovered when processed.
- Higher temperatures, such as 20°C can bring on severe rancidity within 24 hours, as there is insufficient protein to protect all the triglycerides from hydrolysis by lipase enzymes.

Experience has shown that this method results in maximising protein hydration over time, which helps maximise retention of the cream emulsion.

2. What is the best way to thaw Frozen Milk or Frozen Cream?

The best thawing methods mainly depends on the end use of the final product but may also include the facilities and equipment the company has available to store and handle the frozen product. In general, a fast thaw method using mechanical action and heat is best used for frozen product that will be reprocessed, especially using homogenisation for the higher fat frozen products. For products that will undergo less processing after being thawed, a slow thaw process is better suited.

3. Does freezing Milk and Cream reduce the quality of the product?

If the chilling and freezing process is carried out correctly, the Frozen Milk or Frozen Cream will retain the functional and quality parameters of the original ingredient. The freezing process cannot improve the quality of the product but will help keep it with the same quality parameters for later use, if manufactured, stored and thawed correctly.

4. What are the advantages of Frozen Milk or Frozen Cream over the fresh products?

The main advantages of the frozen products include increased ingredient shelf life and availability of immediate supply. Furthermore, the frozen ingredients are easier to manage over longer times than the fresh products with regard to quality and storage space.

5. What are the disadvantages of Frozen Milk or Frozen Cream over the fresh products?

The main disadvantages of the frozen products are the functional and quality problems that may be encountered if they are not thawed correctly. Furthermore, there may be additional costs in storage and energy.

6. What is the typical shelf life of Frozen Milk and Frozen Cream?

Frozen Milk and Frozen Cream can have a shelf life of up to 18 months if stored frozen.

Frozen milk

1. When Frozen Milk is thawed, should it be homogenised?

Frozen Milk should be homogenised if it was thawed by the instant (fast) method as this method can cause some damage to the fat globules. If the Frozen Milk is slow thawed it generally does not need to be homogenised.

2. Is Frozen Milk used to replace the traditional WMP and SMP in food processing and bakery?

Frozen Milk can be used to replace WMP and SMP in bakery applications. The Frozen Milks will give improved flavour and functionality compared to dried products such as WMP and SMP.

3. Can Frozen Milk be thawed and used to replace normal milk?

Frozen Milk can be used to replace normal milk. If the chilling, freezing and thawing process is carried out correctly, the Frozen Milk or Frozen Cream will retain the functional and quality parameters of the original ingredient.

4. When Frozen Milk is used for yoghurt production instead of fresh milk, are there any special processes required and does it affect the final yoghurt product?

If the chilling, freezing and thawing process is carried out correctly, the Frozen Milk is likely to retain the functional and quality parameters of the original ingredient. Therefore, the use of frozen milk will not affect the quality and functionality of the final yoghurt product.

5. When Frozen Milk is thawed, will the fat/cream separate from the skim portion?

If the slow thawing method is carried out correctly, there should be separation of fat or cream.

6. Sometimes in Frozen Milk, some fat particles may be observed – why does this happen?

Occasionally, a small amount of fat particles may be observed in thawed Frozen Milk. The likely reason for this appears to be related to the freezing and thawing of the fat and skim portions occurring at slightly different rates.

Frozen cream

1. During the processing of Frozen Cream is skim milk added?

Skim milk is not added in the processing of Frozen Cream. For Frozen Full Cream Milk, skim and cream are blended together. For the Frozen Cream only cream is used.

2. Are there any impacts on the foaming capacity and whippability when Frozen Cream is thawed?

In general, whipping creams have a slightly different manufacturing process than normal cream. In manufacturing whipping cream, the cream is not usually homogenised and is cooled to a slightly higher temperature. If Frozen Cream is made by this process, it will have similar properties to whipping cream manufactured from fresh cream.

3. What is the difference in functionality between Frozen Cream and UHT Cream?

As UHT Cream is processed at very high temperatures compared to Frozen Cream, UHT Cream tends to have greater creaming and fat plug formation. Stabilisers are normally added to UHT Cream to reduce this effect.

4. What is the purpose of low temperature homogenisation during the manufacture of High Fat Frozen Cream?

Low temperature homogenisation is used to decrease the average size of the fat globules so quick freezing can result in smaller crystal sizes. It also helps to decluster the fat globules and maximise the contact of available protein over the surface of the fat globules.

5. What temperatures are used for fast freezing Frozen Cream?

Temperatures as low as –30°C are used for blast freezing the cream in open or closed stacked pallet arrangements.

6. When Frozen Cream is used to make butter, what are the thawing requirements?

The Fast or Instant thawing method is used to reduce the growth of microorganisms which could produce rancid flavours in the butter.

7. Can butter or concentrated milk be used to make Frozen Cream?

The use of butter and concentrated milk to make Frozen Cream will give poor texture and flavour and is not recommended. Good Frozen Cream needs to be made from fresh milk.

8. If the slow thawing process take place at >35°C over a day, will the process cause rancidity?

If Frozen Cream is thawed at high temperatures like >35°C for a long period of time such as one day it will allow the growth of microorganisms that can produce enzymes which cause rancidity.

9. Why does the slow process of thawing Frozen Cream result in some wheying off and will this affect the performance of the thawed cream?

In the slow thawing process, some whey off may occur but this can be readily re-incorporated back into the cream when it is further processed without impact on the product it will be used in.

10. Which processing steps of Frozen Cream are key to making a product with good whipping and foaming parameters?

Minimal or no homogenisation of the cream as well as a two stage cooling process (cooling to 10°C and then to 5°C) followed by blast freezing will greatly improve the whipping and foaming parameters of the Frozen Cream.

9.7 Glossary

Fat globules

Fat globules are the droplets of fat in milk. The droplets are separated from the aqueous phase by a milk fat globule membrane that surrounds and contains the fat.

Homogenisation

The process used to reduce the size of fat globules in milk and milk products. The process usually involves passing the product through a small opening under high pressure. The process also results in the formation of small globules surrounded by newly formed fat globule membrane made from the protein available in the mix.

Membrane filtration

The membrane filtration process refers to the use of semi-permeable membranes for the separation of molecules based on their molecular size. Membrane filtration is a pressure-driven, crossflow or tangential flow process. Four major membrane filtration processes are: reverse osmosis, nanofiltration, ultrafiltration and microfiltration. WPC and MPC are generally manufactured using the ultrafiltration process.

Pasteurisation

The heating of milk by either batch method i.e. 63°C and holding it for 30 minutes or by a high temperature / short time (HTST) method of 72°C and holding for 15 seconds. The aim is to destroy ALL pathogenic organisms which can cause disease in humans and most of the non-pathogenic spoilage organisms and enzymes that may spoil the product.

Phase separation

Phase separation is the process where two distinct phases occur from a single homogeneous mixture. In milk and cream this can refer to the fat (in fat phase) and skim (in serum phase) portions separating.

Rancid

Rancid or rancidity refers to 'off' flavours and odours in a product resulting from the breakdown of fat, usually by lipolytic enzymes and the release of free fatty acids.

Separation

The process of separating the milk into cream and skim milk portions usually via a centrifugal milk separator.

Thawing

Thawing is the process of tempering a frozen product to a chilled state (0-5°C) where there is no residual ice.

Triglycerides

Triglycerides are the main fat components in milk and are comprised of three fatty acids attached to a glycerol backbone.

Vacreation

A process step involving steam distillation to remove unwanted volatile flavours from the milk/cream.

Wheying off

Wheying off refers to the moisture (in liquid form) separating from a solid product such as yoghurt.

9.8 References

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10 Applications of Australian Dairy Ingredients in UHT Products

Content

10.1 UHT processing options

Ultra High Temperature or Ultra Heat Treatment is known as UHT. The aim of UHT is to produce an end product which is commercially sterile but which has undergone minimal chemical or organoleptic changes due to processing or storage.

The UHT process involves two main steps:

- a continuous flow system for the sterilisation of fluids, and
- aseptic packaging to protect the product from contamination.

The key points in this definition are continuous sterilisation, and aseptic packaging.

UHT processing can therefore be considered as a two stage process:

- Stage 1: the fluid is continuously sterilised
- Stage 2: the packaging material is separately sterilised before the final filling and sealing of the packages under aseptic conditions.

The UHT process thus is very different from the process of retort sterilisation, in which the non-sterile product is filled into a non-sterile container, the package sealed and then both the product and the package are sterilised as one unit as in retort sterilisation of cans of food products.

The major steps in UHT processing are shown in Figure 1. The heating can be either direct via steam injection or indirect via a heat exchanger.

Figure 1 Major steps in UHT processing

Raw material
↓
Deaeration (optional)
↓
Preheat/heat regeneration
↓
Homogenisation (indirect systems)
↓
Preheating/heat regeneration
↓
Preheat holding at 85–95°C
↓
Heating to sterilisation temperature
↓
Sterilisation holding (135–145°C for 2–5s)
↓
Cooling (vacuum flash-down in direct systems)
↓
Homogenisation (direct and indirect systems)
↓
Cooling
↓
Aseptic holding
↓
Aseptic packaging
↓
Ambient storage of UHT product

The key principle in UHT processing is rapid heating to a pre-defined temperature of around 135 - 145°C, holding for 2-5 seconds to ensure sterility and then cooling as rapidly as possible before aseptic packaging. In contrast, in-can sterilisation heats products and the package to 120°C and holds for 20 min. The aim of UHT processing is to achieve sterilisation of the product with minimal damage to its physical, chemical, or sensory properties.

Direct and indirect processing

The essential feature of UHT processing is rapid heating and cooling of the product to minimise chemical and organoleptic change. This is achieved in one of two ways:

- By the "direct" heating process which relies on direct contact of the product with steam, either by steam injection into the product or by steam infusion (see Figure 2). Heating is very rapid, taking only about 0.5 seconds to heat from 75-80°C to around 140°C. After sterilisation, the product is passed through a vacuum chamber operating under the precise vacuum conditions necessary to remove the amount of water added to the product from the steam during heating. The vacuum process also ensures rapid cooling of the product from sterilisation temperature to 75 to 80°C.
- By the "indirect" heating process which relies on attaining sterilisation temperatures by heat transfer through a stainless steel interface, using a tubular or plate heat exchanger (see Figure 3). Regenerative heating, whereby hot milk after sterilisation warms incoming cold milk, and cooling of the product are essential parts of the system. In indirect UHT systems, longer heating and cooling times are required, compared to direct heating.

Figure 2 Direct heat treatment equipment

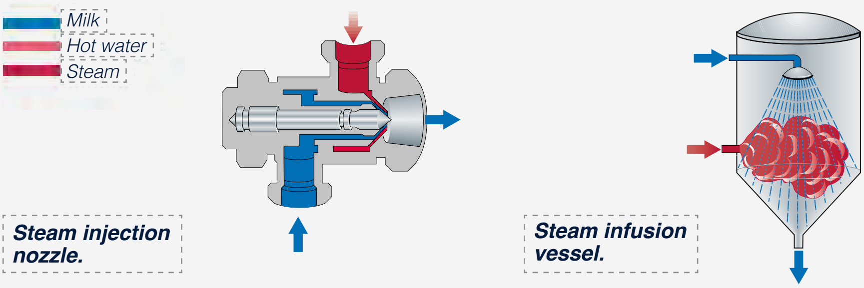

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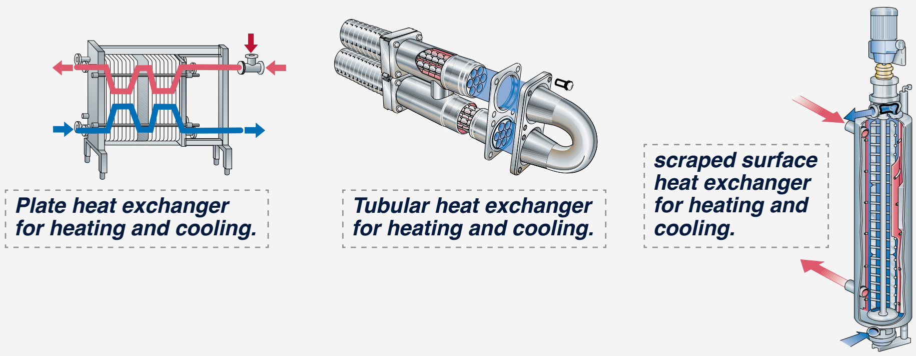
Figure 3 Indirect heat treatment equipment



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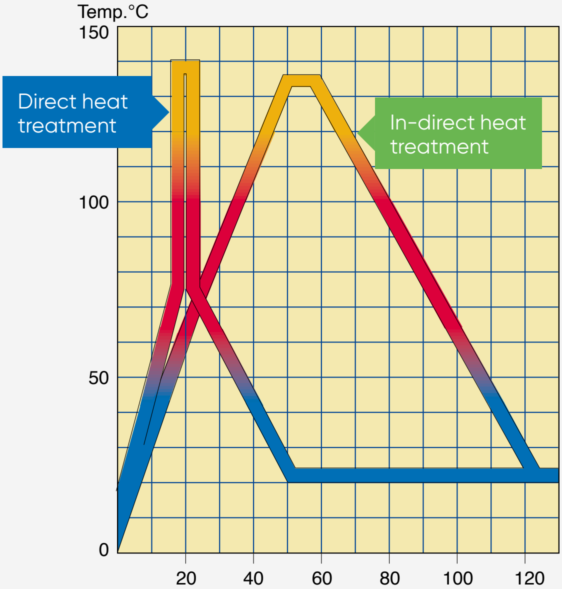
Both processes involve preheating the product to 75 to 95°C and then rapidly heating to the sterilisation temperature of about 140°C. Typical curves for the indirect and direct systems are shown in Figure 4. Note that the overall shape of the direct heating system above 80°C is similar to that of the Ideal Curve. A good indication of the heat damage to the product is the area under the curve. It is clear that the indirect system does more damage to the product than the direct system at identical sterilisation temperatures and holding times. This is due to the slower heating and cooling in the indirect system.

Figure 4 Temperature curves for Direct and Indirect UHT Systems



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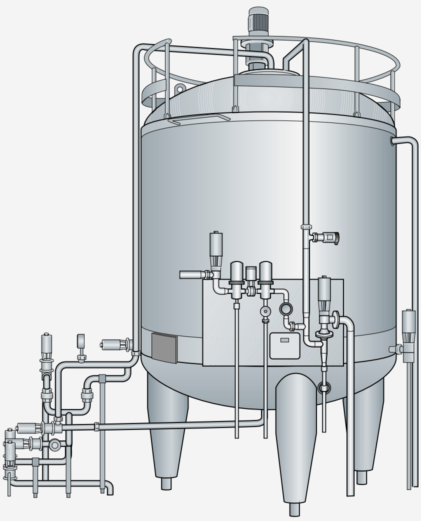
Homogenisation

The purpose of UHT is to manufacture a product which will keep for an extended period without refrigeration. Thus, homogenisation is essential to avoid fat separation in the product. The homogenisation step can be either before or after the sterilisation step. If the homogeniser is located downstream from the sterilisation section, it must be designed to be sterilised effectively and during operation, it remains aseptic. Thus, normal homogeniser valves, pumps and other components must undergo costly modification to ensure that they can be sterilised and stay aseptic during operation. While these modifications make the homogenising process expensive, the advantage is that this yields a better quality product. In particular, downstream homogenisation achieves a reduction in fat separation during storage, and reduced sedimentation possibly due to dispersion of micro particles of burn-on from the sterilisation section, or dispersion of denatured whey proteins. Downstream homogenisation is particularly important for direct UHT systems.

Aseptic holding tanks

Most UHT plants have one or more aseptic holding tanks (A-tank) as an integral part the plant. These vessels allow a balance of flow rates between the UHT processor and the packaging section, so as to prevent the need for recirculation of the product, should processing capacity exceed filling capacity. Recirculation is very undesirable, as it results in increased heat treatment of a portion of the product. In such cases, the aseptic holding tank plays an important part in ensuring consistent good quality of product. A typical aseptic tank is shown in Figure 5.

Figure 5 Aseptic (A) Tank



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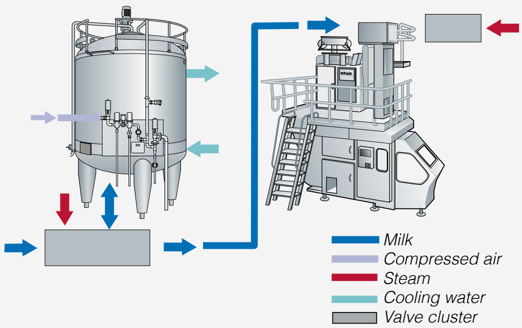
Fillers

Packaging material for UHT products include laminates (either preformed or rolls), bags and plastic bottles. Selection is determined mainly by product requirements, market assessment and cost.

Figure 6 An Aseptic Filler in line with the A-tank



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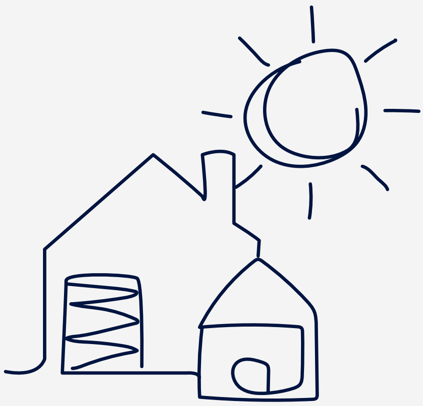
Plant sterilisation

All sections of the plant, particularly after the sterilising and holding section must be sterilised before start of processing and must remain sterile for the duration of the run. This sterilisation may be carried out either by pressurised hot water or by high pressure steam. The time and temperature conditions for this sterilisation step are specified by the equipment manufacturers.

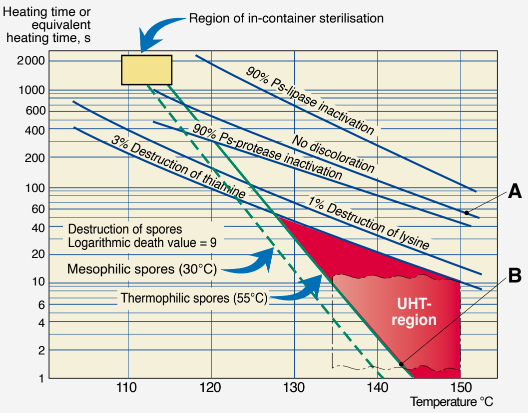


10.2 The effects of UHT processing on dairy products

Changes in the physical and chemical characteristics of UHT milk

The effect of UHT heating on bacterial spore reduction and chemical changes in the milk are summarised in Fig 7. Line A represents the lower limit of temperature and time where milk will discolour and turn brown and Line B represents the lower limits for the destruction of bacterial spores which indicates complete sterilisation of the milk. The other lines in the graph represent enzyme deactivation (lipase and protease) as well as protein and amino acid (thiamine, lysine) denaturation.

Figure 7 Chemical and bacteriological changes during UHT treatment



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Protein denaturation

The extent of whey protein denaturation is important for both functionality and nutrition. This denaturation depends on both the sterilisation conditions and the preheating and cooling regimes. In general, whey protein denaturation is greater in indirect systems compared with direct heating systems.

Reflectance and sediment

In general, conventional retort sterilisation and UHT processing both result in an increase in the opacity of milk. This is due to an increase in the number of reflecting particles present due to denaturation and aggregation of whey proteins. Homogenisation also increases the opacity of milk. As the pH of milk is decreased, the reflectance of the resultant UHT milk initially rises, as would be expected. However, its reflectance reaches a maximum at about pH 6.55 and then decreases very rapidly. The reduction in opacity corresponds to an extraordinarily rapid increase in sediment in the product. This sediment forms immediately after UHT processing and is a heavy material which can be removed by centrifugation at only 100 g for a few minutes. Thus, the milk is stable to UHT processing at pH say, 6.65, but at pH 6.50, the micellar stability of the milk is totally destroyed on UHT processing, and the product is unusable. Further, the sediment will cause rapid burn-on throughout the system and cause complete plant blockage. Therefore, if rapid burn-on and sedimentation in the product are to be avoided, it is essential that the pH of the raw milk be above about 6.65-6.70. A reduction in pH below this value, by chemical means, addition of formulated components, or through the action of bacteria, can result in rapid sediment formation.

pH

It is very difficult to comment on the effect of UHT processing on pH, as many factors can influence these changes. However, some general observations can be made. Firstly, the change in pH is around 0.05-0.10 unit which is small. Secondly, milks from direct UHT systems have a higher pH than the same milk processed by indirect UHT systems. This is probably due to the effect of the differing time and temperature profiles influencing the production of acids via the Maillard reaction. The Maillard reaction occurs when reducing sugars such as lactose interact with the amino groups of amino acids during thermal processing of food.

It can affect the nutritional value via loss of essential amino acids such as lysine, colour changes via brown pigment formation and flavour changes. pH may also change slightly due to removal of carbon dioxide during vacuum cooling of product after heating in direct systems.

Freezing point

Opinion is divided among UHT experts regarding the effect of UHT on freezing point. The balance of evidence however seems to suggest that there is no significant change as a result of UHT processing, and any observed changes are more likely to be the result of dilution or concentration of the product. However, changes in freezing point will occur with direct processing if the vacuum in the flash-down chamber is not set appropriately.

Flavour

UHT milk immediately after processing has a very strong sulphurous, cooked odour and flavour. This is due to release of volatile sulphur compounds including hydrogen sulphide and methanethiol from the whey proteins and milk fat globule membrane proteins. There is a marked improvement in the flavour of the product during the first few days as these compounds are oxidised by the dissolved oxygen in the product. The rate of such improvement is related to the concentration of dissolved oxygen.

Lactulose formation

During UHT processing, some of the lactose (glucose-galactose) is isomerised to lactulose (fructose-galactose). The greater the intensity of the heating the more lactulose is produced. Since unprocessed raw milk contains no lactulose, its content is a good indicator of the severity of heat treatment. It correlates well with the intensity of cooked flavour.

Contamination of the product

Clearly problems with contamination of the product are of major concern to manufacturers. Protocols must be enforced to ensure that any such problems are identified and programs maintained to ensure that the source of contaminants can be clearly identified and removed. While highly heat resistant spore forming bacteria which may survive UHT treatment are a constant concern, post-sterilisation contamination is the most common form of contamination of UHT milk and dairy products.

Changes in the physical and chemical characteristics of UHT milk occurring during storage

Storage temperature is the key factor determining storage induced changes in the product. The rate at which most of these changes occurs is reduced as the storage temperature decreases. The major exception to this rule is the onset of age gelation which occurs most rapidly at about 27°C. Age gelation is a common defect which limits the shelf life of UHT milk by making the product into junket like gel. Age gelation defect is due to the action of proteolytic enzymes which survive UHT processing.

pH

The pH of UHT milk decreases during storage. The rate of decrease in pH increases sharply with increased storage temperature. The change in pH is not necessarily related to the onset of age gelation. Typically, after 3 to 6 months, the pH of UHT milk drops by 0.05 units on storage at 4°C, 0.20 pH units at 15°C and 0.5 pH units at 40°C. The changes, which are approximately linear with time, are mostly due to acids such as formic acid produced by the Maillard reaction. This reaction proceeds slowly at temperatures less than 30°C but much faster at higher temperatures.

Flavour

The flavour of UHT milk during storage is controlled by storage temperature, storage time and oxygen content. The oxygen content of the milk will depend on the particular process employed for manufacture. However, in the long term, the permeability of the container and the amount of headspace in the package play major roles in oxygen availability. Oxidation by the available oxygen is responsible for the development of stale flavours in fat containing products after about 6 weeks' storage at around 25°C.

Some cooked flavour due to sulphur compounds remains during storage. Also a flavour described as rich or heated which is related to the Maillard reaction intensifies during storage as do stale flavours due to oxidation. Bitter and rancid flavours can also develop if the product contains residues of heat resistant proteases or lipases, respectively.

Age gelation

Age gelation is one of the most common defects in UHT products and a major challenge for UHT manufacturers. It is a purely physico-chemical process of coagulation, and the product remains sterile, even though it takes the form of a rennet like gel. The onset of age gelation can occur as early as 2–3 weeks after manufacture but can also be as late as a year after manufacture. The time taken for the onset of age gelation is highly dependent on storage temperature. At temperatures of about 4°C it can be delayed indefinitely; at 15°C, useful retardation can be achieved. Maximum rate of gelation occurs at about 27°C, and gelation is completely prevented by storage at or above 40°C. Of course, storage at 40°C is never an option because the product will have other major defects such as browning and oxidised flavours.

Colour

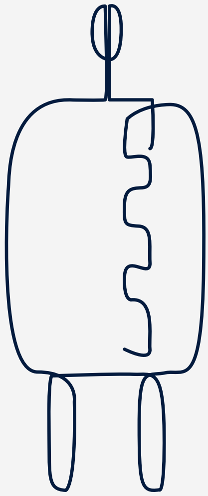
The brightness of UHT milk generally decreases on storage, the rate of decrease dependent mainly on storage temperature. The decrease in brightness is a function of development of Maillard browning reactions. Storage at much above 30°C leads to rapid development of dark colour of the product within a few weeks.

Fat separation

In non-recombined or non-reconstituted products, fat separation is always the result of poor homogenising conditions. This may be the result of inadequate homogenising pressure, inadequate pressure in the second stage of the homogeniser, scratches on the homogeniser valves or leaking by-pass valves. In recombined or reconstituted products fat separation can usually be overcome by addition of the correct stabilisers.

Excessive nominated shelf life of the product leading to market problems

Too often manufacturers of UHT products are pressured by retailers to accept "best by" dates which are too optimistic for the market conditions. Such actions lead to problems with the long term marketing of the products, and such pressure should be resisted. Shelf life should reflect the actual shelf life of the product under practical handling and storage conditions.



10.3 Frequently asked questions (FAQ)

A UHT processing

1. Why does UHT processing give a better product than in-can sterilisation?

The UHT process started from the fact, first noted at the start of the twentieth century, that biological reactions which lead to the destruction of bacteria have a higher thermal co-efficient than the chemical reactions which lead to undesirable changes in the product. These changes include development of off flavours and loss of nutritive value when subjected to high temperature treatments. For example, a 10°C rise in temperature of sterilisation results in an increase in the rate of destruction of *Bacillus stearothermophilus* by a factor of about 10, whereas for the same temperature rise, the rate of browning increases by a factor of only about 3. *B. stearothermophilus* is a comparatively heat-resistant organism, and the rate of destruction of more sensitive organisms such as *B. subtils* increases by a factor of about 30 for each 10°C rise in temperature. Thus, to achieve a similar degree of destruction of *B. stearothermophilus* through increasing sterilisation temperature by 10°C, a reduction of holding time by a factor of at least 10 is possible. However, the browning reactions at this increased temperature, but reduced holding time, will be reduced to about 3/10 of the intensity at the lower temperature. The results of this effect are shown in Table 1 below.

Table 1 Effect of temperature on chemical and bactericidal effects

Temperature °C	Time for equal bactericidal effect	Chemical change for same bactericidal effect
115	1	100
125	.1	30
135	.01	9
145	.001	2.7

Therefore, by increasing sterilisation temperature, and reducing holding time to obtain equal sterilisation effect, the degree of concomitant chemical, physical and organoleptic damage in the product is reduced. The logical development of this is the UHT process, in which high temperatures and short times are employed to yield products which are commercially sterile but with comparatively little chemical, physical, or organoleptic damage. Commercial sterility means that microorganisms will not grow in the product under the normal conditions of ambient storage

2. How does Extended Shelf Life (ESL) processing differ from UHT processing

ESL milk is produced by heating at 120°C to 135°C for 2-5 seconds which is less intense than UHT processing. ESL processing does not destroy all the bacteria specifically not all the spore formers. These organisms may grow in the product during storage at room temperature. Therefore, ESL milk must be stored refrigerated. Its shelf life is 30-60 days at refrigeration temperatures which is considerably less than that of UHT milk at room temperature. Minimising post-heat treatment contamination is the key for maximising the shelf life of ESL products.

The flavour of ESL milk is much closer to that of pasteurised milk heated at 72°C for 15 seconds rather than UHT milk due to the lower intensity of heat treatment. ESL milk can also be produced by a microfiltration (MF) membrane process which filters out most of the bacteria based on size. Heat treatment required for microfiltered milk for ESL is much lower, so this ESL milk has a very desirable flavour.

"Ultra-pasteurised" milk produced in the USA is an ESL product. It is thermally processed at or above 138°C for at least two seconds, either before or after packaging, so as to produce a product which has an extended shelf life under refrigerated conditions. The processing of this product falls within the range of UHT processing but it differs from aseptically packaged UHT milk in that it is stored refrigerated rather than at ambient temperature.

This UHT milk has more cooked flavour than ESL milk processed at ≤ 135°C.

3. What are the advantages of direct and indirect UHT processing?

The direct UHT treatment process

The direct process relies on direct steam injection or steam infusion. Either method results in instantaneous heating of the product to sterilising temperature, through releasing the latent heat of the steam into the product. In both cases, a portion of the steam condenses in the product with around 10% temporary dilution of the product. In the next step, this 10% water is removed by subjecting the product to a vacuum treatment in a chamber operating under precise conditions. The vacuum step also results in very rapid cooling of the product from sterilisation temperature to around 75 - 80°C. As the steam comes in direct contact with the product, use of culinary quality steam is absolutely essential. It is important that the steam does not impart any taints or flavour defects in the product. This can easily happen in UHT plants using direct heat.

There is one further aspect that has caused legal issues in some countries. The addition of water to milk is seen as adulteration and hence is illegal; although the same amount of water is removed by the vacuum process, the same molecules are not necessarily removed, and therefore the product contains some added water, which is against regulations. This aspect prevented the adoption of direct UHT processing for many years in some countries. Furthermore, if the vacuum setting fails to remove all the water added during the heating, the final product will be adulterated. This can easily be checked by the operator by freezing point measurement.

The indirect UHT treatment process

Indirect UHT processing relies on heat transfer through a stainless steel interface, using a tubular or plate heat exchanger. High-pressure steam or hot water is used as the heating source. Regenerative heating and cooling of the product is an essential part of the system. Indirect UHT requires longer time for heating and cooling compared to direct processing. An alternative indirect heating process is the so-called Actijoule process where the heat transfer tube is electrically heated. It is currently used for manufacture of milk and milk products in some countries.

Direct heating UHT vs indirect heating UHT - Which system is preferable?

This is not an easy question to answer because many factors need to be considered. Much depends on the product, equipment, market demands and manufacturing environment. Important facts about Direct and Indirect systems include:

- UHT direct systems are more complex and in general require more control equipment.
- Direct systems require supply of special high quality culinary steam.
- Direct systems have higher operating and capital costs.
- Direct systems can handle viscous materials which can pose problems on some indirect systems particularly those using plate heat exchanger systems.
- Indirect systems are energy efficient and have heat >85% regeneration efficiency compared with around 40% for direct systems.
- Indirect systems face challenges with burn-on deposits in the heating, sterilisation, and cooling sections. Such deposits are formed from mixtures of heat denatured proteins and salts. The deposits reduce rate of heat transfer and can reduce total run times before requiring an intermediate clean. Direct systems, particularly infusion systems, have little or no deposits and can run for >18 hours without cleaning.
- Direct systems can yield product with a low oxygen content. This may be of advantage for improved flavour and retention of some vitamins.
- UHT milk from direct systems is more prone to age gelation than that from indirect systems.

An important consideration for comparison is the effect of each process on milk quality. Now the basis for comparison could be heating at equal holding temperatures and times or equal level of destruction of spores. In general, the direct system with its minimal heating and cooling times gives a product with lower whey protein denaturation and vitamin loss. This would be expected to yield better flavour. However, in practice, the situation is far from being clear. Manufacturers using indirect systems have made great progress in improving their operations, and in many cases the flavour of product from indirect systems is comparable or superior to that from direct systems.

4. What are the possible sources of contamination of UHT products?

If product contamination is at an unacceptable level, it is important to identify and rectify the source of the contamination. It is rare for resistant spores to survive UHT treatment although there have been cases in Europe showing survival of highly heat resistant *Bacillus sporothermodurans*. The sources of contamination always involve post-sterilisation contamination. One exception is spore forming bacteria from ingredients, particularly cocoa, which may withstand the sterilisation conditions due to physical protection within cocoa particles.

The types of organisms in the UHT product can reveal the source of contamination. It has been suggested that contamination with non-heat resistant spores like *B. Cereus* suggests that the plant has not been cleaned or sterilised effectively. In such cases the sterilising process would have eliminated vegetative organisms but not been effective in eliminating spores of moderate heat resistance. One source is a contaminated downstream homogeniser. Regularly replacing homogeniser seals can reduce this type of contamination. There have also been several reported cases of contamination of UHT products with non-spore forming bacteria. Such contamination can only occur after the sterilisation section.

Other studies have shown that spores such as *B. stearothermophilus* trapped under seals and attached to stainless steel have enhanced their ability to survive UHT treatment. Some UHT manufacturers have encountered problems with contamination by the mould *Fusarium oxysporum*, which can lead to flavour and texture defects and blowing of packs. The cause of such defects probably is contaminated air near the filling machines. It is therefore important that air filters on aseptic tanks and around filling machines are well maintained.

A further area which can cause concern is the development of pinholes in heat exchangers, leading to contamination of the product by cooling water. Plate heat exchangers are more prone to this problem than tubular heat exchangers. The problem can be diagnosed by the presence of water based contaminants in the product.

In summary, the causes of contamination include:

- Downstream homogeniser
- Filling machines
- Aseptic tanks
- Seals in homogeniser and other machinery
- Pinholes on plate heat exchangers
- Ineffective CIP and sterilisation.

The steps to overcome these problems with contamination are:

- Ensure that protocols are in place to identify contamination problems as early as possible
- Ensure the CIP and sterilisation are fully validated and verified on a continuous basis
- Identify the contaminants present
- From the types of the contaminating organisms, identify sources of contamination
- Take *corrective* and *preventative* action.

It should be emphasised that the sources of contamination always involve post-sterilisation contamination. There are many examples of manufacturers increasing the severity of heat treatment in response to overcoming isolated problems with bacterial contamination.

This more intense heat treatment results in greater chemical damage to the product which is undesirable. This so-called "Process Creep" is an inappropriate response to such challenges and manufacturers should be on guard against it.

5. How can oxygen in the UHT product impact quality? What are sources of oxygen entering the product and how can this be avoided?

The level of oxygen in the product can have important implications for flavour defects during storage and for the loss of vitamins during processing and storage.

Sources of oxygen and air entering the product include:

- the raw milk
- the aseptic holding tank
- the head space of packages
- permeation through the packaging material.

The impact of oxygen on product quality is determined by the storage temperature of the product.

Processing systems

The amount of air in headspace depends on the packaging systems. Many systems, particularly the form-fill-seal systems which seal below the liquid level, have minimal headspace of around 5-8 ml per litre pack. Other systems which fill into preformed paperboard packages have >30 mL in one package while plastic bottles often have headspace of 50-60 ml per one litre bottle. Clearly the variations in the amount of oxygen present will have a significant impact on flavour changes during storage.

Milk is normally saturated with oxygen (7-9 mg/L), but in the direct process, the oxygen is stripped during the vacuum flash down, and dissolved oxygen levels decrease to only 1-2 mg/L. In a packaging system such as certain TetraBrik machines, there is little opportunity for the product to pick up more oxygen unless an aseptic tank with oxygen-containing headspace is used.

As there is little head space in the package, it is possible in these systems to obtain a very low oxygen product which will remain in that form for an extended period provided the permeability of the packaging material to air is very low.

UHT products which are free of oxygen have the advantage of retaining oxygen labile vitamins, such as ascorbic acid and folic acid, for longer. These can be lost in a few days in product containing oxygen, and lead to somewhat improved flavour after extended storage, although initially they may show poorer flavour.

Indirect systems with no vacuum flash down, those that use aseptic holding tanks and those packaging systems which have large headspace volume will result in products with a high oxygen content. High oxygen content in the product can lead to early development of stale and oxidised flavour defects during storage.

Filling systems

Amongst the form-fill-seal operations, various plastic materials are used in roll forms, with a web thickness of up to 1.5 mm for cups. Lids are usually of thermoplastic lacquered aluminium foil. The packaging material base and lid foils are, for example, immersed in peroxide and dried, and all filling and sealing operations are carried out in a sterile air tunnel at slightly above atmospheric pressure. The seal is formed by heat sealing of the lacquered aluminium web onto vacuum formed cups. The advantage of such systems is the wide range of shapes which can be filled, as per market requirements. However, many of these systems are highly permeable to oxygen, which can lead to a decrease in organoleptic quality during storage. Metal cans are of course impermeable to oxygen, but most paper and plastic laminate packages are at least partially permeable to oxygen. Laminates vary in their composition, and this is reflected in their price. Many laminates contain a layer of aluminium to prevent oxygen contamination, but cheaper versions without an aluminium layer have been used in UHT operations from time to time to reduce costs.

Naturally, the higher oxygen permeability will influence the rate of oxidised and stale flavour development of fat-containing products stored in these packages. Even in the case of aluminium foil laminates, oxygen permeability is possible through the seams in some instances.

Flavour

UHT milk immediately after processing has a very strong sulphurous cooked odour and flavour caused by volatile sulphur compounds which are oxidised by the dissolved oxygen in the product during the first few days of storage. Because of this, the oxygen content of UHT milk decreases rapidly after the first few days. In practice, for samples stored at 2°C, there appears to be general preference for the flavour of low oxygen samples throughout a storage life of three months. At higher temperatures, such as 30°C, high oxygen samples are initially preferred, but after 3-4 weeks comments such as "oxidised" are often noted in fat containing products. Changes in flavour correlate well with changes in oxygen content and sulphydryl content of UHT milks.

Vitamins and oxygen

Vitamin C and folic acid are sensitive to dissolved oxygen in the product, and losses of these vitamins can occur very rapidly when oxygen is available. Table 2 shows the effect of oxygen on losses of these vitamins.

Table 2 Effect of oxygen on ascorbic acid and folic acid contents of stored UHT milk

Vitamin	Oxygen level (ppm)	Storage period (days)	Losses %
Ascorbic acid	0.1	60	20
	1–2	14	90
	8	7	100
Folic acid	0.1	60	0
	1–2	60	5
	8	14	100

The implications of the Vitamin C and folic acid losses are important with regard to label claims for these components in UHT products. Clearly even fortification will not help significantly, particularly if the product package has a significant headspace, as there is often more than enough oxygen present to destroy a considerable amount of Vitamin C and folic acid.

6. What are the challenges in sampling UHT to investigate contamination?

For UHT products, it has been suggested that, after incubation of all filled containers, not more than 1 sample in 5000 should show signs of contamination. After installation and commissioning of a UHT plant, intense assessment of the level of contamination occurring in products is vital to ensure that all parts of the plant are correctly installed and operating well. This will involve assessment of many containers produced over a long period.

After final authorisation of the process and commencement of normal UHT operations and production, it is simply not possible to ensure that the required standard of less than 1 in 5000 packs contaminated is met, without the testing of a significant portion of production. Clearly, incubation and testing of samples means that these samples cannot be used for sale, and it is to the benefit of the company's overall profits if the amount of samples required for testing is reduced to a minimum consistent with safety and overall sampling policy. For example, a statistical analysis of operations has suggested that in order to ensure a 95% probability that the spoilage rate is less than 1 in 1000 (well above the recommended limit of no more than 1 in 5000), a random sample of 300 containers should be examined from a total output of 3000 to 8000 containers (between 10% and 3.75% of production).

For most companies, the statistical patterns used for selection of samples for contamination evaluation would have been recommended by the equipment suppliers. Often they include sampling of comparatively small numbers at regular intervals, somewhat higher number of samples being taken at commencement and completion of production, and at other times, for example during reel changes and flying seal changes as needed.

However, such protocols can often only indicate whether gross contamination has occurred. For example, the normal protocols employed can identify if the contamination rate increases from less than 1 in 5000 to say 1 in 50 or so. However, they often cannot identify if the contamination rate has increased by a factor of 2, 3 or even 10, to 1 in 2500, 1 in 800 or even 1 in 500.

Fortunately, most problems result in a very marked increase in contamination rates such that the protocols used in plants can readily identify that a problem with product contamination has occurred. However, it should be borne in mind by operators that the protocols cannot be relied upon to detect changes of some significance other than those which lead to gross contamination in the product.

In routine operations, it has been suggested that random samples be taken at a rate of 50 per 3000 packs produced, with other suggestions involving sampling about 1% of production and others suggesting only 0.25%. Although these sampling regimes do not indicate precise spoilage rates, it is claimed that this problem is addressed by the accumulation of data and experience over time.

A further factor of importance in assisting determination of the cause of contamination is the need to ensure that all samples are clearly labelled and coded. Evidence of the time of filling, the filling machine and the UHT plant employed is crucial in assisting with assessment of contamination problems. Such coding is also important in the evaluation of long term problems such as age gelation and sedimentation in the product.

B Nutritional aspects

1. What is the effect of UHT processing and storage on nutritional aspects of products?

Results of many feeding experiments, indicate that the nutritional value of UHT milk is comparable to that of pasteurised milk. The biological value, true digestibility and net protein utilisation of the milk proteins are not affected by UHT treatment.

Milk proteins

The first change which occurs on the heating of milk is denaturation of protein which refers to unfolding of the regular structure. This involves changes in the spatial distribution of the proteins, without a breakdown in the peptide bonds.

Denaturation per se has no negative nutritional significance, and in fact can improve digestibility and utilisation of milk protein, as a result of the protein structure unfolding. Further, heat-treated milk is precipitated as a finer curd in the digestive system, which improves enzymic activities and digestibility.

Heat treatment results in loss of lysine which is an essential amino acid in milk proteins. Lysine loss is due to the Maillard reaction which involves the reaction of lysine and lactose. The resultant complex is resistant to digestive enzymes, and the lysine is not available for nutrition. Pasteurisation of milk results in loss of about 1 to 2% of lysine, UHT treatment about 2 to 4% loss, with insignificant differences between direct and indirect systems. Boiling milk results in loss of about 5% lysine; sterilisation 6 to 10% loss and evaporation about 20% loss. No loss of lysine occurs on storage of UHT milk at 2°C, a small loss occurs at room temperature, and at 38°C, lysine loss is around 25% over 6 months.

Greater losses of available lysine can occur in other dairy products. In particular, lactose hydrolysed products are more susceptible to the Maillard reaction because the glucose and galactose formed are more reactive with lysine than lactose. Another product which is susceptible to lysine loss is infant formulae as they often contain elevated levels of lactose and whey proteins which can participate in the Maillard reaction.

A common method of assessing loss of lysine availability or "lysine blockage" is by determination of furosine which is formed from lactulosyllysine, the product of the first stage of the Maillard reaction, by acid hydrolysis. The amount of furosine measured is directly related to the amount of lysine blockage. Furosine is also used as an index of heat treatment but because it increases during storage it is not as useful as lactulose.

Milk fat

Under UHT conditions, there are no adverse effects on the nutritional properties of the milk fat. Small changes occur due to oxidation and hydrolytic reactions, which result in an increase in the free fatty acids due to the action of residual bacterial lipase. In the absence of residual bacterial lipase, the extent of formation of free fatty acids is dependent on storage temperature, being very slow at refrigeration temperatures, but more rapid at elevated temperatures. Such problems can be severe, as even low concentrations of free fatty acids can lead to flavour and aroma defects in UHT products.

Minerals

UHT treatment does not change the mineral content but changes distribution of some minerals between the casein micelle and the milk serum. Human feeding trials with infants indicate that calcium and potassium retention is higher with UHT milk than pasteurised milk.

Vitamins

The level of the fat soluble vitamins A, D, E and K, and B complex vitamins riboflavin, pantothenic acid, biotin and nicotinic acid are not impacted by UHT processing. Furthermore, during storage, there is virtually no loss of these vitamins in light-protected packaging.

C Defects in UHT product

1. What factors control fat separation in UHT products?

Summary

- Fat separation is caused by inadequate or inappropriate homogenisation.
- Even a very small number of larger fat globules in milk, less than 1% of the total fat can lead to major difficulties in fat separation on storage.
- Homogeniser selection, valve design, maintenance and operating temperature and pressure are key factors in controlling fat separation.
- Regular microscopic examination of homogeniser valves is recommended.
- Use of additives, if permitted, to increase the viscosity of the aqueous phase can assist in controlling fat separation.

Discussion

In general, fat separation in UHT milk is the result of inadequate or inappropriate homogenisation.

Why is fat separation such an important issue in UHT products? The simple reason is that, unlike pasteurised products, UHT products are required to retain their stability for 6 to 12 months, during storage at 25 to 30°C. In contrast, pasteurised products need to retain their acceptability for 2-3 weeks during storage at around 4°C. Therefore, homogenisation efficiency is absolutely critical for UHT products whereas it is less critical for pasteurised products. To ensure adequate homogenisation in UHT operations, considerable care must be taken in homogeniser selection, design of homogeniser valves, maintenance, and homogeniser temperature and pressure.

In general, the rate of fat globules rising towards to the top is influenced by the following factors:

- **The rate of rising of fat globules increases as the square of the fat globule diameter.** So, a globule with twice the diameter rises at four times the speed, one with three times the diameter rises at nine times the speed and so forth.
- **The rate of rising is directly proportional to the difference between the density of the fat globules and the external liquid.** In the case of milk, homogenisation creates globules with surrounding membrane of proteinaceous material which is heavier than water. Natural fat globules are lighter than water, but the homogenised fat globules and membrane are a little heavier than the original fat globules. Also, difference between the densities of water and the 'new' globule and membrane complex is decreased. Thus, homogenisation significantly decreases the rate of separation by reducing the average size of the globules. Homogenisation also increases the density of the globules, which reduces fat separation. Under extreme homogenising conditions, the density of the fat globule and membrane complex can be greater than the aqueous phase, causing the fat particles to sink. However, such a phenomenon happens rarely.
- **The rate of rising of fat globules is inversely proportional to the viscosity of the liquid.** Thus an increase in viscosity of the aqueous phase through the addition of gums such as carrageenan or xanthan gum will reduce fat separation.

However these concepts reflect only an ideal situation. In practice, even with good homogenisation there will be a range of fat globule sizes in the end product. What is important in reducing fat separation is not only that the average size of the globules is small, say < 0.5 microns, but that there are very few globules with a size much greater than this.

It is of little value, for example, if the average globule size is 0.5 micron, but 3 or 4% of globules have a size > 1.5 microns. The influence of small numbers of large globules on fat separation rates is illustrated in Table 3 for various theoretical situations.

Table 3 Effect of fat globule size distribution on fat separation

Case Number	Particle size (μ)	Number (%)	Volume (%)	Rising rate of largest particles (smallest =1)
1	0.5	100	100	1
2	0.5	99	78	1
	1.5	1	22	9
3	0.5	99	44	1
	2.5	1	56	25
4	0.5	99.9	97	1
	1.5	0.1	3	9

For milk with all globules of size 0.5 microns (Case 1), the rate of rising has been defined as 1.0. In Case 2, (milk with 99% of globules of size 0.5 microns and only 1% of globules of size 1.5 microns) the 1% of globules of 1.5 micron size contain 22% of the total fat present, and these particles rise at 10 times the normal rate. These figures may be surprising at first, but they are the outcome of the relationship between the rate of rising of globules and the diameter of the particles. Certainly, fat separation will be a problem with this situation. In Case 3, with 99% of globules of size 0.5 microns and 1% of size 2.5 microns, the 1% of globules contain 56% of total fat, and rise at 25 times the normal rate! Severe fat separation is likely. Even in Case 4, with 99.9% of globules of 0.5 microns and 0.1% of size 1.5, the larger globules represent 3% of total fat and rise at ten times the normal rate.

Thus, it can be seen that even very small amounts of larger globules can contain a highly disproportionate amount of the total fat present, and these will rise at many times the normal rate.

Careful and efficient homogenisation is therefore critical to minimise fat separation.

For homogenisation of UHT milk, two-stage valves are often used. One of the main reasons for this approach is to ensure that any clusters which are formed after the first stage of homogenisation are broken up by the second stage. However, from time to time, depending on the systems employed and the valves used, clusters may be encountered. Clusters of small globules will act as one large globule leading to major challenges in fat separation.

Free fat in the product can lead to rapid and severe fat separation. Free fat is caused by either coalescence of smaller particles in the product, or through inadequate recombination techniques leading to fat globule instability. This is not a problem with non-recombined products, and if proper care is taken in the manufacture of recombined products, fat separation can be minimised.

Control of fat separation

As indicated above, control of fat separation is dependent on efficient design and operation of the homogeniser. Even small invisible marks on the homogeniser valves can reduce homogeniser efficiency, allowing formation of a greater number of larger globules. Visible examination of the valve surfaces is not sufficient. Microscopic examination of the surface should be undertaken regularly, and the valves replaced or re-faced as required. If products such as chocolate milks are regularly manufactured, increased wearing of the homogeniser valves is likely. It is essential that UHT factories pay increased attention to valve maintenance.

An increase in aqueous phase viscosity can reduce fat separation. If permitted, the use of additives such as carrageenan and xanthan gum which help increase viscosity of the aqueous phase can assist in controlling fat separation.

Sometimes, incorrect pipeline design can allow some milk to enter the product bypassing the homogeniser, through, for example, a CIP bypass tube. An examination of the plant should be undertaken to ensure that such bypass does not happen.

Laboratory evaluation of product for potential fat separation on storage is not easy. Even a very small proportion of large globules can contribute heavily to fat separation, and these are not readily identified. A useful test is using a visual microscope to measure mean globule size. But in general, this will only indicate if there are major problems with the homogeniser. It is particularly difficult to assess the proportion of large diameter globules when they are present in only small numbers.

2. What influences age gelation in UHT products?

Age gelation is a major challenge for many UHT processors because it is quite unpredictable, and consequences can be problematic. The problem is formation of a gel-like consistency in the product which may occur anytime from about 6 weeks after manufacture to > 1 year. The product is still sterile but appears as a rennet coagulum.

Age gelation primarily involves the action of proteolytic enzymes which survive the UHT process. These enzymes are either:

- bacterial proteases produced during the growth of psychrotrophic micro-organisms which can grow at refrigeration temperatures in raw milk. On UHT processing, the organisms are destroyed, but the proteases may survive the UHT treatment and cause age gelation;
- plasmin, the native milk enzyme, which is present in all raw milk. This enzyme can survive some UHT treatments and cause age gelation during storage.

The rate of proteolysis by these enzymes in UHT milk increases with temperature and reaches a maximum at about 40°C. This does not correlate well with most rapid age gelation which happens at about 27°C. Further, age gelation does not always occur after a specific degree of proteolysis. There seems to be a minimum level of proteolysis below which gelation will not occur. Above this level, gelation occurs only in some samples.

It should also be noted that the development of proteolysis may also lead to bitterness in the product which may be a useful sign of possible onset of age gelation. The bitterness is due to certain peptides obtained by proteolysis of proteins.

Options for control of age gelation

Selection of raw milk and processing options

Plasmin is a proteolytic enzyme present in raw milk and it is important to inactivate or greatly reduce its activity. Preheating milk at 95°C for >30 seconds or 80°C for 300 seconds can inactivate plasmin. Preheating at 95°C for ≥30 seconds is used in indirect heating UHT processing but not for direct heating.

The best way of controlling age gelation by bacterial proteases is to minimise the number of psychrotrophic bacteria in raw milk. Thus, only the best quality fresh raw milk should be used for UHT processing. Even low levels, around 105/mL of particular psychrotrophs, can produce sufficient protease to initiate age gelation in UHT products. Thus, even low levels of psychrotrophs in the raw milk cannot prevent age gelation if the psychrotrophs are of the type that produce heat resistant proteases. However, it is recommended that the total bacterial count in raw milk for UHT processing should be $\leq 10^6$/mL.

The best options for manufacturers to control age gelation is therefore to obtain the best raw milk possible and to UHT process it as quickly as possible using appropriate heating conditions.

In general, UHT manufacturers should aim to get the milk from the cow into the carton within 24 hours. In the case of recombined products, again the aim should be to recombine and process as quickly as possible using the best suitable ingredients for UHT. Milks which have been stored at the farm for around 48 hours or raw milk stored at the factory for more than a few hours should not be used for UHT processing. The number of proteolytic psychrotrophs in raw milk should be tested although the total count of bacteria is also a useful and more readily tested measure.

Low Temperature Inactivation (LTI)

Heating of the raw milk at ~55°C for up to one hour will reduce proteolytic activity. However, a number of difficulties have been found in applying LTI in practice. These include the impracticability of holding large quantities of milk for up to one hour at 55°C. More importantly however, proteases from different organisms show different inactivation temperatures, ranging from 50 to 65°C. As these temperatures are quite specific for individual enzymes, the LTI conditions selected would be ineffective unless the properties of the contaminating enzymes are known for each batch. In practice, therefore, LTI processing has found little commercial application.

Use of sodium hexa-metaphosphate (SHMP)

Age gelation can be controlled by the addition of sodium hexametaphosphate (SHMP) to milk before UHT processing. This compound does not affect the level of proteolysis but interferes with the second stage of age gelation, the aggregation of the partially degraded casein micelles, after proteolysis has taken place. Thus, in samples treated with SHMP, proteolysis continues, but gelation is prevented. This approach controls age gelation but does not prevent bitterness in the product.

It is reported that mono phosphates such as disodium hydrogen phosphate are ineffective in control of age gelation and may in fact accelerate it. The reason for this is not known. Further, there are variabilities in the effectiveness of SHMP, depending on its source.

The use of SHMP to control age gelation appears to be effective, provided that the regulatory authorities permit its addition.

Assessment of product shelf-life prior to the onset of age gelation

It would be useful if, after manufacture, factories could assess the shelf life of the product before age gelation occurs. Only a few options are available, none of which is very satisfactory.

Measurement of primary amino groups

The action of the protease in cleaving the caseins and whey proteins results in an increase in the level of primary amino groups in the product. Of course, there will be a base level of terminal and other amino groups in the unmodified milk proteins and in peptides and free amino acids normally present. Thus, given time, an increase in the level of these groups can be observed in UHT milk which contain proteases. It should therefore be possible for manufacturers to store samples of UHT milk at say 28°C for some weeks, then assess the increase in the level of primary amino groups in the product. This, in turn, would indicate protease activity, and possibly correlate with likely shelf life. However, protease activity is not the only factor required for gelation to occur. At this stage, the factors controlling gelation are not well defined.

Even if such a system were developed satisfactorily, the warning that manufacturers would get is not commercially relevant. The test would take at least four weeks, and possibly 8 to 12 weeks, and by that time the product is likely to be in the market.

Measurement of viscosity

A simple indication of age gelation is viscosity. The viscosity of UHT milk remains constant until 6 - 8 weeks prior to gelation, when a rapid increase is observed. Even a slight increase in viscosity from 2-3 cp to say 10 cp is a good indication that age gelation is likely to occur within the next 2 months. Again however, the warning given to manufacturers is not commercially practical, and the method is not very useful for the UHT supply chain to the market.

Neither of these methods is very satisfactory as they may alert manufacturers about a potential quality defect well after the product has been distributed to the market.

Measurement of protease activity

Ideally, UHT manufacturers would prefer to measure protease activity immediately after manufacture and use this data to determine the product’s susceptibility to age gelation. However, the levels of activity which can cause age gelation are extremely low and many protease assay methods are not sensitive enough to measure these low levels. A new method uses a fluorogenic substrate and incubation time of up to 14 days to detect levels of protease which may cause age gelation after several months.

Identification of native or bacterial enzymes in UHT milk

It is possible to identify the source of the enzyme responsible for age gelation, whether it is caused by enzymes from psychrotrophic bacteria or by plasmin. The methodology looks at the peptides in the milk as the patterns differ depending on the enzyme present. This can be done by high performance liquid chromatography (HPLC) analysis and by measuring the primary amino groups in pH 4.6 and TCA filtrates. The pH 4.6 filtrate contains peptides from both bacterial proteases and plasmin while the TCA filtrate contains the peptides produced by bacterial proteases. If bacterial enzymes are the likely cause of age gelation, an improvement in raw milk quality and handling will address the problem. If plasmin is responsible, increasing the severity of the heat treatment, particularly the preheat treatment, will help alleviate the problem.

3. What factors can cause sedimentation in UHT products?

Summary

- Milks with pH <6.60 can show immediate sedimentation on UHT processing.
- Careful monitoring of raw milk pH is essential in UHT operations. Milks with a pH <6.65 should be treated with caution.
- If immediate sedimentation is encountered after UHT processing, this can be overcome by adjusting pH >6.65 with either alkali or disodium hydrogen phosphate (if permitted).
- Sedimentation which occurs during long term storage is not likely to be a significant problem.

Discussion

Sedimentation is a major defect in UHT products as it adversely influences the mouthfeel of the product. The defect can be in two major areas:

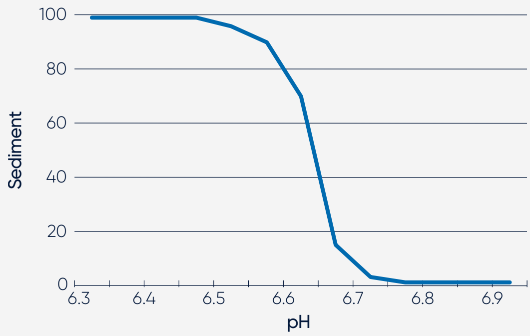
- Sedimentation during or immediately after manufacture, and
- Sedimentation during storage.

Sedimentation immediately after manufacture

In general, sedimentation arising during or evident immediately after manufacture can be due to processing variations such as increased feed pressure because of burn-on in the heating sections of the plant. Such burn-on can also lead to less effective sterilising conditions and increased contamination.

Under the correct processing conditions, milk is quite stable to UHT processing, and sediment formation, if any, is small. However, if the pH <6.65 the sediment formation increases rapidly. The effect of the raw milk pH on sediment formation is shown in Figure 1.

Figure 1 Effect of pH on sediment in UHT milk



It is evident that sediment formation is pH dependent. The scale of 100% sediment on the vertical axis represents all of the casein and most of the denatured whey protein being precipitated. Thus, for pH <6.5, milk is unstable to UHT processing, with all the proteins precipitating as heavy sediment. In pH range 6.65 to 6.5, sediment formation changes from 0 to 100%.

If milk of pH 6.4, which is totally unstable to UHT processing, has its pH raised to 6.8 by adding sodium hydroxide, the milk will generally show no significant signs of instability to UHT treatment. Similarly, if milk of pH 6.8 is UHT treated, and then its pH dropped to 6.5, it will sediment very severely.

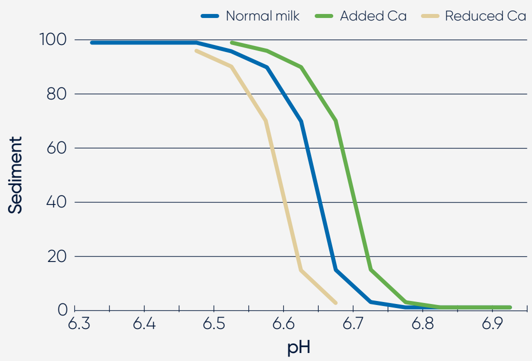
It is only the low pH of milk that is responsible for the instability, not the means of its occurrence. Changes due to addition of acid or through the development of lactic acid by bacteria leading to a drop in pH lead to the same instability and sediment formation.

Development of sediment can have a significant negative effect on processing and product quality. Clearly, if the milk is of low pH and sedimentation occurs, it can rapidly lead to severe blockage of the plant and blown seals. In practice however, such major effects are very rare, given care taken by the industry to ensure that milk is stored under refrigeration and used quickly.

However, further difficulties can occur when the pH of the milk is just below the point at which initial instability and precipitation occurs. For example, if milk which is stable at, say, pH 6.70 is processed at, say, pH 6.67 minor but important sedimentation may occur in the product, and the run time of the plant may be decreased to some extent. This problem does occur from time to time in the industry.

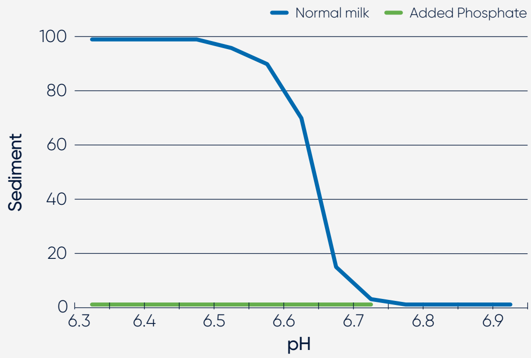
Further work has shown that this instability is closely related to the ionic calcium content of the milk, as shown in the diagram below. In this case, three samples have been examined for instability – first is normal milk, second with increased ionic calcium content, and third with reduced ionic calcium content. As may be seen, the milk with a high ionic calcium content shows the onset of instability at a higher pH, whereas that with decreased ionic calcium shows the onset of instability at a lower pH than the control milk with normal ionic calcium. Thus high ionic calcium milks are less stable to UHT treatment than low ionic calcium milks. A good example is goat's milk, which is high in ionic calcium. It is difficult to process goat's milk through UHT without changes to the process such as the addition of calcium sequestering agents like sodium citrate, disodium hydrogen phosphate or SHMP.

Figure 2 Effect of pH on sediment in UHT milk



When sufficient calcium sequestering agent is added to the milk, it becomes stable to UHT processing. As shown in Figure 3, the pH of the milk is adjusted with disodium hydrogen phosphate and the resultant goat's milk is as stable to UHT processing as cow's milk.

Figure 3 Effect of added phosphate on the sediment in UHT milk



There are several precautions that can be taken to minimise sedimentation during UHT processing:

1 The pH of the raw milk must be measured precisely to 2 decimal places prior to treatment. As can be seen from Figure 3, the performance of raw milks with pHs of, 6.70 and 6.66 can be significantly different in terms of sediment formation on UHT processing. In general, most milk processing operations require pH measurement to only one decimal place. However greater precision is required for UHT milk. Experience will tell what is the minimum that should be accepted, but a good rule of thumb is that milk with a pH much below 6.65 should be treated with caution.

2 If milks of low pH or unexpectedly unstable performance are encountered, there are a few adjustments that will help:
   - Add disodium hydrogen phosphate, sodium citrate or SHMP to the milk (if permitted). This will increase the pH of the milk and increase the calcium sequestering level of the milk. Both of these actions will result in improved stability to sedimentation.

The level of added phosphate or citrate will need to be determined on a case by case basis. It should be noted that addition of disodium hydrogen phosphate may make the milk more susceptible to age gelation.

– It should also be noted that the results above deal directly with single strength fresh milk. Similar problems occur in recombined products, and the impact of this is discussed later in this chapter under FAQ section D. Formulated products may or may not have similar problems – much will depend on the individual components and their impact on both pH and ionic calcium.

2 Sedimentation which occurs during storage

In general, most UHT milks develop a small amount of sediment on storage, but at a level not sufficient to be a major quality problem. It has been suggested that this sediment is formed by the same mechanism which leads to fouling of the heat exchangers in the process, and that the sediment resembles fouling material which has not adhered to the plant surface. Direct heating UHT systems have higher sediment than indirect systems, but increased homogenisation pressure decreases sedimentation. It has been suggested that the extent of sedimentation increases with the severity of heat treatment and the time and temperature of storage. However, extreme homogenisation can lead to increased sedimentation, with the very small fat globules actually settling at the bottom of the container. However, such a situation is rarely encountered.

4 What factors can control the development of off flavours in UHT products?

Off flavours in the product can develop in several ways:

- the action of enzymes like proteases and lipases which survive UHT treatment. These enzymes can be either in the raw milk or produced by bacteria in the raw milk. Whilst the bacteria are destroyed in the UHT process, some enzymes can survive UHT conditions;
- chemical reactions in the milk between milk components, such as the Maillard reaction between proteins and lactose, which can lead to development of off-flavour and a brown discolouration;
- the effect of the UHT process itself on the milk components such as the denaturation of whey proteins which can lead to the development of sulphurous and cooked flavours in the milk;
- the effect of the presence of oxygen which can lead to the development of stale and oxidised flavours in products containing fat; and
- the action of contaminating bacteria in the product.

Contaminating bacteria in UHT milk is not expected in a properly functioning UHT plant. Of the other causes of off flavours, some will have an immediate impact, and others will become more noticeable during storage. For example, the off flavours due to UHT treatment will be immediately noticeable, but may lose intensity during storage, whereas many of the chemical and enzymatic reactions will further develop during storage. The rate of development of unacceptable flavours is closely related to storage temperature.

The effect of the UHT processing on flavour can be minimised by adjusting the heating profile provided the requirements of sterility are met. This is most easily achieved in UHT plants using direct heat which cause less flavour change than plants using indirect heat for the same bactericidal effect.

The flavour of UHT milk during storage is controlled by storage temperature, storage time and oxygen content. The oxygen content of the milk will depend on the particular UHT process. However, during storage the permeability of the packaging and headspace oxygen will also play a major role.

Important flavour changes can occur through the action of heat resistant proteases and lipases which survive UHT treatment. In the case of proteases, these can lead to development of bitterness in the product after 6 weeks storage at 25°C. This effect is reduced substantially at refrigeration temperature.

One of the best indicators of the onset of age gelation is the development of bitterness in the product, which occurs 3-4 weeks before gelation. In the case of lipases, several exocellular lipases of certain *Pseudomonas* species are not inactivated by UHT processing. Thus, breakdown of fat occurs through the reactions of these enzymes. The extent of formation of free fatty acids is dependent on storage temperature, being very slow at refrigeration temperatures, but much more rapid at elevated temperatures, to levels where sensory changes are evident. Problems with heat resistant lipases can be severe, as even low concentrations of free fatty acids can lead to significant flavour and aroma defects.

In an ideal world, the best way to control development of off flavour is to store UHT milk under refrigeration. This may extend the time cooked flavour is noticed in the product, but it will extend the shelf life of the milk considerably, and factors which cause off flavours will be significantly retarded. However, storage under refrigeration negates one of the main advantages of UHT processing, the ability to store the products at room temperature.

So overall, to ensure better flavour in UHT milk:

- use the best quality raw milk
- manufacture as soon as possible after drawing milk from the cow
- use minimal processing conditions appropriate to meeting sterilisation requirements
- use packaging that has low headspace oxygen and is not permeable to air
- store at as low a temperature as possible but do not freeze.
- store out of direct sunlight.

5. What influences the colour of UHT milk?

Four major factors affect the colour of UHT milk:

- processing conditions
- raw milk quality
- storage conditions
- other processing operations such as lactose hydrolysis.

There are many effects of processing temperature on the colour of milk. In general, milk becomes whiter in appearance when heated above 65°C due to denaturation of the whey proteins resulting in an increase in the number and size of reflective particles. So UHT milk is whiter than the original product immediately after manufacture and this is independent on the whitening effect of homogenisation.

However, a browning reaction also occurs on heating of milk, and can continue when milk is stored, particularly at temperatures above 35°C. This reaction, called the Maillard reaction, is the result of interactions between the amino acid lysine of the milk proteins and the lactose. The reaction is very complex, but leads to the development of brown colours in the product.

Raw milk quality can have an influence on milk colour due to sediment formation in the product during processing. If the pH is below 6.65, sediment may form in the product which leads to a reduction in the reflective particles present, and a drop in perceived colour.

Storage conditions are particularly important in development of colour in UHT milks. For example, milks stored above 35°C develop a noticeable brown appearance quickly. This effect is much less noticeable for product stored below 25°C.

Other processing operations can lead to increases in the colour development in UHT milks. Of particular interest are those which increase either the lactose or the reducing sugars in the product. In both cases, this will result in an increase in Maillard reactions. Particular care must be taken with lactose-hydrolysed products. In general higher levels of reducing sugars, glucose and galactose leads to a marked increase in browning. This is noticeable if the hydrolysis is carried out prior to UHT processing and can lead to a noticeable brown colour in the initial product. Also browning occurs during storage at elevated temperatures much more rapidly than in conventional UHT milk.

Thus, the best way of minimising colour defects in UHT milk is to:

- use the best quality raw milk
- use lower temperature and time heating conditions required for sterilisation
- store at as low a temperature as possible but do not freeze
- store away from direct sunlight.

6. What influences the manufacture of lactose hydrolysed products?

Lactose hydrolysed UHT milks offer two advantages over unhydrolysed products:

- Lactose hydrolysed products are sweeter than unhydrolysed products. Lactose hydrolysis involves cleaving the lactose into glucose and galactose. Each of these sugars is noticeably sweeter than lactose. Complete hydrolysis of lactose in milk results in an increase in sweetness equivalent to the addition of about 1.5% sucrose. Such an increase in sweetness can be beneficial, as formulated products containing hydrolysed milks may require addition of less sugar to reach the desired level of sweetness. This can reduce costs and calories - one helping profitability, the other assisting marketing.
- A significant percentage of the world's population suffers from lactose malabsorption. Normally, digestion of lactose involves cleavage of the disaccharide into glucose and galactose in the gut by the action of an enzyme, *-galactosidase. The resultant monosaccharides are then absorbed and metabolised by the body. However, much of the population of the world loses the ability to secrete sufficient β-galactosidase to effectively digest their normal intake of milk after about 10 years of age. This results in a marked decrease in the ability of this segment of the population to properly digest lactose after this age. Thus, when those who are lactose intolerant consume lactose containing products, a significant amount of the lactose passes undigested into the lower intestine, where it is fermented, leading to production of gas, an increase in osmotic pressure and a flow of fluid into the bowel. This in turn leads to feelings of discomfort, bloating, and in severe cases stomach cramps and diarrhoea. Lactose intolerant populations include most of those from Southeast Asia and Japan, Black Africans, African Americans, Native American Indians, and Indigenous Australians.

Lactose hydrolysis of UHT milk can really only be effectively carried out by the use of the enzyme *-galactosidase. This enzyme has been available commercially for many years. In one option, the raw milk is hydrolysed by the addition of the enzyme, and the hydrolysed milk then subjected to UHT sterilisation. This sequence of hydrolysing lactose before UHT heating is not desirable. Glucose and galactose are much more reactive than lactose and cause more Maillard browning during manufacture. These reactions lead to the development of off flavours and noticeable browning of the product. A preferable option involves injection of sterile β-galactosidase enzyme solution in very low quantities into the UHT sterilised milk prior to aseptic packaging. The process may use injection into an aseptic holding tank, or into the pack itself prior to sealing. In this sequence, the hydrolysis takes place over 10 days after manufacture, in the sterile pack. The amount of enzyme required is much lower compared to that in the previous sequence where hydrolysis was carried out before UHT, since the reaction can take place over a longer time and there is no concern regarding bacteriological growth in the product. Operational costs are thus considerably reduced. Further, the enzyme is added after heat processing, so that there is no excessive browning of the product occurring during sterilisation. However, addition of the enzyme after sterilisation carries with it the risk of contamination of the sterile product.

An important concern is the freedom of the enzyme preparation from protease contamination. Cheaper enzymes often contain significant levels of protease, which can lead to the development of bitterness and, in some cases, gelation on extended storage. UHT manufacturers using such systems should ensure the high quality of the β-galactosidase enzyme.

7. What is the role of heat stability test and alcohol stability test in evaluation of milks suitable for UHT processing?

Heat stability

The classic heat stability test is commonly used for the evaluation of milks suitable for the manufacture of milk powders with particular functional properties. The test involves sealing milk into a bottle or tube and immersing it into an oil bath at 140°C. The time taken in minutes until visible sediment or coagulation in the milk is noted. The test is also used by some UHT plants for selection of milks for UHT processing.

The heat stability of milks tested in this manner does not show any sharp change in coagulation time as a function of pH between 6.70 and 6.60. However, a small difference in pH at this level can result in a sudden increase in the sedimentation in the product. Thus the use of heat stability as a means of selection of milks for UHT processing is seriously flawed because it does not indicate if the pH of the milk is too low for effective manufacture without sediment formation. At best, it may be said that:

- if the milk fails the heat stability test, it should not be used for manufacture of UHT milk;
- if the milk passes the heat stability test, it may or may not be satisfactory for UHT manufacture.

Heat stability tests do not give any indication of the effective shelf life of UHT milk

Alcohol stability

The alcohol stability test is widely used in the dairy industry for selection of milks. The test involves adding various amounts of alcohol to milk and noting when coagulation occurs. In general, if milk is stable in ≥74% alcohol it will be stable to UHT processing. It has been shown that a decrease in pH or an increase in ionic calcium results in a decrease in alcohol stability. Thus, the use of a combination of alcohol stability test, pH, and level of ionic calcium in the milk can provide a very good indication of the stability of milk to UHT processing. This also provides an indication of UHT plant run times which is a very important economic factor. The alcohol stability test alone may be a reasonable indicator of the general acceptability of milk for UHT processing but manufacturers should be cautious relying on it completely.

D Recombining

1. Recombining and reconstitution – what is the difference?

It is important that a clear differentiation be made between the terms recombination and reconstitution.

Recombination is defined as the process in which previously separated components of milk, principally skim milk powder (SMP) and anhydrous milk fat (AMF), are brought together again in a water phase, along with any additional ingredients and necessary stabilisers, to form the desired end product. Since the ratio of AMF to SMP can be varied, a wide range of products can be manufactured by recombination, each having its characteristic ratio of fat to solids-not-fat. The composition and characteristics of the products made by recombining are normally similar to those of the equivalent products made by traditional manufacturing methods.

There are two obvious benefits to manufacture by recombining:

- The separate components may be stored for extended periods without the need for refrigeration, facilitating export and storage.
- The total mass involved in handling and transport of ingredients AMF and SMP is reduced by a factor of more than 7 (in the case of milk) by removal of water.

Reconstitution is defined as the process of addition of water to milk powder to produce a product similar in total solids and composition to the liquid milk from which it is made. Whole milk powder is the usual powder used for reconstitution, resulting in a product similar in composition to fresh milk, but skim milk powder may also be reconstituted to yield skim milk.

Reconstitution provides only product from one powder unlike recombination which can provide a range of products.

2. What are the principles of manufacturing UHT recombined products?

Recombining involves combining products such as skim milk powder (SMP) and anhydrous milk fat (AMF) and treating them with processes such as homogenisation to manufacture recombined products.

The major UHT product in much of South East Asia is sweetened UHT with around 3% added sugar.

Factors for selection of raw materials for recombining

Milk Powders

Milk powders for recombining are of three types based on heat classification: high-heat, medium-heat, and low-heat. These terms refer to the heat treatment given to the milk prior to evaporation and spray drying, and not to the stability of the recombined product for heating. For example, milk might be preheated at 72°C for 15 seconds for low heat powder, at 73-75°C for 1-3 min for medium heat powder, and at 80-85°C for 30 min for high heat powder.

The preheat treatment used in powder manufacture does not appear to have any significant impact on the storage of the UHT product, either in terms of flavour or the onset of age gelation. There may be marginal flavour benefits in using medium or low heat powder, but this is not significant. Generally, low or medium heat powders are used for UHT recombined products, as high heat powders may impart cooked flavour to the product.

When selecting milk powders for UHT, two major factors must be considered: stability to UHT processing, and control of age gelation during storage:

Stability to UHT processing – The major concern is the stability of the reconstituted milk to UHT processing. If milk of pH >6.65 is UHT processed, considerable sedimentation will develop in the product. However, the pH at which instability occurs is slightly lower for recombined products than for fresh milk. Higher stability of milk powder-based UHT products is due to the lower ionic calcium in recombined products. Thus, UHT factories based on recombining operations may have fewer challenges with sedimentation than those using fresh milk. Further, the use of medium or high heat powders results in even better stability compared to low heat powder products.

Control of age gelation – The control of age gelation is a greater challenge in UHT products using milk powders. The enzymes causing age gelation originate from psychrotrophic organisms in the raw milk. These organisms are destroyed by the UHT treatment, but the enzymes they produce in raw milk may survive UHT treatment and cause gelation in the stored product. Another proteolytic enzyme naturally present in raw milk is plasmin and may cause age gelation particularly when low heat powders are used.

Milk powders targeted for use in the manufacture of UHT milk must be manufactured taking into consideration the above factors. In particular, steps should be taken to ensure that the opportunity for the growth of psychrotrophic organisms is restricted during manufacture of the powders.

Milk fat

Anhydrous milk fat (AMF) which meets usual manufacturing specifications is adequate for use in recombined UHT milk. Normal care regarding prevention of oxidation of milk fat is required to ensure that AMF does not bring flavour defects into the product. Provided that the fat is made from good quality milk, that care is exercised during manufacture and nitrogen flushing of containers is effective, AMF will store well at ambient temperature. High storage temperatures accelerate the development of off flavours. It is also essential that there is regular turnover of the AMF stock so that AMF storage time is minimised.

If AMF is stored in open drums, it should be melted and used as rapidly as possible. It should be noted that rest results on peroxide value and acidity are not always good indicators of the stability of fat towards oxidative spoilage.

UHT "filled milks" are also commonly manufactured in many countries. In these products, the source of fat is a cheaper vegetable fat such as palm kernel or coconut oil. However, in many cases, these fats are more unsaturated than milkfat and can undergo much more rapid oxidative deterioration. In such cases, particular care must be taken not only during manufacture, but also in the packaging to prevent oxidation of the product. Contact with oxygen must be kept to a minimum. Head space oxygen and dissolved oxygen can accelerate development of oxidative defects.

Water

Water is the single biggest component of UHT recombined products, but it is often the most overlooked. Colour, flavour and odour of the water may affect the quality of the end product. Hard water can affect protein stability on heating. Potable water quality is therefore an essential requirement for any UHT recombining operations.

Emulsifiers and stabilisers

In general, stabilisers and emulsifiers from specialist companies are preferred by most manufacturers. Stabilisers and emulsifiers are added to the milk to ensure that the milk fat emulsion formed during homogenisation remains stable during processing and storage, and to improve the mouth feel of the product. A wide range of systems have been suggested over the years, but most UHT manufacturers now use proprietary mixtures provided by specialist companies. Generally, a single product, comprising a mixture of stabiliser and emulsifier is provided to the UHT recombining manufacturer.

These products are designed to increase the heat stability of the product, to improve fat dispersion and stability during processing and storage, and to improve the organoleptic qualities of the product, through development of a more desirable viscosity and a richer mouth feel. Some stabilisers also prevent froth during mixing operations.

Emulsifiers commonly used in UHT recombining operations include mono and diglycerides, and soya lecithin. Emulsifiers reduce fat separation by formation of a membrane at the fat and water interface. Hydrocolloids are often used as stabilisers in UHT products. These act by increasing the viscosity of the product, improving mouthfeel and reducing the rate of fat separation. Hydrocolloids commonly used include carrageenan and alginates.

Flavours and sweeteners

Sweetened products are very popular in the UHT market. It is common to introduce a low level of vanilla into such products for further improvement in palatability. The vanilla used must be stable to UHT processing, and if steam injection with a vacuum flash down is used, the vanilla must be comparatively non-volatile.

Sucrose is the most commonly used sweetener in UHT recombined products, but other sweeteners such as glucose, fructose and glucose syrups, and artificial sweeteners are also used. In the case of sugars such as glucose, considerable care must be taken as the higher level of reducing sugars leads to increased browning of the product during processing and storage because of increased Maillard reactions. Any artificial sweeteners must of course be stable to UHT processing, and to extended storage.

Formulation of UHT recombined milks

The use of reconstitution is comparatively inflexible in terms of the ease of changing SNF and/fat ratios. For this reason, recombining rather than reconstitution is often the preferred methodology employed in UHT operations.

The use of recombining for the manufacture of UHT milk allows for wide variations in the composition of the final product. The major factors are the level of solids-not-fat and the level of fat present. A number of factors will influence the levels selected, the major ones being economic factors (the relative cost of fat and SNF) and those related to the acceptability of the product.

A further key factor in many markets is the level of added sugar. A considerable portion of the milk consumed in many Southeast Asian countries is sweetened by the addition of 1-4% sugar. Thus UHT products destined for these markets should consider the level of sweetener.

As well as milk fat, SMP and sugar, most UHT products also include an emulsifier and a stabiliser.

Typical formulations are:

Unsweetened Product	
Anhydrous Milk Fat	3.6
SNF	9.3
Stabiliser and emulsifier	0.2
Water	86.9

Sweetened product	
Anhydrous Milk Fat	3.6
SNF	8.5
Sugar	3.5
Vanilla	0.1
Stabiliser and emulsifier	0.2
Water	84.1

As indicated above, the formations can vary very widely – SNF and butterfat contents and ratios can be selected to meet specific cost and product specifications.

Manufacture of recombined UHT milk

The process for the manufacture of UHT recombined products is as follows:

1 The required quantity of skim milk powder is blended into the water at 40-45°C;

2 Other ingredients are added whilst agitating the mix. The butterfat such as AMF must be added last, after liquefaction by preheating to 40-45°C prior to use;

3 The AMF should then be dispersed in the mix. This may be carried out by agitation, or by moderate homogenisation. Conditions will depend on the homogeniser, but may involve two stages of homogenisation say 1500 psi or 10MPa stage 1 and 500 psi or 3.5 MPa at 65°C. In many plants, agitation is sufficient, as the recombined product is subjected to UHT processing and homogenisation with minimal storage. It is also recommended to pasteurise the product (HTST, 73°C for 35s) if the product is to be stored before UHT processing. The product should be cooled to 4°C and UHT processed as soon as possible;

4 The mix is UHT processed at 138°C for 3 sec, with homogenisation at 3000 psi or 20 MPa stage 1 and 500 psi or 3.5 MPa.

One key aspect of the process is to ensure that the product is not stored for an excessive period of time after recombining, prior to UHT processing. Excessive storage can result in further growth of psychrotrophic organisms, leading to problems with age gelation during storage of the UHT product.

Downstream homogenisation after sterilisation is preferable to upstream homogenisation before sterilisation for recombined products. For whole milk, the benefits of downstream homogenisation, are minor for indirect processes. For recombined products however, there are gains in terms of reduction of sediment formation in the product by use of downstream homogenisation. For this reason, in spite of the additional cost and complexity, a number of UHT plants processing recombined products prefer downstream homogenisation.

10.4 Glossary

Age gelation

Age gelation is a common defect of UHT milk which limits the acceptable life of UHT milk by conversion of the product to a junket-like gel. It is not due to bacterial action, but rather to the action of proteolytic enzymes which survive UHT processing.

Alcohol stability test

The alcohol stability test is widely used in the dairy industry for selection of milks for heat processing. It involves adding various amounts of alcohol to milk and noting when coagulation occurs.

Aseptic holding tank

Most UHT plants have had aseptic holding tanks installed as an integral part of the operation. The aseptic holding tank permits ready balancing of flow rates between the UHT processing and the packaging sections.

Aseptic packaging

Aseptic packaging systems are designed to fill sterilised fluids into aseptically prepared packages without contamination of the product.

Browning

Browning of milk is the result of interactions between lactose and protein. Browning will occur quite rapidly under very high temperature processing, but also occurs during long term storage of dairy products.

Direct UHT processing

Direct processing is a form of UHT sterilisation which relies on direct contact of the product with steam. After sterilisation, the product is passed into a vacuum chamber which removes the condensed steam and also results in a very rapid cooling of the product from sterilisation temperature to a temperature of about 75 to 80°C.

Emulsifiers and stabilisers

Emulsifiers and stabilisers are used by the dairy industry to assist in formation of stable emulsions and to improve the stability of milk and dairy products during processing and storage. They are essential in recombined products.

Fat separation

Fat separation can be a major defect in stored UHT products. It involves excess visible fat on the surface of the product, and in severe cases, a hard crust of fat on the surface of the product.

Free fat

Free fat in milk is fat which is not encased in the native milk fat globule membrane. It is caused by disruption of the native milk fat globule membrane, or, in recombined products, through coalescence of smaller fat particles in the product or through inadequate recombination techniques leading to fat globule instability.

Heat stability test

The heat stability test is commonly used for the evaluation of milks to be used for the manufacture of milk powders with particular functional properties. The test is also used by some UHT manufacturers for selection of milks for UHT processing but is not recommended for this purpose.

Homogenisation

Homogenisation is widely used by the dairy industry to reduce the size of fat globules in dairy products, and therefore to reduce fat separation during storage. Homogenisation is essential during the manufacture of UHT products containing fat.

Indirect UHT processing
Indirect processing is a form of UHT sterilisation which relies on obtaining sterilisation temperatures by indirect heat transfer by means of a stainless steel interface, part of a tubular or plate heat exchanger.

Lactose hydrolysis
Lactose hydrolysis involves cleaving the lactose, into glucose and galactose. Lactose hydrolysis in the dairy industry is commonly performed by the use of the enzyme β-galactosidase.

Lipases
Lipases are enzymes which cleave fats to produce free fatty acids. In milk, they can lead to severe off-flavours.

Maillard reaction
The Maillard reaction occurs when reducing sugars such as lactose interact with the amino groups of amino acids during the heat processing of food. Maillard reactions can affect nutritive value such as loss of essential amino acids like lysine, colour changes such as brown pigment formation and flavour such as cooked flavour defects.

Plasmin
Plasmin is a native milk protease that is present in all raw milk. The enzymes it produces can survive some UHT processing conditions and lead to bitter flavour and age gelation in the product.

Proteases
Proteases are enzymes which split proteins. In UHT milk, the action of proteases can destabilise the colloidal protein suspension of the milk and lead to gelation. They can also cause bitterness.

Protein denaturation
Protein denaturation is caused by the application of heat. It leads to the unfolding of the molecular structure of the protein and a loss of functionality. A good example is the change that occurs in the properties of egg white on heating. In milk, whey proteins are denatured during UHT processing.

Psychrotrophic bacteria
These bacteria, which are present in raw milk, can grow under refrigeration conditions. Many produce proteases which may survive UHT processing and cause defects in UHT milk during storage.

Reflectance
For most purposes, reflectance of milk refers to the amount of light it reflects. It is closely related to the opacity and colour of the milk.

Sediment
Sediment refers to insoluble material which forms a precipitate in UHT milk. Its formation in UHT milk can be a major defect. It can occur either immediately after processing or after extended storage.

Steam infusion
One option in the direct UHT process, which relies on direct contact of the product with steam, is to inject the product into a chamber of steam. This process is known as steam infusion.

Steam injection
One option in the direct UHT process, which relies on direct contact of the product with steam, is to inject steam directly into the product. This process is known as steam injection.

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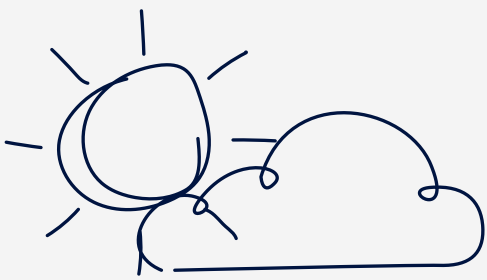


11 **Applications of Australian** Dairy Ingredients in Yoghurt

Content

11.1 Introduction

Yoghurt is a fermented milk product and is defined at the global level under Codex Standard CXS 243-2003 revised 2018 – Standard for Fermented Milks. The Standard uses the following definition for Fermented Milks:

'A milk product obtained by fermentation of milk, which milk may have been manufactured from products obtained from milk by the action of suitable microorganisms and resulting in reduction of pH with or without coagulation (iso-electric precipitation). These starter microorganisms shall be viable, active, and abundant in the product to the date of minimum durability. If the product is heat treated after fermentation the requirement for viable microorganisms does not apply.'

The Standard further adds information for the cultures to be used for the different Fermented Milk types and defines Yoghurt as containing: Symbiotic cultures of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*.

Regarding the composition, the Standard states the following:

Component	Limit
Milk protein (% m/m)	min 2.7%
Milk fat (% m/m)	less than 15%
Titratable acidity expressed as % lactic acid (% m/m)	min 0.6%
Number of microorganisms in the starter culture (cfu/g)	min 10^7
Labelled microorganisms where a content claim is made (cfu/g)	min 10^6

The Australia New Zealand Food Standard Code 2.5.3 Fermented Milk Products (2016) defines Fermented Milk as *'a food obtained from fermentation of milk or products derived from milk, where the fermentation involves the action of microorganisms and results in coagulation and a reduction in pH'*. It further defines Yoghurt as a *'fermented milk where the fermentation has been carried out with lactic acid producing microorganisms'*. It also states that the Fermented Milk and Yoghurt must:

1 be fermented milk or yoghurt as appropriate, or fermented milk or yoghurt with other food added; and

2 have a pH of no more than 4.5;

3 have no less than 106 cfu/g microorganisms used in the fermentation; and

4 if the food is derived from cow's milk – contain no less than 30g/kg protein (measured as crude protein).

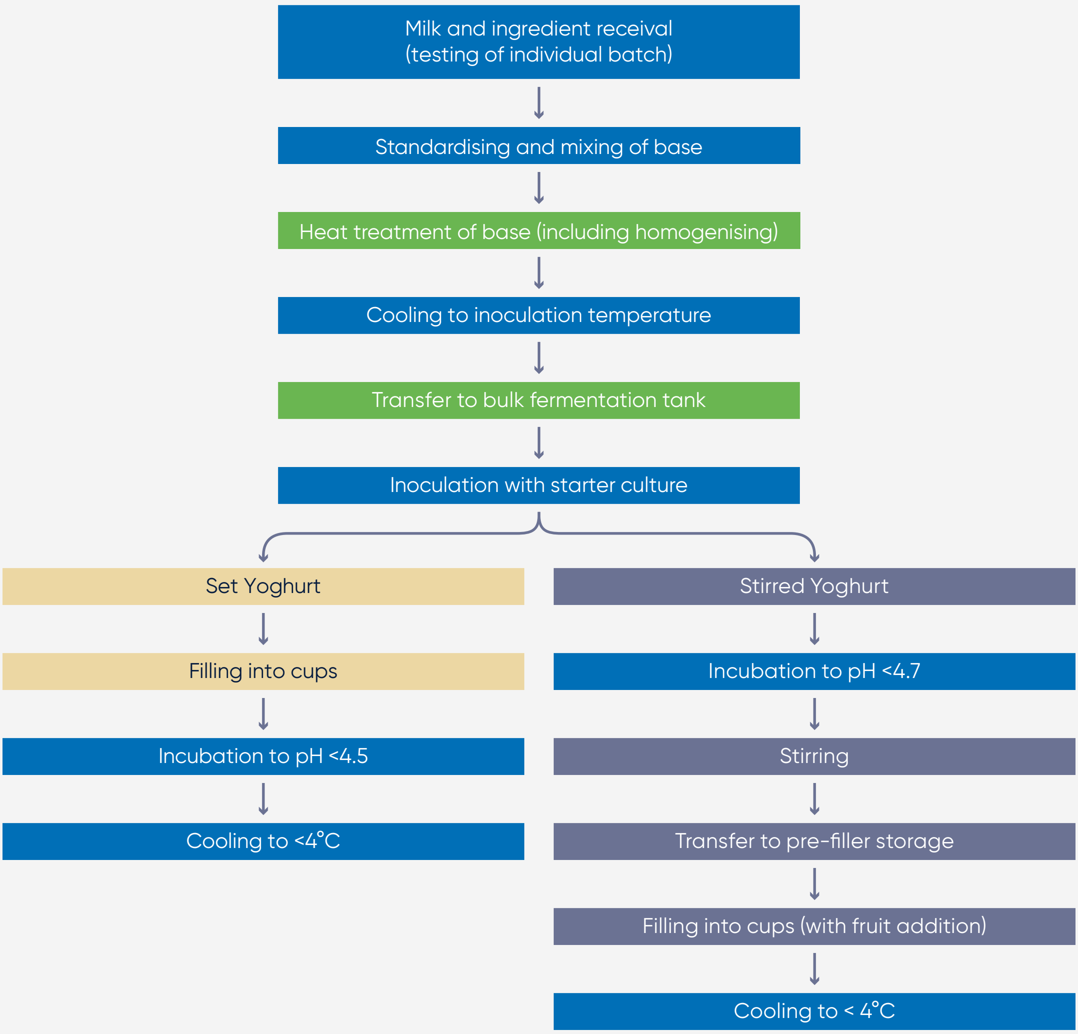
The yoghurt manufacturing process, although relatively simple, can be challenging to consistently manufacture high quality yoghurt. Furthermore, it is important to optimise ingredient and manufacturing costs.

Defects such as whey separation, graininess and nodule formation indicate raw material quality is poor or the processing steps have not been carried out properly. A good understanding of the dairy chemistry and mechanism of yoghurt making theory is important for producing top quality yoghurt.

Raw materials are sometimes selected with a focus on minimising ingredient cost rather than inferior ingredients adversely impacting yoghurt quality. Mixing processes are not controlled as well as the rest of the process and temperatures are sometimes allowed to vary. All these factors contribute significantly to defects in yoghurt such as inconsistent product viscosity, and poor flavour, appearance and mouthfeel.

As with many other products, good quality yoghurt manufacture relies on selection of high quality ingredients and strict control of the manufacturing process. The objective must be to minimise the variation in the ingredients, process, equipment, and materials to minimise the batch-to-batch variation in the product quality.

Figure 1 Yoghurt Manufacturing Process Flow Chart



11.2 Yoghurt types

1 Set yoghurt

This type of yoghurt involves incubating and cooling the yoghurt in its packaging.

2 Stirred yoghurt

In stirred yoghurt, the milk is incubated in tanks, cooled, and then packed.

3 Flavoured yoghurt

Several types of flavour additives including fruit, berries, sweeteners, grains, and nuts can be added to natural yoghurt. These can be added in processed forms, as purees or as syrups and can be mixed directly into the natural yoghurt before packaging or added into the bottom or top of the pack during packaging.

4 Drinking yoghurt

Drinking yoghurts are low in viscosity and are designed for direct consumption by drinking instead of eating using a spoon. During the manufacturing process, the yoghurt is stirred and usually cooled to about 18-20°C prior to packaging.

5 Frozen yoghurt

Frozen yoghurt has become popular in recent times as a healthy alternative to ice cream which is high in fat and sugar content. The manufacturing process involves either mixing yoghurt with ice cream or pre-freezing the yoghurt and then whipping it in a continuous ice cream freezer.

6 Strained or concentrated yoghurt

This yoghurt type involves removing some of the whey from the yoghurt to concentrate the solids. This is usually done by using a separator, like the production of Quarg cheese.

7 Long life yoghurt

Long-life yoghurts can be manufactured in two ways. The first involves heat treating the finished product either in the filler balance tanks before packaging or in the package itself. The second method involves manufacturing and packing the product under aseptic conditions.

11.3 The role of milk proteins

The type and level of milk proteins in the base for yoghurt manufacture are the most important factors determining the quality of yoghurt. The ratio of whey proteins to casein as well as the total protein content as a proportion of the total solids are the main factors that contribute to the final yoghurt matrix. Incorrect ratios of the proteins can lead to defects such as runny or soft yoghurt, nodulation or graininess and whey separation. Many manufacturers standardise to levels of total solids or protein in the base mix but may not standardise to ratio of casein: whey protein. The variation in in raw material composition and quality can cause differences in yoghurt quality from batch to batch.

The yoghurt structure is formed through a combination of denaturation of the whey proteins under controlled conditions and then fermentation of lactose which aids in producing a casein coagulum in an acidic environment. If this is done correctly under controlled conditions, the result is a firm matrix that may withstand reasonable mechanical handling. If the set conditions are not properly controlled, it can result in defects in the product.

Any reduction or addition of the milk protein components, especially whey proteins, will result in dramatic changes in the viscosity of the yoghurt. If there is insufficient whey protein available to bind with casein, the matrix tends to be loose, resulting in soft or runny yoghurt. On the other hand, higher than required levels of protein only adds to the ingredient cost without any benefits in yoghurt quality.

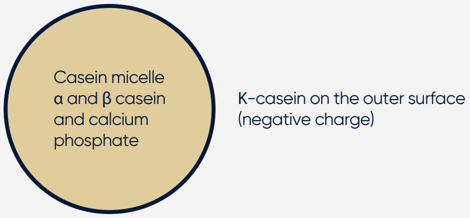
It is common practice to adjust the total protein level by the addition of whey protein products such as Whey Protein Concentrates (WPC), Whey powders and Whey Protein isolates to increase the ratio of total whey proteins to casein.

Rather than simply adding a percentage quantity of whey protein, it is essential to standardise each batch individually and accurately to achieve the protein level and the casein : whey protein ratio. At the very least, a plant with liquid milk intake should adopt a process of tracking trends for protein components throughout the year and adjust the recipe accordingly to ensure that base mix composition stays the same throughout the year. Research suggests that the casein: non-casein protein should be approximately 3.3:1 for good quality yoghurt, although this can vary from product to product.

Factors that can denature whey proteins include heat treatment, enzyme action from bacteria, acid production by lactic acid bacteria and mechanical action such as pumping. If protein has been denatured prior to the heat treatment step it will result in major defects in the yoghurt. Denatured protein will be readily available to bond with a variety of other compounds depending on what is available. This results in milk of inferior quality because it has an opportunity prior to the heat treatment to form networks of protein molecules. Ultimately this leads to the formation of large complexes of proteins that form many small soft nodules. In extreme cases, this may lead to a defect called graininess where the protein has compacted to form hard particles; this visible compacted protein leads to texture defects discovered during consumption of yoghurt.

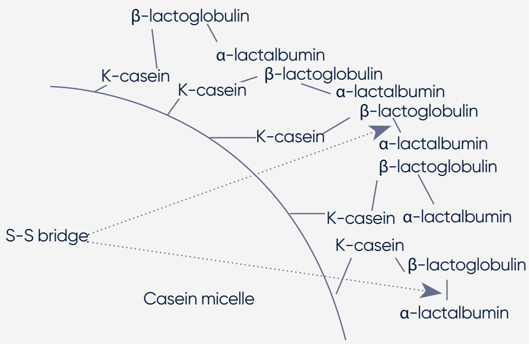
Where protein has been allowed to deteriorate to such an extent that the casein is denatured, usually through acid production, the casein will also be readily available to bond. As soon as this casein meets the hot surface of a heat treatment plant it will coagulate due to the combined action of acid and heat. The result is that casein sticks to the heat treatment surface immediately and can cause blockages; this deposit looks like a white oily or fatty substance like soft rubber and, in extreme cases, can be difficult to remove.

Figure 2 Changes in the structure of casein during fermentation

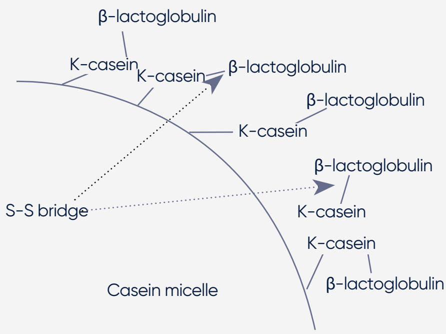


Milk pH 6.6–5.9; no change in structure of casein micelle.

Net negative charge on the external surface of the casein micelle in fresh milk of pH 6.7 becomes slightly less negative with addition of hydrogen ions that come from the dissociation of lactic acid produced by the yoghurt starter bacteria.



Milk pH 5.5–5.2,α-lactalbumin bonds with β-lactoglobulin to form a smooth structure on the surface of the micelle. Calcium continues to dissolve from the calcium phosphate in the casein micelle structure.

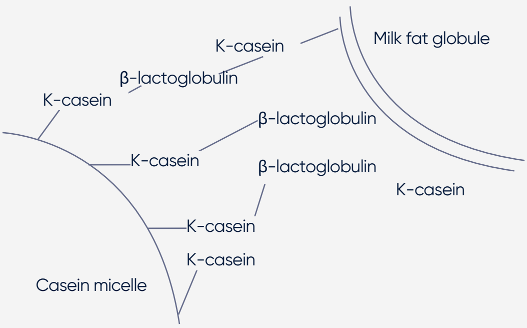


Milk pH5.5–5.2, partial denaturati on of casein micelle, bonding of β-lactogloblulin to K-casein on the surface of the casein micelle to form an irregular shape with spaces between protein strands. Weak bonding occurs across micelles as β-lactoglobulin binds with K-casien across micelles. Calcium begins to dissolve in the main structure of the casein micelle. Charge on the outside of the casein micelle is becoming nore neutral with the addition of hydrogen ions.

Complex compounds can also originate from foreign material or undissolved particles. Where milk powders are used in the base mix, undissolved particles also attract protein resulting in defects such as graininess and nodules. In extreme cases, grainy yoghurt can be sandy in texture.

The whey proteins must be in their natural state at the time of heat treatment; if they have been denatured previously this can lead to major defects. The selection of ingredients therefore is one of the most critical aspects of good quality yoghurt manufacture. No matter if the ingredients are powders, concentrates or raw milk straight from the farm they must be handled and treated in such a way as to minimise the impact on the proteins prior to heat treatment and the yoghurt mix must be standardised, heat treated and fermented to maximise the opportunity for these proteins to form a uniform controlled matrix.

Figure 3 Interaction of casein and fat

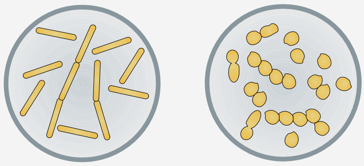


Once denatured β-lactoglobulin has unbond S-H groups that bond to Kcasein in the milk fat globule membrane. This allows the casein micelle to become bond to the milk fat globule membrane and hence the milk fat. Approximately 10-20% of the fat present in normal milk can be bonded to the casein in this way.

11.4 Fermentation

The two major starter cultures used in the manufacture of yoghurt are *Lactobacillus delbrueckii* subsp. *bulgaricus* (referred to as *Lactobacillus bulgaricus* throughout this chapter) and *Streptococcus thermophilus* (see Figure 4). Other culture types which do not meet Codex requirements but may meet regional requirements also include *Lactobacillus helveticus*.

Figure 4 *Lactobacillus bulgaricus* (left) and *Streptococcus thermophilus* (right)

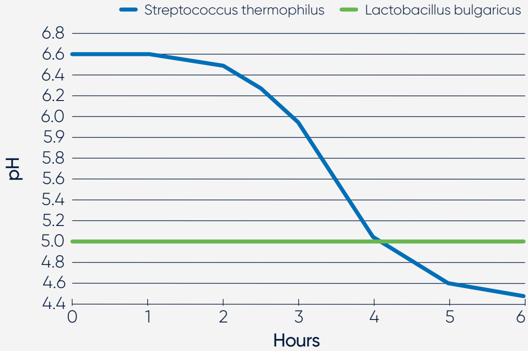


Dairy Process Handbook

Each of these cultures has its own optimum growth conditions that are required to produce their own unique set of flavour and aroma characteristics. *Streptococcus thermophilus* provides the smooth and buttery flavour while *Lactobacillus bulgaricus* provides more acidic, and sharper taste. *Streptococcus thermophilus* grows first when added to the yoghurt base as it prefers pH closer to 7.0 which is neutral level.

Once the pH has dropped to around pH 5, *Lactobacillus bulgaricus* (LB) tends to take over and grow faster while *Streptococcus thermophilus* (ST) has its growth inhibited by the lower pH.

Figure 5 ST/LB Culture pH Changes



Culture manufacturers use this and a selection of strains with specific traits to develop mixed cultures that grow quickly and result in a predictable pH drop within a specific time frame. The final pH and time taken can normally be predicted reasonably accurately. Factors that influence the pH drop are more associated with the factory manufacturing unit. Any change in the growth of cultures results in changes to the time, pH, flavour and odour characteristics of the yoghurt.

In large-scale commercial manufacture, where external suppliers provide starter cultures, multiple strains of *Streptococcus thermophilus* and *Lactobacillus bulgaricus* are used.

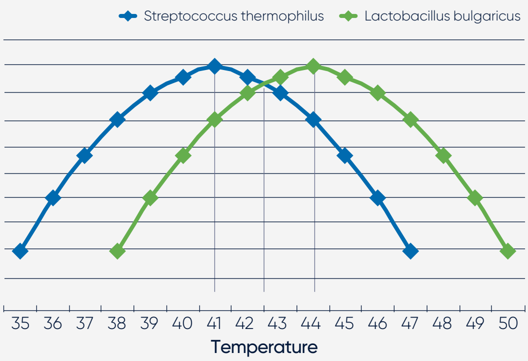
Streptococcus thermophilus is susceptible to antibiotics, especially penicillin, and sanitisers. Even a small quantity of a sanitiser remaining in the fermentation vat can inhibit the growth of *Streptococcus thermophilus*, which in turn slows the pH drop and consequently slows the growth of *Lactobacillus bulgaricus*.

A slight variation in the incubation temperature may also affect the ability of either culture strain to grow at its optimum. Depending on the strain, *Streptococcus thermophilus* has an optimum growth temperature of approximately 38 – 42°C. *Lactobacillus bulgaricus* has a slightly higher optimum growth temperature of approximately 45°C.

This means that the fermentation temperature is normally set as a compromise between these two. If the temperature is lowered or raised by as little as 1°C, it will mean that one of the culture strains will grow faster but the other will be slower. In effect, this changes the impact of each culture strain on the final product in terms of final pH, flavour, odour, mouthfeel, viscosity and syneresis.

If the temperature is too low, *Streptococcus thermophilus* will grow better but the growth of *Lactobacillus bulgaricus* will be slower. This can result in a milder, smoother yoghurt but may mean long fermentation times and the resultant pH being hard to reach within a reasonable time. If the temperature is too high, *Streptococcus thermophilus* will grow slowly and it will take longer to reach the pH which favours growth of *Lactobacillus bulgaricus*. At this point, *Lactobacillus bulgaricus* grows very rapidly and tends to produce too much acid resulting in excessive pH decrease and syneresis in the final yoghurt.

Figure 6 Culture growth temperatures



11.5 Cooling and pre-filler storage

At the conclusion of fermentation, the pH should be close to 4.6 which is the isoelectric point of casein. At this pH the net charge on the casein micelles is zero, so the casein micelles coalesce together to form the protein matrix and gel. At this stage, the yoghurt base needs to be pumped to a pre-filler storage tank. Mechanical action can break the matrix. If the fermentation is allowed to continue beyond pH 4.6 the protein matrix will shrink, the curd will be acidic and defects such as syneresis and whey formation will appear in the yoghurt.

In order to control and stop the fermentation beyond pH 4.6, a combination of culture selection and cooling of the yoghurt base to around 20°C is practiced. Selection of cultures needs to be considered carefully in balancing the need for short fermentation times (with very active culture strains) combined with the need to halt the fermentation with cooling of the yoghurt base.

Selection of culture strains that lower the pH to just below the isoelectric point helps to stop further fermentation, and limit post-fermentation acidification. A selection of strains of *Lactobacillus bulgaricus* is available from several commercial starter culture manufacturers. These have been specifically isolated to inhibit their growth below a predetermined pH.

The pump and cooling system for the yoghurt should be placed as close as possible to the fermentation tanks so that there is very little mechanical action on the yoghurt prior to it being cooled. Cooling should be to a temperature low enough to slow culture activity, while still being high enough to allow effective pumping and filling.

The temperature for filling is normally around 20°C for most applications as this allows for storage and transport through pipework and vats at the ambient temperature. This temperature also helps filling machines to operate at slightly higher rates than would be the case with a more viscous product. In using this temperature, however, it is important that the time taken prior to filling is as short as possible; filling would normally be completed within 12 hours of storage of the yoghurt base.

11.6 Conclusion

The manufacture of consistent, good quality yoghurt is achieved by minimising the variations in the process. These include selection of top quality consistent ingredients, controlling the rehydration and standardising steps, fermentation and storage to target levels as per standard operating conditions Defects in yoghurt are due to poor selection of ingredients, and poor treatment during storage, mixing, heat treatment or fermentation. Some manufacturers spend time and resources analysing and adjusting processes after fermentation such as storage of base, transport, and filling. Experienced manufacturers suggest that it is better to focus on selection of good quality ingredients, minimising variations and controlling the fermentation and storage.Yoghurt made under controlled conditions is able to withstand some mistreatment or abuse, provided it is not excessive, without any lasting effect on the yoghurt matrix. The quality of packaging materials is also equally important.

11.7 Frequently asked questions (FAQ)

Table 1 Common process defects

Defect	Reason	Cause
Runny yoghurt	Total solids too low	Poor standardising
	Protein level too low	Poor standardising
	Casein level too low	Poor standardising
	Casein to whey protein ratio too high	Poor standardising
	Excessive mechanical action after fermentation	• Shearing at too high pressure • Pumping too far to filler • Vibration
	pH too low (past isoelectric point)	• Delay in filling after fermentation • Over-active culture
	pH too high (isoelectric point not reached)	• Insufficiently active culture • Protein content incorrect • Sanitiser contamination • Antibiotic residue or presence of other inhibitory compounds
Nodule formation	Dry ingredients not fully rehydrated	• Mix temperature too low • Mixing time insufficient • Mixing equipment inadequate • Poor solubility of dry ingredients
	Protein denatured prior to heat treatment	• Low heat powders not used • Low heat powders with high proportion of denatured whey protein • Milk stored at too high temperature • Excessive pumping of milk
	Excessive heat treatment	• Recirculation through pasteuriser • Time/temperature incorrect
Graininess	Extreme heat treatment	• Recirculation through pasteuriser • Time/temperature incorrect
	Dry ingredients not fully rehydrated	• Very poor solubility of ingredients
	Protein content is too high above a threshold, especially if a significant amount of dry ingredients are used to increase the protein	• Poor solubility of dry ingredients • Dry ingredient levels too high • Mixing time insufficient • Mixing equipment inadequate
	Protein denatured prior to heat treatment	Very poor quality milk protein
Whey separation	Over acidification	• Overactive culture • pH allowed to drop too far past the isoelectric point • Culture still active after packaging and cooling • Yoghurt temperature allowed to increase during cooling or storage
	Casein to whey protein ratio too high	Poor standardising of yoghurt mix

A Raw materials

1. How does selection of low, medium and high heat powders impact on yoghurt manufacture?

The best quality yoghurt requires milk powder which on recombining yields milk similar in quality to raw milk, where most of the whey proteins are undenatured. So, low heat powder with low WPNI is better suited to yoghurt manufacture.

The undenatured whey protein concentration, as measured by WPNI, changes significantly with season, region, cattle breed and the treatment of the milk. Some regions have great difficulty in producing low heat powder at different times of the year even though the milk is handled carefully and the quality may be exceptionally good. This is simply because there is a natural tendency for low levels of total whey proteins at that time of year or in that region. The result is that a low level of total whey protein in the raw milk must give a low level of total whey protein in the powder so the undenatured component of this must also be low. This gives a false or misleading result that the milk powder is medium or even high heat. This is because the whey protein in milk used for powder manufacture is very low.

The opposite effect can also apply in regions where there is a naturally high concentration of whey protein in the raw milk. A high content of total whey protein in raw milk will result in a high content of total whey protein in the powder. In this case, the level of undenatured whey protein may also be high even though medium heat temperatures were used. This gives a false or misleading result that the milk powder is low heat and is suitable for yoghurt manufacture when in fact it will have a high level of denatured whey protein as well. For example, milk powder produced using medium heat time and temperatures of 80 - 90°C for a few minutes may still record a WPNI >6.0 mg/g if the undenatured whey protein content was high initially.

Many yoghurt factories using milk powders encounter significant variation in yoghurt quality especially in syneresis, graininess and nodule formation even though they are using low heat powder consistently. It is possible that this may be due to milk not being handled correctly prior to evaporation and drying especially when milk with a naturally high total whey protein content is used.

In order to reduce variation in the quality of the milk powders used to manufacture yoghurt, it is important to measure total whey protein and undenatured whey protein to get a better picture of the relative ratio of denatured and undenatured whey protein.

2. How do the functionalities of WPCs differ from SMP when used in yoghurt?

The use of SMP will increase the total solids in the mix – especially lactose and protein. As lactose is high in SMP, this will result in a marginal increase in viscosity but may also cause an increase in powder flavour.

Whey Protein Concentrate (WPC) with 50% or 80% protein can increase viscosity if used to optimise casein : whey protein ratio to 3.3:1. Care must be taken to ensure WPC has high levels of undenatured protein. The quantity of WPC 50 or 80 required will be significantly lower as WPC has higher levels of protein than SMP at around 34-35%.

3. How do you minimise ingredient costs in manufacture of yoghurt?

The most effective way of minimising ingredient costs is to use very good quality ingredients that have been selected specifically for yoghurt manufacture. Any compromise in quality usually results in inconsistent and inferior quality yoghurt that may adversely impact sales and profits.

Some manufacturers who use poor quality ingredients compensate for this by increased use of stabilisers and emulsifiers. It is debatable whether this is less expensive, but this can lead to changes to flavour and consistency of yoghurt which consumers may dislike.

It is possible to use specialised powders for yoghurt manufacture where casein : whey protein levels have been optimised and spray dried as low heat powder. This pre-standardised powder provides convenience and savings in purchase, transport, storage and mixing of ingredients.

4. How can the powder flavour in yoghurt be minimised or avoided?

Powder flavour in yoghurt is due to the selection of dry ingredients not suitable for yoghurt. The use of high heat, medium heat or powders with high levels of protein denaturation result in a powdery flavour in yoghurt. Powders must be selected for minimum protein denaturation so that they are similar in quality to raw milk.

5. For milk powders and whey products used in yoghurt manufacture, what is optimum temperature and hydration time?

The type of powder selected often determines the mixing times, temperatures and blending equipment that reduces air incorporation.

For most applications, at least 15 min blending at 40°C is recommended, this mixing to be done prior to any heat treatment. A common error in yoghurt manufacture is to assume that the heating of the mix in the heat treatment unit assists in dissolving any undissolved powder particles. In fact, undissolved particles act as seed points for protein denaturation and result in sandy or grainy texture or nodules.

It is possible to mix powders at lower temperatures if their quality is good and mixing systems are suited for yoghurt manufacture. Blending systems that reduce the incorporation of air while providing effective mixing are available and capable of mixing powders at or below 4°C in a relatively short time. Several yoghurt manufacturing units rely on recirculation using centrifugal type pumps at high capacity to blend the dry ingredients. These systems are not suitable and usually lead to graininess or whey separation defects. Better systems are those purpose-built for the operation such as tri-blenders or colloid mills.

Powder blending high-speed mixer

6. What are the specifications for powders suitable for yoghurt manufacture?

The following table sets out the minimum standards for powders for yoghurt manufacture.

Table 2 Minimum Standards for Powders for Yoghurt Manufacture

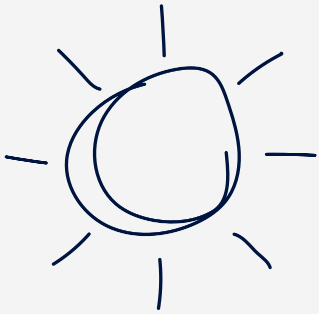
Attribute	Description	Standard
Moisture		3–4%
Fat	As required for yoghurt fat level	
WPNI	Whey Protein Nitrogen Index	Low heat >6.0 mg/g
Solubility index	A direct measure of the undissolved powder remaining after reconstitution at 20°C and centrifuging.	<0.1ml. from 10g
Sludge	A measure of the degree of sludge build up after reconstitution and allowing the sample to stand for some time.	Nil
Scorched particles	A measure of any scorched, burnt or discoloured particles in the powder that do not dissolve.	Nil (disc A)
Dispersibility	A measure of the ability of the powder to disperse in water in a given time frame.	>90%
Wettability	A measure of the ability of the powder to come completely in contact with water over a period of time.	<5 sec.
Sinkability	A measure of the ability of the powder to become completely immersed in standing water over a period of time.	<10 sec.
Gelation test	A measure of the ability of the powder to gel and coagulate following heat treatment at 100°C and 120°C and incubation over time.	Gelled in 24 hrs
Alcohol test	A variant of the gelation test where alcohol is used at a 1:1 ratio of the reconstituted milk to test the tendency to gel.	Gelled

7. What are the key factors for making yoghurt with consistently high viscosity?

It is possible to consistently manufacture high viscosity yoghurt by standardising the proteins and total solids in the yoghurt mix. A key factor is the selection of good quality ingredients that are similar to good quality raw milk. Another factor is to increase the protein content of the mix by selecting good quality high protein ingredients such as WPC 80. It is advisable to use WPC 80 or WPI 90 with high levels of undenatured whey proteins. These products have high protein and low lactose levels. The addition rate of WPC 80 will be around 2% but will vary according to each batch and recipe requirements as per composition of milk and other ingredients.

The temptation to simply add WPC/WPI, or any other supplement, at a standard rate must be avoided as this does not account for variation in the composition of other ingredients.

The viscosity of the yoghurt can be evaluated using a Bostwick consistometer and measuring the distance the yoghurt moves over 1 minute. This should be between 6 and 11 cm per minute at the point of packaging, 4 to 6 cm after cooling and less than 4 cm at the point of sale.



Brookfield viscometer used for accurate viscosity testing.

Bostwick consistometer used for rapid estimates of viscosity.

8. What is the difference between yoghurt made from reconstituted milk and from fresh milk?

The main difference between fresh milk and reconstituted milk is the impact of the preheating and evaporation process on the denaturation of whey proteins in the powder used for yoghurt manufacture. The major whey proteins, α-lactalbumin and β-lactoglobulin can be denatured by heat treatment during preheating of milk prior to evaporation depending on the time and temperature of heat treatment. Denaturation can be minimised by using temperature and time close to pasteurisation time and temperature for milk. Denatured protein does not form part of the yoghurt matrix on setting, instead, it contributes to graininess and whey separation. Ideally, yoghurt made from fresh milk will have minimal denatured whey protein, however, the seasonal variation of milk protein levels makes standardisation of milk for protein levels rather challenging. There may be conflicting demands on the fresh milk in many larger plants so that the yoghurt process must utilise milk that may not be ideally suited for yoghurt manufacture. Yoghurt from fresh milk exhibits a wide range of variation in consistency, viscosity and whey separation due to varying levels of whey protein. Yoghurt from reconstituted milk and WPC 80 has the advantage of being much more consistent if selected properly but may have the disadvantage of having higher levels of denatured whey proteins which may lead to graininess or whey separation. Powders selected based on WPNI and undenatured whey proteins lead to more consistent yoghurt with fewer defects. The yoghurt mix can be standardised with WPC80 to produce the correct level of proteins for good quality yoghurt.

9. Can UHT milk be used to manufacture yoghurt and how does this impact yoghurt quality?

The purpose of UHT is to destroy most of the bacteria and spores to make milk virtually sterile while at the same time having minimal impact on the milk components. This is achieved by heating milk to a very high temperature for a very short time, for example 140°C for 2 – 5 seconds. Most milk components such as casein, lactose and milk fat are relatively heat stable and are not impacted by this time and temperature combination. The whey proteins are more susceptible to heat and may be denatured to some extent. If a very short time is used, the impact on these whey proteins can be minimised. This depends largely on the ability of the process to rapidly raise the temperature of the milk from 4°C to UHT temperatures and then rapidly cool it to the set temperature. Modern plants can operate better controls to achieve this.

There are several volatile flavour compounds that may be released due to the high heat treatment and this can have an impact on the flavour profile of the milk and the yoghurt. The flavour changes due to UHT temperature and time must be considered before making decisions regarding using UHT milk for yoghurt manufacture.

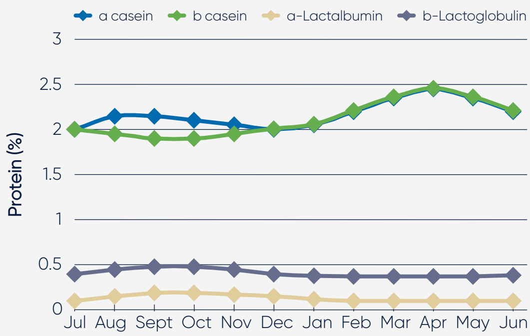
B. Processing

1. What are the best ingredients for increasing the whey protein content of the yoghurt mix?

The base mix for yoghurt manufacture will require an increase in the protein and total solids content to obtain the best quality yoghurt. Several products are available to achieve the correct ratio of casein to whey proteins while increasing the total solids. WPC 80 and WPI 90 are best suited to increase whey protein levels to the desired casein : whey protein ratio. The reason for the addition of whey protein must be to improve the flavour and functionality of yoghurt (such as gel strength and syneresis) by balancing the correct components for the yoghurt required. The relative cost reduction should be seen as a bonus from this rather than the sole reason; in this way, manufacturers are not tempted to increase the use of whey products beyond what is the optimum and risk defects from overuse. The temptation to compromise on product quality or select inferior quality products should be avoided. In most cases, the cheaper ingredients create quality defects and lead to loss of sales and profits.

The protein level in milk changes during the season as shown in the Figure 7.

Figure 7 Seasonal Variations in Protein Levels in Milk



Variation in protein components due to seasonality (Protein is expressed as %)

In view of the seasonal changes, yoghurt manufacture using fresh milk is challenging. The protein level needs to be increased to make good quality yoghurt and the following ingredients are possible options:

Skim milk powders (SMPs) – SMP does not alter the casein : whey protein ratio in the yoghurt and should not be used by itself. SMP in combination with WPC 80 which supply whey proteins is a good option. SMP should be low heat and denatured protein levels must be very low or nil.

Skim milk concentrates (liquid) – Evaporation of skim milk yields skim milk concentrates and can be used to partly raise milk solids in yoghurt mix. However, this should be combined with a supply of whey protein such as WPC.

Whey powders – Non hygroscopic whey powder is a cheap source of milk solids for yoghurt mix. However, with salt content of 9-12% on a dry matter basis, whey powders can add excessive amounts of salts which can significantly impact the flavour of the yoghurt; the high salt content may slow the activity of starter bacteria, slow the fermentation and extend the fermentation time. So, use of whey powders should be minimal or avoided altogether.

Demineralised whey powders such as D-40 with 40% demineralisation and 6-7% salt level is a much better alternative. It has lower mineral salts, does not slow the action of starter bacteria and is effective in producing good flavour characteristics and increasing the viscosity and consistency of the yoghurt.

WPC – Whey Protein Concentrates are the most effective way of raising the whey protein level, balancing flavour profile, and providing desirable texture characteristics. WPC is made from processing whey through a UF membrane which removes most of the dissolved salts like Potassium and Chloride which are associated with poor flavour characteristics and with inhibiting starter cultures. There are mainly three types of WPC – 35, 50 and 80 which refer to the protein levels in the powder. It is best to use WPC 80 but WPC 50 or WPC 35 are also okay to use in the yoghurt base.

Old style powder mixing system

2. What are the advantages and disadvantages of using stabilisers in yoghurt manufacture?

Stabilisers are commonly used in yoghurt manufacture. The most effective ones are starch based or gelatine or a combination such as gelatine, pectin, agar-agar and starch. The function of a stabiliser is to thicken the yoghurt, increase the viscosity and improve the consistency. This improves customer acceptance and overcomes defects such as runny yoghurt or whey separation. Stabilisers must be listed on the ingredient list and therefore must be added to all yoghurts for that SKU which increases ingredient costs. Generally, yoghurt made with good quality ingredients does not need stabilisers or thickening agents. If stabilisers are added it may be a sign that the process is not controlled as effectively as it should be. If circumstances are such that it is not possible to access the best quality ingredients, for example when the price of milk powders is high, one option is to use alternate ingredients and stabilisers to increase viscosity and thickness. Occasionally, stabilisers can increase yoghurt thickness excessively and such yoghurt is difficult to pump through to the filling process after fermentation.

3. How can the nutritional and bioactive functionality of yoghurt be improved? Which ingredients can help achieve this?

Probiotics – Probiotics are live bacteria and yeasts that are considered good for human health, especially for the digestive system. Addition of probiotic cultures enables extending the healthy attributes of yoghurt. This can also help provide a marketing edge over traditional yoghurts. The probiotic cultures are based on the natural flora of the gut and include single strains as well as mixture cultures. The most common probiotic cultures used are:

- *Lactobacillus acidophilus*
- *Lactobacillus casei*
- *Bifidobacterium* spp.
  (various species of this genus)

These are normally used in conjunction with *Streptococcus thermophilus* which imparts desirable sensory attributes to the product.

A key challenge with probiotic cultures is to keep them viable in yoghurt at or below pH 4.5. At this pH, probiotic bacteria do not grow although strains of probiotic cultures have been developed which are able to survive and grow in yoghurt. Another key challenge is for probiotic bacteria to survive the high acid environment in the stomach before they can reach the gut. One option is to add whey protein which increases the buffering in the yoghurt which protect the probiotic bacteria.

Furthermore, cultures have been developed to improve the texture of yoghurt. Certain strains of *Streptococcus thermophilus* and *Lactobacillus bulgaricus* can produce exopolysaccharide (EPS) which can increase viscosity, smoothen the texture and creaminess, lower the syneresis and prevent 'ropy' type texture defects as shown below

Ropy texture defect in yoghurt

The bioactive properties of whey proteins in yoghurt have not been marketed well. Components of whey products, especially proteins, have not been utilised well enough. Several whey proteins lower serum cholesterol, enhance the immune system and reduce incidence of cancers, especially colon cancer. Technologies are now available to isolate and purify specific components of milk and milk proteins for use as functional ingredients.

4. How can whey separation in yoghurt be minimised?

Whey separation is generally caused by two factors a) poor selection of ingredients, or b) lack of control in heating of the yoghurt mix. The first cause refers to improper standardisation of yoghurt mix based on total solids rather than on casein : whey protein ratio critical for the protein matrix to bind the water. Furthermore, whey proteins which have been previously denatured due to poor storage are unable to bind water and can cause whey separation.

The second cause refers to insufficient heating of yoghurt mix leaving a larger proportion of whey proteins in their native state. These proteins are not part of the protein network in yoghurt which binds the water and prevents whey separation. This is less common as most processes ensure that heat treatment is effective, usually 90°C – 95°C for 5 to 6 minutes.

During fermentation, it is possible that small variations in temperature lead to considerably different growth rates for the cultures used. Mixed strain cultures are most commonly used but elevated or lowered temperatures mean the growth of each strain will either be depressed or enhanced. This can lead to either excessive or insufficient acidification as well as flavour and texture changes.

Highly active cultures also tend to produce too much acid, particularly strains of *Lactobacillus bulgaricus*. This causes the protein matrix to shrink and expel whey and the flavour becomes too acidic.

Mechanical action

The factors discussed above lead to a coagulum that is weak and easy to break. Mechanical factors such as vibration, pumping, movement or temperature change after packaging can weaken or partially break the matrix which allows the entrapped water to be released (whey separation). This may be noticeable at the time of fermentation, packaging or, more commonly noticed by the consumer, when the yoghurt is approaching the end of its shelf life.

Defect in yoghurt showing whey or water leakage.

5. Why does yoghurt become sandy or form nodules?

Sandy or grainy texture or nodules in yoghurt are usually the result of poor selection of ingredients or insufficient rehydration of the dry ingredients such as SMP. In particular, denatured protein in the ingredient is likely to attract other protein molecules during the fermentation process and form a large complex or particle. During the heat treatment of the yoghurt mix, the denatured protein bonds more protein. As the pH drops during fermentation, and approaches the isoelectric point, more protein is attracted to the denatured protein. This results in the formation of tightly packed protein particles or compacted protein to form nodules which contribute to a sandy texture defect detected during consumption. This defect can be prevented by using ingredients with no denatured protein.

Another major cause of sandy or grainy yoghurt is improper rehydration of dry ingredients such as SMP or whey powder. If the powders are not hydrated correctly, the undissolved particle attracts proteins during fermentation and after heat treatment of the yoghurt mix. Possible ways to prevent this defect include filtering the mix after mixing the ingredients. Filtration is only partly effective as it doesn't filter out the smaller particles. Centrifugal clarification of the mix prior to heat treatment is an option which is effective but does add time and costs to the manufacturing. Homogenising the mix after the heat treatment to break up the small particles is also a useful option. The most effective prevention step is to effectively design the powder mixing process so that rehydration is maximised, ingredients are of the best quality and rehydrate well. The rehydration step must be designed such that blending is quick, efficient, and complete; this may necessitate the re-engineering of blending and pumping equipment and adjusting the temperature. The blending temperature should be above 20°C and preferably around 40°C.

Defect in yoghurt showing small and large nodules which cause sandiness. Larger nodules are visible in the yoghurt, but many small nodules can be seen under close examination. Shearing the yoghurt after fermentation will reduce the large nodules but many small nodules remain. Although not easily visible, the small nodules may be detected on the tongue if they are hard enough. The yoghurt is also much more likely to exhibit whey separation as the matrix has not been formed properly, the protein forms into localised nodules instead of a smooth matrix.

6. During fermentation of the yoghurt mix, how can the aroma development and fermentation time be balanced?

The selection of the blend of starter cultures has the greatest impact on flavour and aroma of yoghurt. The flavour of yoghurt desired by key target market segments determines the mix of cultures to be used. For example, very sharp and 'clean' yoghurt flavour will require a higher level of *Lactobacillus bulgaricus* cultures as these produce most of the lactic acid in yoghurt and produce acetaldehyde (flavour compound) that contributes greatly to this type of flavour. If the target market prefers a smoother and creamier yoghurt, a higher proportion of *Streptococcus thermophilus* cultures are recommended because these produce less lactic acid but develop more diacetyl flavour compound which contributes the smooth buttery flavour.

The next important step is accurate control of the fermentation process, in particular the temperature. Variation of even 1°C in fermentation temperature, will change the relative growth of different strains of the mixed culture causing changes in flavour, texture, fermentation time and pH of yoghurt. Mixed strain cultures can be a mix of five or more strains, some for rapid acid production that may not contribute to flavour greatly, some with low acid production that may contribute significantly to flavour. Selection of the correct strains of culture is important but to produce a consistent flavour profile in the shortest possible time, great control must be exercised over the fermentation process, especially ingredient selection, mixing and temperature.

Sensory grading of yoghurt after fermentation is important to pick up. A simple grading sheet may be used to record any notable flavour or odour characteristics of the yoghurt base after fermentation and cooling to 20°C. If a stronger than normal smooth diacetyl flavour is noted it can indicate that *Streptococcus thermophilus* has been dominant. This may mean that the incubation temperature was lower than optimum or the fermentation time was longer than needed.

If a sharper than normal flavour was noted it can indicate that *Lactobacillus bulgaricus* has been dominant. This may be due to the fermentation temperature being slightly higher than normal, especially if the fermentation time was shorter than planned. Lack of sharpness and creaminess in yoghurt suggests that rapid lactic acid producing strains have been dominant, reducing the fermentation time but cultures for flavour production were restricted from growing.

Longer fermentation times may be due to antibiotic or sanitiser residues in milk which may inhibit the growth of starter cultures, especially *Streptococcus thermophilus*. *Streptococcus thermophilus* produces the initial pH drop that allows *Lactobacillus bulgaricus* to grow well. Slower growth of *Streptococcus thermophilus* leads to a delay in the growth of *Lactobacillus bulgaricus*, and this extends the fermentation time.

Longer or shorter than expected fermentation times can be an indication of loss of control and can lead to flavour and consistency defects. The process should be strictly controlled, striking a balance between fermentation time, consistency, viscosity and desired flavour.

7. What are the economical benefits of using good and consistent quality ingredients?

Selection of best quality ingredients can largely eliminate the need for stabilisers and emulsifiers. Standardising the yoghurt mix to the correct protein and total solids levels and the casein : whey protein ratio is critical for both quality and minimising ingredient costs. Several other factors help to improve the quality of yoghurt. These include (i) absence of antibiotics, (ii) gentle handling and cooling of milk from farm to processing, and (iii) good quality raw milk and ingredients.

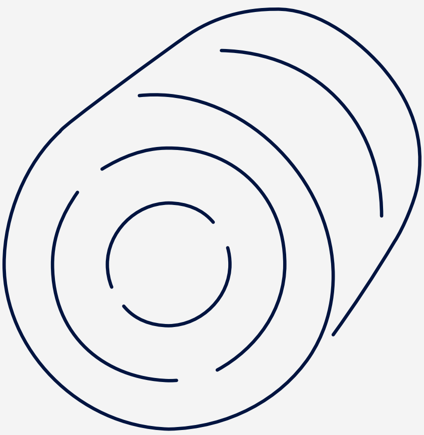
8. How can stability of drinking yoghurt be achieved in the absence of stabilisers?

Drinking yoghurt must stay liquid, be not too viscous and generally this can be achieved with lower levels of protein. At the same time, there must be sufficient nutrients for cultures to grow and sufficient lactose for growth of lactic acid cultures.

The protein in drinking yoghurt can separate from the water phase upon storage. The function of stabilisers is keep the components in solution. Stabilisers can increase ingredient costs so their level of addition must be optimised.

Factors that may help in minimising the cost of production include:

Accurate standardising of the protein level to suit the product and meet the food standards code, changing the ratio of casein to whey proteins to minimise the tendency of protein to form a matrix. The networks between the whey proteins and casein are less likely to form again after mechanical agitation, therefore a possible increase in the sulphydryl groups and sulphide bonds after heat treatment combined with mechanical action after fermentation is more likely to ensure that drinking yoghurt stays in a stable and homogeneous form.



Vigorous mechanical action after fermentation can include homogenisation, which acts to break particles down to a size small enough to ensure a stable and homogeneous product.

Ingredients that have been properly mixed, hydrated and distributed evenly will stay in a stable and homogeneous form.

Use of cultures that produce EPS (exocellular polysaccharides) may also help in uniform distribution of the proteins in drinking yoghurt. If a yoghurt culture produces enough EPS, there may be no need to use stabilisers in the product. Balancing the production of EPS with flavour, sweetness and acid production must be considered when EPS-producing cultures are used. Excessive use or growth of EPS cultures may lead to a slimy yoghurt.

C Cooling and Packaging

1. The coagulum formed during fermentation is sensitive to mechanical treatment. What factors need to be considered during equipment design especially at the cooling stage to reduce the breakdown of the coagulum?

The design of plant must enable the yoghurt to be cooled to approximately 20°C and filling to be completed as quickly as possible to inhibit activity of starter cultures and minimise mechanical disruption of the protein gel. The fermentation tanks must be located as close as possible to the final filling point. Stirred yoghurt is very gently agitated in the fermentation tank, this step is not one of vigorous agitation but rather of 'folding' and blending the yoghurt gently until a smooth base is obtained.

After fermentation, cooling of the product must be rapid but gentle. It is advisable to use large diameter pumps and pipework with single flow-through design. These pumps are normally positive displacement screw type impeller pumps designed specifically for aseptic and gentle transfer of high viscosity products. They are designed to be cleaned easily by allowing high flow during cleaning, with bypass at only the screw impeller section.

The outlet from the fermentation tank must be close to the pump and then pumped directly into the cooling heat exchanger, designed for gentle heat transfer. Shell and tube heat exchangers are normally used. The yoghurt is normally cooled to approximately 20°C and placed in storage vats prior to filling. It is important that the storage vats are located close to the filling point so minimal movement of the yoghurt is required.

Design of plant usually incorporates some mechanism for reducing any lumps, nodules or grains that may be present after fermentation. This is usually in the form of a backpressure or shear valve, coarse filter or strainer prior to cooling. Although effective in reducing these defects after they are formed, they may also contribute to the mechanical breakdown of the yoghurt, which may promote whey separation, particularly towards the end of the product's shelf life.

Vibration can break down the yoghurt matrix so is it is important that all agitators, stirrers and pumps are not subject to any vibration. Vibration can be due to equipment being out of balance, loose from its foundation, of incorrect size or poor design.

Vibration may also occur during or after the filling operation, especially during transport of filled tubs and cartons to cool rooms for cooling and storage. Any vibration or movement during cooling will tend to disrupt the gel matrix of the yoghurt. Vibration due to transfer by road or rail from manufacture to point of sale will also break the protein matrix.

On the positive side, when yoghurt is manufactured with high quality ingredients and with accurate process control, the yoghurt can withstand a reasonable amount of mechanical agitation. The final pH just below 4.6, the isoelectric point for casein and the formation of a strong matrix helps to keep the yoghurt together and give it thixotropic properties which helps it recover well from some mechanical disruption.

2. Yoghurt has thixotropic flow behaviour, how does the viscosity recover and what is the extent of this recovery after the filling stage?

The ability of yoghurt viscosity to recover or thicken after filling is largely dependent on the final pH of the yoghurt. Yoghurt with pH 4.6, isoelectric point of casein is far more likely to recover well after mechanical agitation and filling. The standardisation of the casein : whey protein ratio and protein : total solids ratio to correct levels assists in formation of a strong matrix between casein complexes and whey proteins. Mechanical action and further acid development can disrupt the matrix. The matrix may not form again easily leading to defects such as whey separation and runny yoghurt.

The matrix strength is strongly dependent on pH and it is important that the pH does not decrease too much. This will facilitate strong protein networks able to withstand mechanical handling and pumping. The matrix will not shrink and release whey.

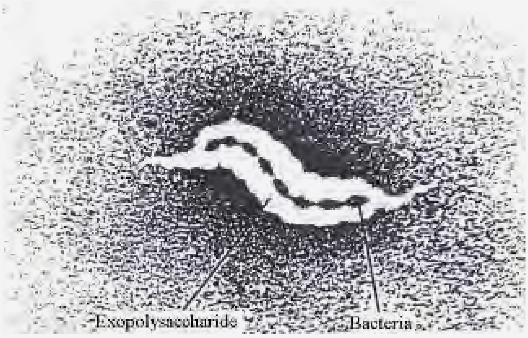
When yoghurt is cooled to around 20°C, the fat is slightly solidified. This helps with strengthening the matrix and improving viscosity Other components such as whey proteins also help increase viscosity by gelling.

Thus the pH of the yoghurt, the key factor in recovery of viscosity after filling, acid production and pH after fermentation is well controlled, the yoghurt will maintain and recover any lost viscosity. Any loss of control over acid production after fermentation will lead to runny yoghurt and whey separation.

The recovery of viscosity improves further when the yoghurt is cooled to below 4°C. Even yoghurt that appears runny can significantly improve once filling is complete and 4°C storage temperature is reached. If the initial viscosity of the yoghurt is low, this must be investigated and rectified.

It is possible to manufacture yoghurt with good viscosity without the need to add stabilisers with accurate control of the process. In many cases, accurate control is not maintained resulting in some variation in acid development, pH and viscosity Stabilisers often have to be used to mask this variation.

The use of EPS-producing bacteria in cultures is another option for achieving and keeping the required viscosity without the use of stabilisers. As mentioned earlier, EPS cultures are surrounded by a polysaccharide capsule, which acts as a stabiliser, reducing the need for other stabilisers.



Principle of exocellular polysaccharide production by bacteria to increase viscosity

3. How can the post-fermentation acidification of yoghurt be controlled?

Post-fermentation acidification, called 'post-acidification' is caused by the continued activity of the starter culture after the target fermentation pH 4.6 has been reached. Proper selection of culture strains can assist in minimising pH drop after the end of fermentation. Starter bacteria strains are selected for rapid production of lactic acid, particularly strains of *Lactobacillus bulgaricus*. These strains may be selected to lower pH to a predetermined point, under normal conditions, and then to plateau out at that point. They do this by producing enough lactic acid to inhibit their own growth or by becoming less active below 20°C or even dormant below 4°C. Culture activity is then controlled by filling the product and cooling it as quickly as possible.This ensures pH does not decrease below pH 4.6.

Post-acidification is largely due to poor handling of yoghurt after fermentation. For example, delays in filling may cause a slight pH drop. The pH scale is logarithmic and a pH drop from around 4.5 to 4.0 indicates significant acid production as the result of a very considerable increase in acid concentration. Even a slight decrease in pH, say from 4.6 to 4.4 has a large impact on flavour which is easily detected. Furthermore, this can lead to whey separation especially towards the end of yoghurt's shelf life.

Another common cause of post-acidification is delay between filling and cooling, usually due to delays in filling pallets or due to machine breakdowns. These delays allow the culture in individual tubs to continue acid production until they are finally cooled to a temperature below which their activity slows down. Another cause is yoghurt tubs held at higher temperatures during distribution or retail sale.

D Storage and distribution

1. What are the main factors that affect yoghurt stability after packaging?

It is important to cool the yoghurt as quickly as possible after packaging; this is usually achieved by stacking cartons in an open formation in the cool room to allow cold air to circulate between cartons. The cartons and tubs will gradually cool to below 4°C in 8 - 12 hours. The initial cooling from 20°C to less than 10°C occurs rapidly but the remaining cooling takes longer mainly due to the small difference in temperature between the cooling air and the yoghurt. Rapid initial cooling is important to minimise whey separation and slow the growth of any contaminant microorganisms.

Cooling of full-fat or reduced-fat yoghurt over 8 to 12 hours should ensure latent heat released due to fat crystallisation is also countered to prevent temperature rise during storage.

The shelf life of yoghurt is generally more than a month; in Australia it is six weeks. It is important that yoghurt is stored below 4°C during its entire shelf life.

Yoghurt which has been correctly manufactured can withstand reasonable mechanical action after it has set properly. Movement due to conveyors, forklifts, trucks and transfer to shop or supermarket shelves should have little impact on the yoghurt provided the integrity of the tub and the temperature remain unchanged. Vibration can impact the yoghurt, causing whey separation and runny yoghurt, especially during the first 48 hours after filling. The yoghurt viscosity increases after 48 hours and can withstand mechanical handling and vibration much better. It is important to ensure that the method of transport does not result in excessive vibration or movement.This can be achieved by limiting the speed of trucks, using trucks that ensure a smooth ride, taking roads to storage depots that are smooth and using smooth-tyred fork lifts.

Typical yoghurt carton with air holes to view contents and improve rate of cooling.

11.8 Glossary

Acidification
The formation of acid, or a more acidic environment.

Alcohol test
A variant of the gelation test where alcohol is used at a 1:1 ratio of the reconstituted milk to test the tendency to gel. It is sometimes used as a rough quality test on raw milk looking for immediate coagulation. It can test denaturation of protein due to acid development through poor handling.

pH
A measure of the acidity or alkalinity of a substance on a scale of 0 to 14 with 7 being neutral. It is a measure of the concentration of hydrogen ions on a logarithmic scale equal to log^{10} $(1/[H^{+}])$.

Culture
Bacteria selected and purified to perform a specific task, in the case of yoghurt the fermentation of lactose into lactic acid and the production of flavour compounds.

Detergent
A cleaning agent used to remove soil deposits or loading.

Dispersibility
A measure of the time required for powder to completely disperse in water. It is measured by dissolving the powder under controlled conditions, allowing standing for a short time then pouring a quantity off and calculating the total solids in the dissolved milk as a proportion of the original powder.

EPS
Exocellular polysaccharide (exopolysaccharide), a viscous material produced by some starter bacteria that becomes encapsulated in it and increases viscosity in yoghurt.

Fermentation
Acid formation by culture bacteria that ferment sugars.

Gelation test
A measure of the ability of the powder to coagulate following heat treatment at 100°C and 120°C and incubation. This test can be useful in the selection of milk powders for yoghurt manufacture by directly testing its ability to form a matrix as it is an indirect measure of the level of undenatured whey protein. This test can also be used on liquid ingredients.

Graininess
The formation of small hard grains in yoghurt associated with excessive heat treatment or very poor quality ingredients.

Homogenisation
Subjecting milk to high pressure, primarily to reduce the size of milk fat globules but also to break down solid or semi-solid particles and distribute them evenly throughout the mix. In yoghurt, homogenisation creates a uniform blend of protein.

Isoelectric point
The pH at which the net charge on the molecule or group of molecules forming a network/micelle is zero; for the casein micelle, the isoelectric point (pI) is 4.6.

Nodulation
The formation of soft balls in yoghurt usually consisting of denatured protein, sometimes referred to as 'fish eyes.'

Pasteurisation
Heat treatment for a defined temperature and time (for High Temperature Short Time Pasteurisation, HTST, it is equivalent to at least 72°C for at least 15 seconds to destroy pathogenic organisms. In yoghurt manufacture, heat treatment is nominally called pasteurisation but is of higher temperature and time to denature protein.

Sanitiser

A chemical or similar agent used to lower the bacterial load to an acceptable level, usually commercially acceptable.

Scorched particles test

A measure of any scorched, burnt or discoloured particles in the powder that do not dissolve. It is a simple filtration test where reconstituted milk powder is filtered through a cloth disc and analysed for any remaining particles. A set of standard photos is used to compare the discs.

Sinkability

A measure of the time taken by the powder to become completely immersed in standing water over a period of time.

Solubility

A direct measure of the undissolved powder remaining after reconstitution at 20°C and centrifuging the solution.

Standardisation

The controlled mixing or blending of different components to produce a desired ratio of these components in the final mix.

Syneresis/Whey formation

The defect in yoghurt which shows separation of the water or whey from the yoghurt matrix.

UF

Membrane process called Ultrafiltration.

Viscosity

A measure of a fluid resistance to shear stress.

Wettability

A measure of the time taken by powder to be completely wetted when brought in contact with water.

WPC

Whey Protein Concentrate, a concentrated form of whey, in which the protein level has been increased by flushing out lactose and other soluble ingredients using UF.

WPNI

Whey Protein Nitrogen Index, used to quantify undenatured whey protein in milk powders.

Yoghurt

A fermented food product manufactured by the controlled addition and fermentation of lactic acid producing bacteria in milk, fortified before fermentation with additional milk solids.

11.9 References

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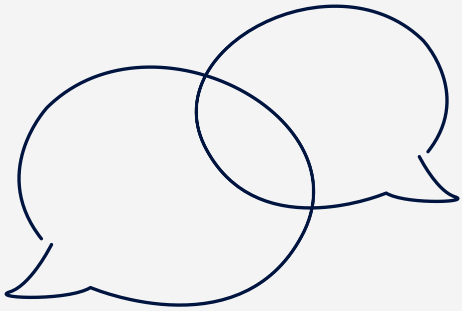


12 Applications of Australian Dairy Ingredients in Ice Cream

Content

12.1 Classifications of ice cream

Ice cream is a frozen product containing water, milk products, sweeteners, stabilisers, emulsifiers, and flavourings. Ice cream may also contain colourings, egg products, starch derivatives, syrups, fruit and confectionery.

Legal requirements in Australia

The Food Standards Code developed by Food Standards Australia New Zealand (FSANZ) describes ice cream as “a sweet frozen food that is made from cream or milk products or both, and other foods, and is generally aerated”. The compositional requirements are a minimum of 10% milk fat, and a minimum of 168 g/L of food solids. The Code referring to nutrient claims allows for the production of low fat and reduced fat varieties of ice cream.

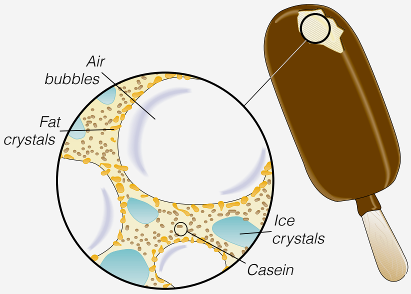
12.2 Application of key ingredients in ice-cream making

The basic constituents in ice cream mix are milk fat, milk solids not fat, (MSNF) sugar, flavours, colours, stabilisers, emulsifiers, air, and water. The interaction of these ingredients as well as the relative proportion of each component is important. The quality of the ice cream produced depends on target consumer requirements and is a balance between flavour, body, texture, and colour. The body and texture are determined by the principal ingredients, the stabiliser and the emulsifier system but will also be affected by the amount of air incorporated during freezing and churning. This incorporated air is called the overrun and will vary depending on the formulations of the mix and the type of freezer used. Overrun in ice cream manufacture is particularly important because it determines not only the quality of the ice cream but the incorporated air increases the volume of the ice cream mix by around 100% which increases the quantity of ice cream and therefore the profit margins. For example, one litre of ice cream mix can yield around two litres of ice cream due to the air incorporation which equates to 100% overrun.

Ice cream can be considered as ‘foam’ in which the air is dispersed as small air cells within the partly frozen continuous phase of an oil in water emulsion. This phase also contains dissolved solids such as sugars, salts and colloidal substances such as proteins and stabilisers. Figure 1 below shows the microstructure of ice cream consisting of air bubbles, ice crystals, fat, MSNF and stabilisers.

There are many ingredients which can be used to manufacture ice cream such as cream, unsalted butter, anhydrous milk fat (AMF), condensed skim milk, skim milk powder (SMP), whole milk powder (WMP), butter milk powder (BMP), dry sugar, glucose syrup and dextrose.

Figure 1 Microstructure of Ice Cream



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Some major considerations in the selection of the type and quantity of ingredients include legal requirements, cost, availability, and consumer preference.

The table below from Marshall and Arbuckle (1996) show some typical ice cream formulations.

Milk fat

Fat accounts for most of the rich, creamy taste of ice cream and only a limited amount of substitution with other fat ingredients can be made without changing this attribute. Fat gives body to the product and provides a smooth texture.

Table 1 Approximate Composition (%) of commercial ice cream and related frozen desserts

Product	Milkfat	NMS	Sweeteners[1]	Stabilisers[2] and emulsifiers	Approximate TS
Nonfat ice cream (hard)[3]	<0.8	12–14	18–22	1.0	35–37
Lowfat ice cream (hard)[3]	2–4	12–14	18–21	0.8	35–38
Light ice cream (hard)[3]	5–6	11–12	18–20	0.5	35–38
Reduced fat ice cream (hard)[3]	7–9	10–11	18–19	0.4	36–39
Soft–serve ice cream	3–4	12–14	13–16	0.4	29–31
Economy ice cream	10.0	10.0–11.0	15.0	0.30	35.0–37.0
	12.0	9.0–10.0	13.0–16.0	0.20–0.40	
Trade brand ice cream	12.0	11.0	15.0	0.30	37.5–39.0
	14.0	8.0–9.0	13.0–16.0	0.20–0.40	
Deluxe ice cream	16.0	7.0–8.0	13.0–16.0	0.20–0.40	40.0–41.0
(premium–super premium)	18.0–20.0	6.0–7.5	16.0–17.0	0.0–0.20	42.0–45.0
	20.0	5.0–6.0	14.0–17.0	0.25	46.0
	6.0–10.0	2.7	14.0–17.0	0.40	36.0–38.0
Mellorine		**(Protein)**			
Frozen yoghurt	3.25–6.0	8.25–13.0	15.0–17.0	0.50	30.0–33.0
	0.5–2.0	8.25–13.0	15.0–17.0	0.60	29.0–32.0
	<0.5	8.25–14.0	15.0–17.0	0.60	28.0–31.0
Sherbet	1.0–3.0	1.0–3.0	26.0–35.0	0.40–0.50	28.0–36.0
Ice	–		26.0–35.0	0.40–0.50	26.0–35.0

1 Includes sucrose, glucose, fructose, corn syrup solids, maltodextrins, polydextrose, and other bulking agents, some of which contribute little or no sweetness.

2 Includes cellulose gum and cellulose gel.

3 Terms for specific fat content claims are defined in 21 CFR 101.62.

The higher the fat content, the smoother is the mouth feel due to the lubricating effect of fat. Butter fat melts around 34-35°C which is just below our body temperature and so it melts on the tongue, adding to the smooth mouthfeel. Legal requirements in many countries mean that ice cream must contain a minimum of 10% milk fat.

Cream is the preferred source of milk fat but there may be difficulty in ready supply and storage of cream. The ice cream industry often uses anhydrous milk fat (AMF) as an inexpensive source of milkfat. AMF can be stored at room temperature but is prone to oxidative off flavours if not stored correctly.

Milk solids not fat (MSNF)

Milk solids not fat (MSNF) consists of milk proteins, lactose and minerals which contribute a pleasant milky flavour to ice cream and are more important to body and texture properties. The milk proteins include casein which has important whipping properties. Lactose is a disaccharide which has low levels of sweetness – around one sixth as sweet as sugar (sucrose). As the fat content is increased, the MSNF is decreased to maintain a proper balance of total solids. The proteins bind water, have an emulsifying effect on the fat and give viscosity and chewiness to the body. The MSNF also contains milk salts and lactose. MSNF normally make up 7-12% of the mix. If used in excessive amounts, the milk solids can cause a condensed milk or milk protein flavour. Excessive amounts of lactose can lead to sandiness in ice cream due to the large lactose crystals.

The use of MSNF tends to reduce the apparent richness of the fat and other delicate flavours. Consequently, a balance must be found between the proportion of flavouring agents, the MSNF portion, the sugar and the fat content which emphasises the importance of formulations.

Sources of MSNF include liquid skim milk concentrate, liquid skim milk and dried powders such as SMP, BMP, Whey Powder of WPC. The preferred source of MSNF for ice cream manufacture is fresh liquid skim milk concentrate (25-35% total solids) as this provides the required MSNF without potential off flavours (cooked or stale flavours) which can occur in dried powders.

Liquid skim milk, skim milk concentrates and skim milk powder are costly sources of MSNF, so some bulk ice cream manufacturers substitute with maltodextrins or use cheaper sources of MSNF such as whey powder or buttermilk powder to reduce ingredient costs.

Whey products

Commonly used whey products include demineralised whey powder (D-40), WPC (35-80% protein), and WPI (>90% protein). When used at the optimum level, whey products improve flavour, body and texture and provide better heat shock resistance. As whey products are cheap, they are often used as partial replacements for MSNF and stabilisers, allowing manufacturers to save on ingredient costs. Excessive use of whey products with high lactose contents can lead to lactose crystallisation and defects such as sandiness and off flavours such as cheesy and salty.

Commonly used whey products in ice cream include:

- Demineralised Whey (D40, D70)
- Whey Protein Concentrate (WPC 35% protein: WPC35)
- Whey Protein Concentrate (WPC 50 protein: WPC50)
- Whey Protein Concentrate (WPC 80% protein: WPC80)
- Whey Protein Isolate (90% protein: WPI)

Sugars

Sugars play a key role in any ice cream and have the following functions:

- provide sweetness
- contribute to the body and texture
- lower the freezing point of the product so that the product is soft and smooth at low temperatures.

Sugar levels of 14-16% are optimum and preferred by consumers. Higher sugar content may adversely affect the body of the finished product.

Sugar syrup is preferred by ice cream manufacturers because of its ease of storage and handling. Dried sugar is also suitable for use.

For improving the handling properties of the finished ice cream and to reduce costs, sugars other than sucrose are sometimes used. These sugars typically include glucose syrup and dextrose. The use of glucose syrup in the correct proportion may produce an ice cream which can be served directly from a deep freezer. In particular:

- glucose syrup is less sweet than sucrose and may be used to replace some of the sucrose to improve the firmness and mouthfeel of the product as well as to increase the shelf life;
- enzymic conversion of glucose to fructose, and lactose to glucose and galactose, increases the sweetening value of these sugars and opens new avenues for ice cream manufacturers interested in reducing costs.

Lactose (milk sugar) is not intentionally added to ice cream but is a component of the dairy ingredients such as milk, milk concentrates, SMP, WMP, and whey powders which are added to the ice cream mix. Some people are lactose intolerant, i.e. they do not produce enough lactase enzyme to digest the lactose. Instead, undigested lactose sits in the gut causing gas, bloating, stomach cramps, and diarrhoea. This can be overcome by adding the enzyme lactase, which can hydrolyse lactose to galactose and glucose.

Emulsifiers

The function of emulsifiers in ice cream is:

- to improve whipping properties of ice cream
- to achieve a smoother texture and consistency of ice cream
- to improve resistance to shrinkage
- to increase "stand up" time or slow the meltdown of ice cream
- to increase drying of the surface and minimise dripping of the product.

Emulsifiers contain a lipophilic portion which associates with the fat and a hydrophilic portion which associates with the water phase. The emulsifiers act at the air and water interface and help in the formation of small air cells. Factors such as fat content, degree of homogenisation, and MSNF : water ratio influence the concentration of emulsifier required. Several emulsifiers are used in ice cream including glycerine esters, sorbitol esters, other esters and mono diglycerides of fatty acids. Esters are usually added at 0.3 – 0.5% (w/w) of the ice cream mix.

Stabilisers

The functions of stabilisers are to absorb free moisture and to stop the formation of very large ice crystals. This makes the frozen product more resistant to heat shock or damage during handling. Other functions of stabilisers include:

- improve the incorporation of air in the ice cream mix
- improve body and texture of ice cream
- improve melt down properties of ice cream
- improve handling properties during storage of ice cream.

Two types of stabilisers are commonly used, the gelatine type, and those of vegetable origin such as guar gum, locust bean gum, carrageenan, xanthan gum, sodium alginate and sodium carboxymethylcellulose.

The action of stabilisers is attributed to their ability to bind water either as water of hydration or in a gel structure and to form a glass structure under freeze concentration.

Stabilisers are added @0.2 – 0.4% w/w of the ice cream mix.

Water and air

Water is an important constituent of ice cream although it is often overlooked as it is normally present in the other ingredients. If water is added directly to the mix, it must be clean, have no off-flavours, and be of good microbiological quality.

Water is the continuous phase in ice cream, all other ingredients being dispersed or dissolved in it.

Water is present as liquid, solid (ice) or a mixture of the two states. The air is dispersed through the water-fat emulsion which is composed of liquid water, ice crystals and solidified fat globules. The interface between the water and air is stabilised by a thin film of interfrozen material. The interfaces of the fat are covered by a layer of fat emulsifying agent.

The proportion of water present should be balanced against the total solids of the ice cream mix. If the proportion of water is high, large ice crystals form.

Air is another essential component of ice cream and is used to increase the volume of the final frozen product. This increase is called overrun. The quantity of air incorporated influences the final quality and cost, but must comply with legal requirements.

Colours and flavours

The colour of ice cream should match with flavour and intense enough to be easily recognised. Adults like paler colours while children prefer bright colours. The permitted colours, both natural and artificial, are listed in the Food Standards Code.

Flavours are available as natural, nature identical, and artificial, and are easily incorporated into the ice cream mix. The level of flavour addition should be intense enough to be easily recognised and delicately pleasing to the palate. Higher levels of flavours lead to unpleasant and 'chemical' notes. Where fruits are added, it is often necessary to add flavours to enhance the overall flavour.

A wide variety of flavours, fruits, nuts, confectionery, and pastry can be added to frozen products. The most popular flavours are vanilla, chocolate, and fruit flavours. Popular fruit flavours include strawberry, raspberry, blackberry, boysenberry, mixed berry, mango, passionfruit, and mixed tropical fruit.

Bulking agents

As consumers have become more health conscious, interest in reduced and low calorie foods is growing. In such products, it is necessary to substitute part of the sweetener with artificial sweetener and replace part of the fat with bulking agents.

Polydextrose is a bulking agent that is a water-soluble polymer of dextrose. This product is only partially metabolised by humans, hence yielding only four kilojoules (one calorie) per gram or one quarter of the amount derived from carbohydrate.

Maltodextrins (D-glucose) may be used to replace milkfat as they can provide solids or bulking and a suitable mouth feel.

Sorbitol is a sugar alcohol. While it has the same energy value as sucrose it does not contribute to blood sugar levels.

Table 2

	Low fat/Low calorie ice cream Recipe 1	**Low fat/Low calorie ice cream Recipe 2**
Milk fat	4%	4%
M.S.N.F.	12%	12%
Aspartame	0.1%	0.1%
Polydextrose	12%	6%
Maltodextrin	0%	6%
Stabiliser and Emulsifier	1%	1%
Total solids	29.1%	29.1%

12.3 Key steps in ice cream manufacture

Ice cream mix preparation is a multi-step process involving the blending and dispersing of several liquid and solid ingredients into a homogeneous fluid product that is pasteurised, homogenised and cooled (see Figures 2 & 3 below).

Mixing and blending

Mixing of the ingredients is carried out with strong agitation and heating. High speed stirrers (e.g. colloid mills and Tri blenders) produce a coarse emulsion (see Figure 4). This is important for providing a uniform feed to the homogeniser. Solids are always added to warmed liquids.

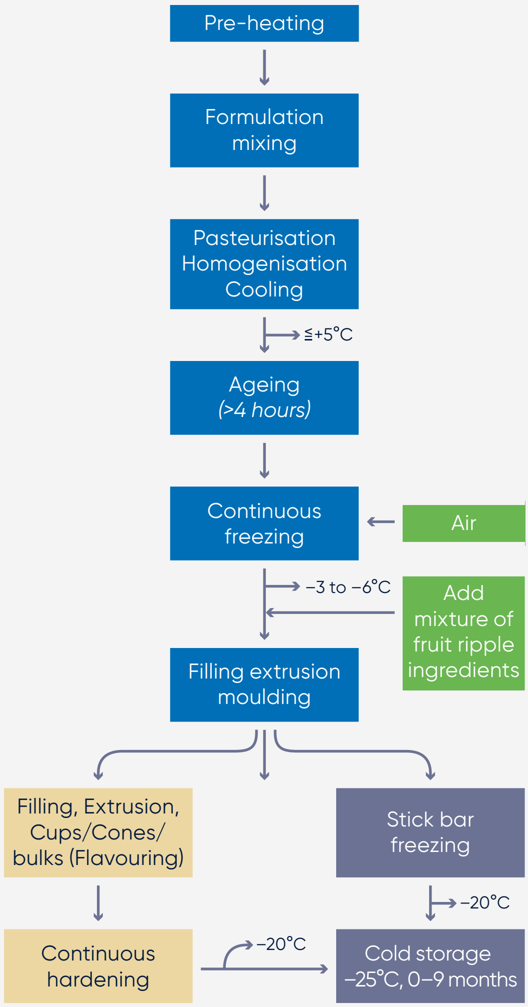
Mixing may be manual or automatic, batch or continuous, according to the scale and sophistication of the operation.

The liquid ingredients such as cream, milk, water and liquid sugar are first added to the mixing vat. These are agitated and heated to 45°C - 50°C before the dry ingredients are added.

1 Ice cream mix preparation module	8 Ageing tanks
2 Water heater	9 Discharge pumps
3 Mixing and processing tank	10 Continuous freezers
4 Homogeniser	11 Ripple pump
5 Plate heat exchanger	12 Roto-filler
6 Control panel	13 Can filler, manual
7 Cooling water unit	14 CIP unit

Dry ingredients such as sugar, milk powder, stabiliser, emulsifier and cocoa should be mixed first to avoid lumping and ensure even distribution. Often the stabiliser and emulsifier are preblended with the dry sugar prior to addition to the mix. The time and method for adding the stabiliser depends upon the type of stabiliser used. Most stabilisers are added to a relatively cold mix which is then heated so the stabilisers are completely dispersed and hydrated.

Figure 2 Ice cream Manufacture Process Flow



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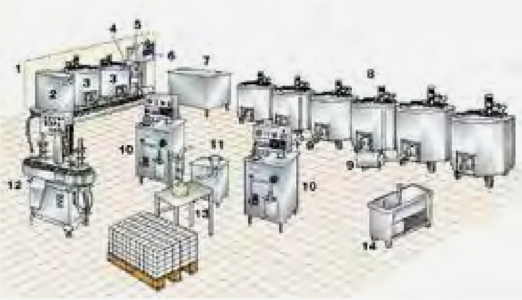
Adding gums at too high a temperature can lead to lumps of partially hydrated gums (called fisheyes) which are extremely difficult to break up and disperse. Stabiliser dispersion seldom presents a problem when the mix is batch pasteurised. When the mix is processed in the HTST pasteuriser, difficulty may be encountered with limited time for dispersion and hydration as the mix is passing through the plate heat exchanger.

Figure 3 Ice Cream Production Plant



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The short holding period at elevated temperatures may be insufficient for the stabiliser to disperse and hydrate, so it may be necessary to add more stabiliser to the mix.

Once blending is complete, the mix is filtered through a cloth or stainless steel mesh to remove large undissolved solid material.

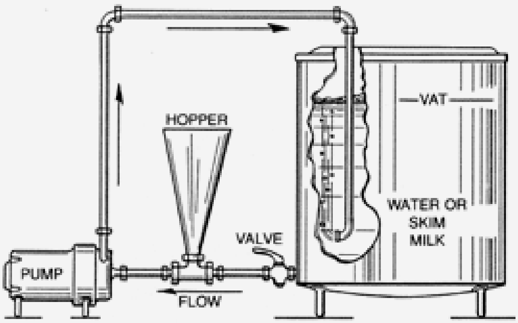
Heat treatment

Ice cream mix is pasteurised to destroy all pathogenic microorganisms, improve keeping quality, dissolve ingredients and improve flavour. Pasteurisation also causes an increase in water-holding capacity of the proteins, especially the whey proteins.

The temperature time combination required to pasteurise the mix is much higher than that for milk because higher fat, sugar and solids levels protect the microorganisms. Typical temperature time combinations used for batch pasteurisation is 65-68°C for 30 minutes and for HTST 79.5°C for 25 secs (see Figure 5).

If continuous HTST pasteurisation is followed by a vacuum deodorisation and a cooling step is used, the mix must be heated to at least 90°C. In all cases, regenerative cooling to below 5°C follows the pasteurisation step. Ice cream may also be Ultra Heat Treated (UHT) at 150°C for 0.2-6 seconds, sometimes for soft serve ice cream mix.

Figure 4 Mixing & Blending Systems



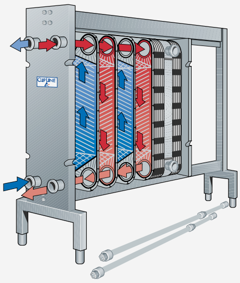
"Powder funnel" mixing system (Marshall, 1996)

Colloid mill

Tri blender

Figure 5 Heat treatment systems

DR Tech's Batch Pasteuriser



HTST pasteuriser

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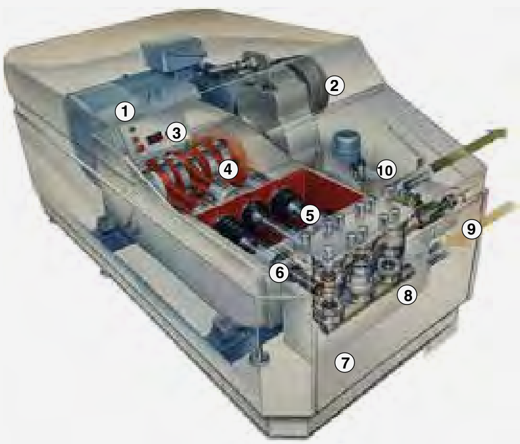
Homogenisation

The homogeniser reduces the size of the fat globules to less than 2 microns in diameter (see Figure 6). It is an essential step for milkfat or vegetable fat. New globules are formed with new membranes using milk proteins and emulsifiers. Two stage homogenisers are often used to prevent clumping of the new globules. Homogenisation ensures the fat globules do not destabilise during the freezing process. Unhomogenised mix does form the 3-dimensional network of fat globules and hence has poor meltdown characteristics. Homogenised fat allows distribution and agglomeration to provide a three-dimensional structure supporting the ice cream microstructure. This in turn results in smooth ice cream with increased richness and mouthfeel and increased resistance to melting.

For homogenisation to be effective the temperature must be high enough to ensure that all fat is liquid. Homogenisation is done at 63 - 74°C and pressures of 10.3-20.7 MPa (1500 to 3,000 psi) at the first stage and 3.4 MPa (500 psi) at the second stage.

Figure 6 Homogeniser



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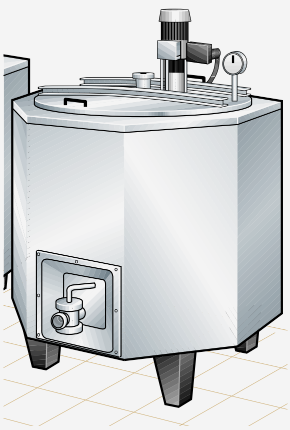
Ageing

After homogenisation, the mix is cooled in a plate heat exchanger and held at 2-4°C for 1-4 hours. Where gelatine is the stabiliser or for batch freezing, ageing can be up to 24 hrs. See Figure 7.

The changes in the ice cream mix during ageing include:

- Crystallisation of fat as the mix cools;
- Hydration of the proteins and the stabiliser, increasing mix viscosity.

Figure 7 Ageing Tank



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Freezing

During the freezing process, the liquid mix is converted into a partially frozen semi plastic mass. At the same time, air is incorporated to produce a smooth and solid foam. The quantity of air incorporated determines the quality and volume of the final product. The volume of air incorporated into the ice cream mix is referred to as overrun.

Two types of ice cream freezers are used:

- The batch type, which freezes a measured quantity of mix to a specific volume of ice cream. Once frozen the ice cream is removed and the process repeated, one batch at a time;

- The continuous type, which takes in a continuous flow of ice cream mix and discharges a continuous flow of partly frozen ice cream (see Figure 8).

Both types of freezers have a freezing cylinder where the cooling is performed by indirect cooling using direct expansion of a refrigerant. As heat is removed from the mix by the refrigerant, ice forms on the cylinder wall. A dasher with sharpened, metal blades attached, revolves within the cylinder, and scrapes the surface to continually remove the frozen film of ice cream. Many small ice crystals are rapidly formed, scraped off, and mixed with the unfrozen liquid. At the same time, the moving parts of the dasher whip the partially frozen mass to distribute the air as minute bubbles and produce the desired overrun.

Batch freezers are not commonly used in the large scale commercial situation due to their limited capacity and their high labour requirement. The ice cream cannot be frozen to below 5 to 6°C because it must be sufficiently fluid to flow from the freezer to empty it.

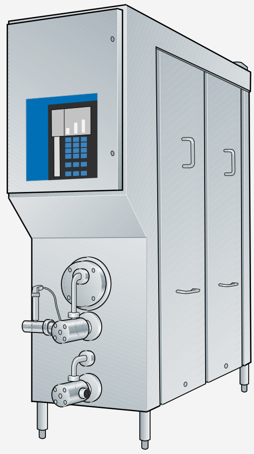
Continuous ice cream freezers have capacity of 100-10,000 litres per hour. This type of machine is used exclusively in commercial ice cream plants. If larger capacities are required, multiple units are installed and ice cream discharge from several machines is connected together to supply ice cream continuously to automatic or semi automatic packaging or filling machines.

Continuous freezers can be used for every flavour of ice cream, for ice milk, sorbets, sherbets, ices, or other frozen desserts. When the flavouring consists of particulate matter, such as nuts, whole fruit or candy pellets, the mix is run through the continuous freezer and then the ice cream is passed through a fruit feeder, which automatically feeds and mixes the flavour particles into the ice cream.

Ice cream is usually discharged from continuous freezers at 5 to 6°C but this can be changed to alter the consistency of the partially frozen ice cream to meet the needs for packaging.

The lower the discharge temperature, the stiffer the ice cream and the smoother the texture. However, lowering the discharge temperature reduces the capacity of the freezer because the product must be held longer in the freezer to lower the temperature.

Figure 8 Continuous Freezer



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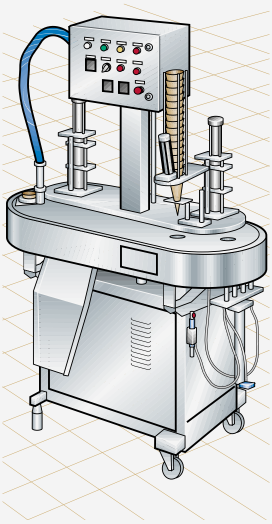
Packaging

The ice cream from the freezer is a semi solid mass with 50% of the water being frozen, which can be packaged into tubs, cups, cones or moulds. This can be done manually by an operator or automatically by machine (see Figure 9). In the latter case, the machine dispenses the tub and ice cream, adds the lid, and mechanically seals the container. The filled tub may then be accumulated with other tubs before being put in an outer container or shrink wrapped with plastic to help in subsequent handling. After this step, the product is moved to the hardening room sometimes via a hardening tunnel or blast freezer.

Figure 9 Cup and Cone Packing Machine



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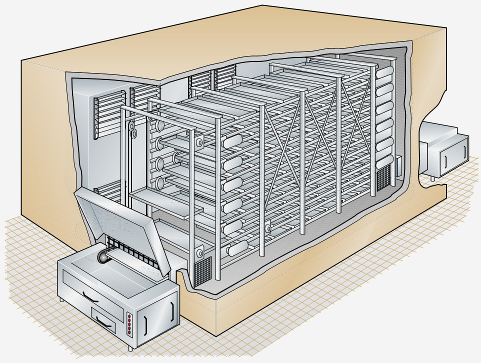
Fruit feeders and variegating devices

A fruit feeder is a device for incorporating solid foods, such as fruit and nuts, into the extruded ice cream. The semi frozen ice cream is piped to the fruit feeder and a mechanical device such as an auger, adds a known amount to the ice cream stream. Variegating devices are ripplers or swirlers that incorporate syrup and other liquids into the extruded ice cream.

Hardening

When the ice cream leaves the freezer, it is in a semi solid state and must be further frozen to become solid enough for storage and distribution. During freezing, approximately 50% of the water is frozen when the ice cream comes from the freezer at around 6°C. For a smooth texture in hardened ice cream, it is necessary to rapidly freeze about 80% of the remaining water so that the ice crystals formed will be small. Therefore, most hardening rooms are maintained at temperatures of 29°C to 35°C.

Figure 10 Ice Cream Hardening Tunnel



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Some larger plants use hardening tunnels which discharge the ice cream into a low temperature storage room (see Figure 10). Because of the various sized packages which need to be hardened, most tunnels are of the blast air type, operating at 35° to 40°C. One or two litre tubs are usually hardened in these blast tunnels in about one hour.

Some plants use contact plate hardening machines. Several vertical freezing plates are arranged side by side and spaced to the thickness of the ice cream packages. The plates are separated and the packages lowered in between the plates. The contact allows for rapid removal of the heat from the package to produce a smooth textured ice cream.

After hardening, ice cream must be kept at low constant temperatures to maintain its smooth texture. Any increase in temperature may allow the partial thawing of the product. Upon refreezing, ice crystals become bigger and cause defects especially with mouthfeel of the product.

12.4 Advanced technology and machines in ice-cream manufacture

Erich Windhab, a food engineering professor at the Federal Institute of Technology in Zurich, has developed a new process which churns and pumps the ice cream out of an extruder at lower temperatures and with smaller ice crystals and smaller air cells than the traditional process. After conventional freezing (to –7 °C) and whipping, the ice cream passes through a low temperature twin-screw extruder from which it exits at around –15°C. The ice cream can then be moulded and packaged. There is no need for traditional hardening. Finished products have smaller ice crystals and smaller air cells, retain more of their shape upon melting, and have "creaminess" similar to ice creams with high fat levels.

"High pressure homogenisation technologies are now being utilised in the ice cream industry," says Bruce Tharp, Ph.D., owner of Tharp's Food Technology, Wayne, PA. "Homogenisation at four to five times the normal pressure (12,000 rather than the usual 2,500 PSI) can decrease the size and increase the number of fat globules providing better distribution of the available milkfat in a fat-reduced product."
– Klahorst, S (1997).

"A process innovation in ice cream aeration is an added step, called 'preaeration,' in which air cells are incorporated into the mix before the freezing step, rather than the conventional method of aerating and freezing simultaneously. By separating the processes into a sequence, a smaller, more stable air-cell structure can be achieved." – Klahorst, S (1997).

12.5 Frequently asked questions (FAQ)

A Ice cream ingredients

1. How does the chemical composition affect the quality of ice cream?

Table 1

Chemical Composition	Standard Ice Cream	Premium Ice Cream	Super Premium Ice Cream
Milkfat	10–11%	12–14%	15–20%
M.S.N.F.	10–11%	7–8%	6–8%
Sweeteners	14–17%	13–17%	16–17%
Stabiliser/ Emulsifier	0.3%	0.3%	0.2%
Total solids	35–37%	40–41%	42–44%

Milkfat contributes to the rich creamy flavour and smooth texture of ice cream. As the milkfat melts in the mouth, it has a lubricating effect which gives ice cream the smooth mouthfeel. Lower levels of fat result in defects such as lack of a creamy flavour and in weak body and texture. In low fat products, bulking agents and additional stabilisers are used to overcome these defects. Higher levels of milkfat give a greasy mouthfeel. In high milkfat products, additional sweeteners are added to balance the higher fat content.

Milk solids not-fat (MSNF) provide ice cream with a "milky" flavour and give the final product a desirable body and texture. Lower levels of MSNF lead to a weak and watery texture. Higher levels of MSNF lead to defects such as condensed milk flavour and a heavy soggy body. It can also result in large lactose crystals giving ice cream an unpleasant gritty and sandy texture.

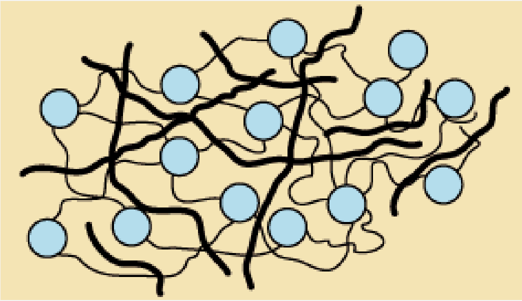
The purposes of sweeteners such as sucrose, glucose syrup, dextrose and lactose are:

- to provide sweetness, help to balance the fat
- to improve body and texture by adding total solids
- to function as flavour enhancers
- to control freezing point depression and improve ability to scoop the ice cream.

Lower levels of sweeteners can result in an unbalanced product - too greasy, imbalanced flavour level and a weak and watery texture. Higher levels of sweeteners can result in excessive depression of freezing point resulting in a soft and sticky ice cream. High levels of glucose syrup result in off flavours such as metallic.

Stabilisers such as hydrocolloids bind free water, preventing ice crystal growth which results in a smoother ice cream. The water binding effect of stabilisers can affect the ice cream's mix viscosity, texture, body, mouthfeel, melting resistance, tolerance to heat shock and flavour release. Stabilisers are typically added at a rate of 0.2-0.5 % (this rate may vary depending on the product type and equipment used). Too little stabiliser can result in a final product with low tolerance to heat shock, resulting in a coarse icy product. Too much stabiliser can result in a final product with excessive viscosity, giving it an excessively chewing, gummy mouthfeel.

Figure 1 Hydrocolloids binding up free water



The purpose of emulsifiers is:

- to improve whipping properties
- to provide a smoother texture and consistency
- to increase resistance to shrinkage
- to slow meltdown of ice cream
- to increase drying of the surface which reduces dripping of the product.

Emulsifiers are added at a rate of 0.1-0.2 %. A lower level of emulsifier can result in large air cells, resulting in a fluffy or crumbly product, which melts rapidly. Higher levels can result in slow meltdown, excessive dryness and non-refreshing mouthfeel.

2. What are the advantages of using WPC in ice cream?

Whey protein concentrate (WPC) helps with improved ice cream flavour, body, texture, and gives better resistance to heat shock. As WPC is relatively cheap compared to milk proteins and stabilisers, manufacturers can also reduce ingredient costs.

According to Dr Steven Young, (1999), other advantages of WPC include:

- Increased emulsification and whippability, improving fat distribution and air incorporation, resulting in a well-structured ice cream
- Increased viscosity and water binding, resulting in reduced free water and smaller ice crystals, giving a smoother ice cream
- Can be used as a bulking agent e.g. replacing milkfat.

Excessive WPC can result in large lactose crystals, sandiness and on and off flavours.

3. What are the factors to consider if using milk powders in ice cream?

Dried milk powders are a relatively cheap source of milk solids and give ice cream a milky flavour and the correct body and texture.

Whole milk powders, SMP, buttermilk powders and whey powders are used in ice cream. Care needs to be taken with WMP they are high in fat which can undergo oxidation giving the ice cream a stale flat flavour.

Low, medium, and high heat SMP can be used in ice cream. A potential advantage of high heat SMP is that it has a higher proportion of denatured whey proteins which tend to absorb more water, resulting in better body and texture.

A potential disadvantage of high heat SMP is it can yield cooked flavours. Care needs to be taken with WMP as the fat can get oxidised during storage and result in a stale, flat flavour.

Buttermilk powders containing lecithin can improve the whippability of mixes and provide a rich buttery and creamy flavour. Again, if the fat is oxidised, it can lead to stale flavour.

Whey powders are often used in ice cream as they are a cheap source of milk solids and improve ice cream body and texture due to the presence of denatured whey proteins. A potential disadvantage of whey powders is their high lactose content. Excessive lactose in ice cream can result in large lactose crystals giving ice cream an unpleasant gritty and sandy texture.

Table 2

Typical Composition	% Water	% Fat	% Protein	% Lactose
Skim Milk	91	0	3.6	5.1
SMP	4	0	37	52
Condensed Milk	27–28	0	10–11	15
Whey Powder	4	0	13	73
WPC 35	4	2–3	30-35	53–56

When using dried milk powders and other dry ingredients, care needs to be taken to prevent lumps forming during mixing and blending. Lumps can be avoided by pre-mixing dry ingredients such as milk powders with dry sugar, by sifting the dry ingredients, and by the slow addition of dry ingredients to the warm liquid ingredients at 30°C–50°C. High shear mixers such as tri blenders and the use of powder funnels can minimise lumping.

4. What is the function of stabilisers in ice-cream?

A common defect in ice cream is the presence of large ice crystals, resulting in a coarse icy product. These large ice crystals are due to "heat shock" which means ice cream is subjected to temperature fluctuations during production, storage, and distribution. For example, during storage if ice cream melts due to a power breakdown and then freezes again, the ice crystals become larger. The addition of stabilisers to ice cream mix helps to minimise the effects of heat shock.

Stabilisers (hydrocolloids) bind up free water, preventing ice crystal growth which results in a smooth ice cream. The water binding effect of stabilisers can influence the ice cream's viscosity, texture, body, mouthfeel, melting resistance, tolerance to heat shock and flavour release (see table below). Commonly used ice cream stabilisers include sodium alginate, locust bean gum (LGB), carboxy methyl cellulose (CMC), carrageenan, guar gum and xanthan gums. These stabilisers bind water either by gelation, increasing viscosity, hydrogen bonding, and creating cross linking between molecules. Guar gum is popular with ice cream manufacturers because of its ability to produce a good texture at a low cost. Locust bean gum is a highly effective stabiliser but is expensive. Often stabilisers are used in combination such as with locust bean gum and carrageenan. Carrageenan is often used as a secondary stabiliser to reduce water leakage of the mix which can be induced by other stabiliser gums.

5. How do carbohydrates affect the mouthfeel and texture of ice cream?

Typically ice cream will contain the following carbohydrates: lactose, sucrose and glucose syrup.

Table 3 Characteristics of commonly used ice cream stabilisers

Properties	Alginate E401	LBG E410	CMC E466	Carrageenan E407	Guar E412	Xanthan E415
Mix viscosity	Medium	Medium	High	Low	High	Medium
Texture and Body	Short Brittle	Medium Smooth	Long Smooth	Short Brittle	Chewy Smooth	Chewy Smooth
Mouthfeel	Cold	Warm	Creamy & warm	Cold	Medium	Medium
Melting resistance	Good	Very good	Fair	Fair	Good	Fair
Heat shock	Fair	Very good	Good	Fair	Bad	Good
Flavour release	Good	Very good	Fair	Good	Bad	Good
Synergy	No	Yes	No	Yes	Yes	Yes

Source: Danisco

Hydrocolloids can thicken, stabilise, or gel aqueous systems.

Figure 2 Thickening effect – Very few interactions

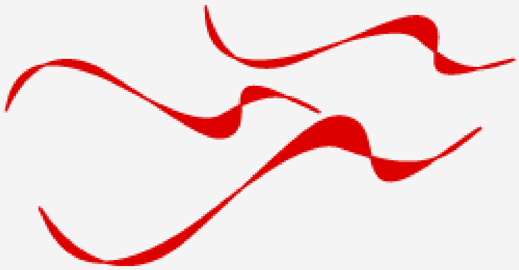
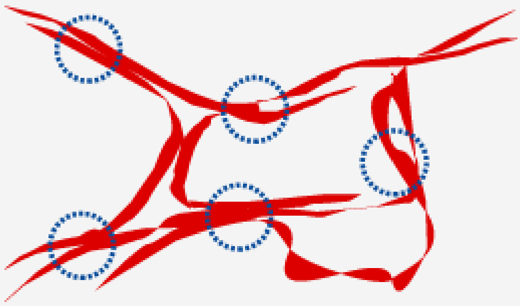


Figure 3 Gelation – Many junctions zones



Lactose is a component of dairy ingredients such as milk, milk concentrates, and milk powders. Excessive lactose in ice cream can result in large lactose crystals causing an unpleasant gritty and sandy texture. Care needs to be taken when selecting ingredients for the ice cream mix to ensure that the formulation does not contain excessive amounts of lactose.

Sucrose is primarily added to impart a sweet, clean flavour, and to improve the texture by lowering the freezing point depression of the ice cream.

Glucose syrup can function as a bulking agent giving ice cream a firm and chewy body and improve texture by lowering the freezing point depression of the ice cream.

Glucose syrup's effect on ice cream body and texture will vary depending on the dextrose equivalents' (DE) content. Glucose syrups with a high DE can cause excessive freezing point depression resulting in a soft and sticky ice cream. Glucose syrups with a low DE can cause metallic type off flavours which can be avoided if such sugars are less than 30% of the total sweeteners. An advantage of glucose syrups with a low DE is that they can be used as a bulking agent, increasing total solids without causing excessive sweetness.

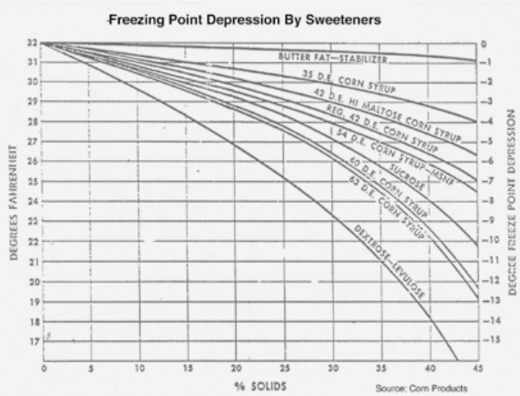
The addition of sugars depresses the freezing point of the ice cream mix. Now, if the freezing point is not sufficiently depressed, excessive water will be converted to ice during freezing resulting in a hard ice cream which is difficult to scoop. On the other hand, if the freezing point is depressed too far, there will be less water converted to ice during freezing resulting in a soft and sticky ice cream. So the level and type of sugars have a critical role to play in the softness or hardness of ice cream.

Table 4

Sugar	Relative sweetness	Freezing pt depression
*Sucrose	1.00	1.0
Glucose (Dextrose)	0.75	1.9
Fructose	1.73	1.9
Invert	1.27	1.9
HFCS (42% Fructose)	1.00	1.8
Glucose syrup (68 DE)	0.72	1.28
Glucose syrup (62 DE)	0.68	1.15
Glucose syrup (52 DE)	0.58	0.99
Glucose syrup (42 DE)	0.48	0.8
Glucose syrup (32 DE)	0.4	0.61
Glucose syrup (25 DE)	0.28	0.48
Glucose syrup (20 DE)	0.23	0.38
Maltose	0.32	1.0
Lactose	0.16	1.0

**Sucrose is used as a reference point and given a value of 1.*

Figure 4 Freezing point depression by sweeteners



B Ice cream processing

1. What is the mechanism of ageing and how can it be controlled properly?

Ageing involves rapidly cooling the pasteurised ice cream mix and holding it at 2-4°C for 1-4 hours and much longer - 24 hrs - if gelatine is used as a stabiliser. The ageing process improves the whippability of the ice cream mix resulting in an improved body and texture.

During ageing, the following changes are taking place:

- Fat crystallisation: The melting point of milk fat is 34-35°C and at 2-4°C, the bulk of the milk fat is crystallised. This is a slow process and the fat crystals must have sufficient time to form and stabilise. Furthermore, when the crystals are formed, latent heat of crystallisation is released which raises the temperature of the mix. So additional cooling is needed to maintain the temperature at 2-4°C
- Hydration of Milk Proteins and Stabiliser: As discussed earlier, both milk proteins and stabilisers bind water. Again, this is a slow process and they need time for the emulsion to be stabilised before the ice cream mix is churned and frozen. During ageing, as the proteins and stabiliser bind the water, the viscosity of the mix increases.

Ageing helps to ensure the ice cream develops the correct structure in terms of air cell and fat globule size.

If ice cream mix is not correctly aged, the product is likely to develop body and texture defects during freezing. Uncrystallised fat will not coalesce correctly during churning, resulting in a weak structure. Mix viscosity is important for air incorporation.

Ageing tank

C Ice cream freezing

1. How is overrun of ice cream measured?

Overrun measures the increase in volume or weight of the ice cream mix due to air incorporation and is expressed as a percentage. It can be calculated as follows:

$$\% \text{ Overrun} = \frac{\text{Weight of 1 litre of mix} - \text{Weight of 1 litre of ice cream}}{\text{Weight of 1 litre of ice cream}} \times 100$$

This formula uses weight per litre, but it is equally correct to use the weight of any other known volume, so long as the same measure is used throughout the calculations. It is also possible to base overrun calculations on volume.

$$\% \text{ Overrun} = \frac{\text{Volume of ice cream made} - \text{Volume of ice cream mix}}{\text{Volume of ice cream mix}} \times 100$$

Example

In a standard ice cream made without any fruit additions, the weight of 1 litre of ice cream mix is 1.1kg. One litre of ice cream extruded from the freezers weighs 0.5kg. (using the weight overrun formula)

$$\% \text{ Overrun} = \frac{1.1\text{kg} - 0.5\text{kg}}{0.5\text{kg}} \times 100$$

$$= \frac{0.6\text{kg}}{0.5\text{kg}} \times 100$$

$$\% \text{ Overrun} = 120\% \quad \times 100$$

Tables are available so that overrun can be calculated by simply weighing a known amount of product. It is important to determine the density of the mix, for each type of mix, and use the appropriate table for each product. It is also important to consider the effect on overrun of fruit additions as these add weight without air being incorporated, and so the product appears to have a lower overrun than actual.

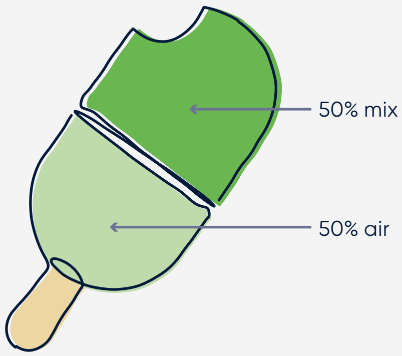
The amount of air that can be incorporated into a mix is limited by several factors. An overrun that is too high results in an ice cream which becomes fluffy and weak bodied. If insufficient air is included, the ice cream will have a soggy and heavy body. The maximum overrun that can be obtained will be limited by the machine capacity, the ingredients used in the mix formulation and the processing steps used during manufacture.

The air used should be excellent quality and may need to be filtered. The supply pressure should be uniform for the air to be evenly incorporated into the mix. Although research workers have investigated the use of other gases such as nitrogen and carbon dioxide, air is still the most common.

2. What factors influence overrun of ice-cream and how can these be properly controlled?

Overrun refers to the amount of air incorporated into the ice cream mix during freezing. Standard ice creams have 100% overrun (or more) i.e. the finished product contains 50% mix and 50% air. Premium ice creams have lower overrun levels of 30% to 60% to give a heavier body and richer flavour.

100% Overrun



During freezing, air is incorporated into the ice cream mix. Initially the air cells are quite large but are then reduced in size as freezing progresses. In batch freezers air is incorporated by the folding and whipping action of the dashers or scrapers. Each batch freezer is designed to give a particular overrun which is 30 -60%, and it is difficult to adjust the overrun. Continuous freezers can be easily adjusted to give a desired overrun of 20 - 100% or even higher. In continuous freezers, air is injected as small bubbles under pressure, overrun can be controlled by adding more or less air, by controlling the mix pump speed and by controlling the back pressure. Overrun control will vary according to the freezer design. In the Tetra Pak Hoyer KF N models, air incorporation is controlled manually by regulating air inlet pressure from a constant cylinder pressure maintained by the outlet pump. In other freezers overrun control is completely automated using PLCs. Manufacturers need to consult with equipment designers to determine optimal overrun control.

Tetra Pak Hoyer KF N model

D Ice cream storage and distribution

1. What is heat shock?

Heat shock refers to the damage to ice cream microstructure caused by ice thawing and refreezing due to increase and decrease in the temperature of ice cream. As temperature rises, the small ice crystals melt forming water. Next when temperature decreases, the water freezes but this time into large ice crystals. If this temperature fluctuation is repeated, the number of smaller ice crystals is reduced and number of large ice crystals is increased. This results in coarse and icy texture. Another consequence of repeated heat shock is loss of overrun as shrinkage of ice cream.

The addition of stabilisers helps to minimise the effects of heat shock by controlling the movement of free water.

2. Why does ice cream develop off flavours during storage and how can this be prevented?

Oxidised off-flavours: Ice cream can develop oxidised flavours during storage if its packaging does not protect it from exposure to UV light. Ice cream is constantly exposed to the UV lights in distribution warehouses and in retail cabinets. Oxidation of milkfat results in unpleasant cardboardy, fishy or metallic flavours. These off-flavours in ice cream can be minimised by using opaque packaging, incorporating antioxidants and UV-light blockers into packaging films, and reducing exposure of ice cream to UV light and catalysts such as copper and iron.

Absorbed flavours: Ice cream can easily absorb volatile flavours from the environment. Incorrectly stored ice cream can absorb off flavours from the surrounding environment such as paint, detergent, onion and other volatile flavours. Ice cream should be stored away from such products.

3. What is the shelf life of ice cream?

The shelf life of ice cream is 1–2 years if stored under ideal conditions. Ice cream needs to be stored at <-18C. Excessive temperature fluctuations and repeated thaw and refreeze cycles will reduce the shelf life and impact quality due to the development of large ice crystals and possibly volume shrinkage.

E Defects in quality and prevention

1. What are typical defects in ice cream products?

Texture

There are four major texture defects:

- **Coarse or icy**
  This is due to large ice crystals in the ice cream. Common causes include high levels of water in the mix, slow freezing, insufficient freezing and heat shock.
- **Snowy or flaky**
  This defect is due to too much air in the ice cream making it light. Possible causes include, low total solids, ice cream withdrawn from the freezer before the correct temperature is reached and high overrun.
- **Sandiness**
  This is caused by the presence of very hard crystals of lactose which are the result of high MSNF particularly lactose in the mix. Heat shock, incorrect stabiliser, and the use of higher proportions of whey powder also cause this defect.

- **Buttery**
  This defect is signified by the presence of hard particles of fat. It is caused by poor homogenisation of the mix, lack of emulsifier and prolonged agitation during freezing. Very low overrun with high fat (~15%) may also cause this defect.

Body

In ice cream, body refers to general appearance, mouthfeel and chewiness.

- **Heavy/soggy** refers to heavy, wet, colder than usual ice cream. The defect is caused by low overrun, insufficient air.
- **Light and fluffy** refers to snowy and flaky body cause by very high overrun and too much air.
- **Gummy** defect causes the product to not easily melt in the mouth. This is due to higher levels of stabiliser added to the mix.
- **Crumbly** defect refers to ice cream which breaks into pieces instead of holding together. Probable causes include low levels of stabiliser, sugar or total solids or high overrun.
- **Weak and watery** defect results in ice cream melting quickly. Major causes include insufficient total solids in the mix and insufficient freezing in the freezer.
- **Meltdown**. When ice cream melts, it should produce a creamy homogeneous liquid like the mix it was made from. If air incorporation is not uniform, large air pockets form resulting in meltdown during consumption. Major cause is low levels of stabiliser and improper air incorporation. An extension of this defect is the appearance of a green liquid during melting. Occasionally, an interaction between certain stabilisers and milk proteins causes precipitation of the protein resulting in a 'curds and green liquid whey' effect like that which occurs during cheesemaking.
- **Shrinkage** is a defect specific to ice cream and occurs when the ice cream loses volume and shape during storage. This is due to loss of overrun or escaping of air from the ice cream. This defect can be minimised by using correct levels of total solids in the mix, rigid packaging, and minimising heat shock and mechanical shock during storage and handling.

2. Troubleshooting common processing challenges in ice cream

Overrun control: Ice cream may have a lower than required overrun due to:

- High mix viscosity, which makes it difficult to incorporate air into the mix;
- Poor homogenisation which affects the fat globule size, reducing the ability of milk fat to correctly coalesce to merge with air cells;
- Incorrect air supply such as blocked air inlet valve or incorrect pressure;
- Blunt freezer blades which reduce the efficiency of air incorporation or whipping;
- Over churning during freezing which forces air out of the ice cream.

Ice cream too soft from the freezer: This may be due to:

- High temperature of the mix after ageing and entering the ice cream churn;
- Higher speed of pumps feeding mix to the ice cream churn;
- Inefficient freezing due to blunt blades of the churn;
- Incorrect formulation of the ice cream mix such as incorrect sugar level impacting the freezing point depression or low levels of stabiliser and emulsifier.

Ice cream buttering: small globules of butter can form in the ice cream churn due to:

- High temperature of the mix from ageing tank entering the ice cream churn requiring excessive churning in the freezer.

Incorrect formulation of the ice cream mix, such as:

- Poor homogenisation resulting in large size of the fat globule, reducing the ability of milk fats to correctly coalesce;
- Blunt blades in the ice cream churn requiring excessive churning during freezing;
- Low temperature of ice cream drawn from the churn.

Cooked flavour in Ice cream: this defect is caused by:

- Inferior quality milk powders which have been excessively heat treated;
- Excessive heat treatment of ice cream mix during mixing and pasteurisation.

Icy texture: This defect in body is signified by large ice crystals and caused by:

- Incorrect formulation of the ice cream mix such as low levels of total solids and stabiliser;
- Slow freezing of the ice cream mix;
- Heat shock and temperature fluctuations during handling and storage.

12.6 Glossary

Ageing

Process of cooling the pasteurised mix to 0-5°C to allow fats to crystallise and proteins and stabilisers to fully hydrate.

Bulking agent

Bulking agents are additives used to increase the bulk of a food, often without affecting its nutritional value.

Emulsifier

A substance which stabilises an emulsion (such as oil in water emulsion in ice cream).

Food acids

Acids from foods such as lactic acid and citric acid which are sometimes added to ice cream to give a "sharper" flavour.

Freezing point

The temperature at which the ice cream mix begins to freeze; standard ice cream freezes at –2.8°C to -2.2°C.

Freezing point depression

The ability of a sugar to lower the freezing point of an ice cream mix; the lower the molecular weight, the greater the ability of a molecule to depress the freezing point for any given concentration.

Hardening

Process of cooling ice cream to -30°C to -40°C to allow 80% of the water to freeze.

Heat shock

Refers to the deterioration in product quality due to repeated thaw and refreeze cycles that occur during product storage and distribution.

Overrun

A measure of how much air is in ice cream

$$\frac{\text{volume of ice cream} - \text{volume of mix}}{\text{volume of mix}} \times 100 = \%\ \text{Overrun}$$

Milk solids not fat (MSNF)

Consist of milk proteins, lactose and minerals.

Stabilisers

Thickeners and gelling agents which bind free water in ice cream resulting in smoother texture (avoid large ice crystals).

12.7 References

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