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SPECIAL ISSUE ON

DAIRY PROCESSING

#COVER STORY

Aspects of Dairy Processing

MARKETING AND PROJECTED GROWTH

The Milk Value Chain in India

NOURISHING A NATION

Exploring the Potential of Yak Milk

COMPOSITION, NUTRITION PROPERTIES, APPLICATIONS

Shelf-Life Prediction of Cheese





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From the Editor-in-Chief's Desk

Welcome to this Special Issue of AgriTech Today Magazine. As we embrace the rapid advancements in the agricultural industry, it is my pleasure to shed light on dairy processing. As Editor-in-chief, I am thrilled to present to you a comprehensive exploration of the trends, innovations, and challenges within this dynamic sector.

Dairy processing plays a crucial role in bridging the gap between the abundant raw milk production and the diverse dairy products that enrich our lives. The dairy processing sector has undergone remarkable transformations in recent years, driven by technology, consumer preferences, and sustainability concerns.

As Editor-in-chief, I understand the significance of keeping you, our esteemed readers, well-informed and up-to-date with the latest industry developments.

Lastly, I would like to extend my heartfelt gratitude to our contributors, researchers and the entire AgriTech Today team for their dedication and tireless efforts in bringing you this edition. We hope you find this magazine enlightening and empowering as we together witness the remarkable journey of dairy processing.

Thank you for your continued support, and we look forward to embarking on this exciting dairy processing exploration with you.

Sincerely,

Editor-in-chief

***"We never know
the value of the
moment until it
becomes a
memory"***

Guest Editor's Note



Dairy technology deals with the processing of milk and its products. Dairy technology study involves processing, storage, packaging, distribution, and transportation of dairy products by implying the science of bacteriology, nutrition, and biochemistry. If we talk about recent advancements, the industry has benefited many generations whether it is a dairy farmer or a retail seller. Many technologies are available for the enhancement of milk processing starting from the milking to the consumer hand. There could be one more revolution in India. The industry needs to target convenience and facilities. Dairy technology, microbiologist, chemist, and engineers work together to make the complete system default free. The real-time testing of milk, mechanized collection of milk, automated dairy plant operation, and so on. With the click of a button, one can now track data/ information at the farmer level in the milk pool. In addition, technology is making critical inroads to modernize and revolutionize the dairy sector's other major spheres.

Though the industry is very well stabilizing, its proper application is needed to assist the largely unorganized Indian dairy industry to structure itself better. Most of the pain points, or challenges experienced in handling a perishable commodity such as milk, can only be solved by using technology-based solutions. This special issue has many commendable articles including the value chain of milk, the potential of yak milk, shelf-life prediction, application of non-thermal technologies, packaging, etc.

I Congratulate the entire editorial and reviewers' team of Agritech Today Magazine for the wonderful special issue on dairy processing.

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Message

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The subject of dairy processing deals with the various stages involved in handling milk and its products, encompassing processing, storage, packaging, distribution, and transportation. It incorporates principles from dairy engineering, technology, microbiology, bacteriology, nutrition, and biochemistry, among others. Recent advancements in this field have brought significant benefits to both dairy farmers and retail sellers. A plethora of technologies has emerged, improving milk processing from milking to the end consumer. India's dairy industry appears to be on the cusp of another revolution, with a strong emphasis on convenience and upgraded facilities.

Collaboration among dairy technologists, microbiologists, chemists, and engineers is driving the creation of a seamless and efficient system. Key developments, such as real-time milk testing, mechanized milk collection, and automated dairy plant operations, are gaining prominence. Access to data and information at the farmer level has been streamlined, and ongoing technological innovations continue to modernize and revolutionize different aspects of the dairy sector.

One of the most significant challenges in dealing with perishable commodities like milk is being addressed through technology-based solutions. These advancements are crucial to improving the industry's efficiency and reducing wastage. The special issue of Agritech Today Magazine focusing on dairy processing includes insightful articles covering diverse topics such as the milk value chain, shelf-life prediction, non-thermal technologies, yak milk potential, and packaging. Congratulations to the entire editorial and reviewers' team for their valuable and relevant contributions to this commendable edition.

Chitranayak

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Aspects of Dairy Processing: Marketing and Projected Growth

Ashita Arora and Preeti Birwal

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In India dairy industries plays a very important role in both foreign and domestic market by bridging the gap between Indian farmers and consumers. These industries plays a very important role in employment generation in all registered factory sector covering approximately of 12.0% which caters 1.93 million people. Industries which are unregistered in this sector generates employment opportunities to 5.1 Million workers according to 73rd national sample survey organisation. In India's dairy processing industry hits its record and it expected contribution to output will be \$535 billion by 2025-26.

Growth of dairy processing

The contribution of the dairy processing sector in Gross Value Added (GVA) has been rising rapidly that is Rs.1.34 lakh crore in year 2014-15 and Rs 2.37 lakh crore in year 2020-21 at a Compound Annual Growth Rate (CAGR) of 9.97%. To attract Foreign Direct Investment (FDI) in the dairy sector, Government of India adopted a favourable investment policy in which 100% FDI is allowed under the automatic route for manufacturing of food products' and 100% FDI is allowed under the approval route for retailing business which includes e-business, regarding dairy products which is being manufactured or produced in India. Ministry of dairy processing industries has built a Nivesh Bandhu Portal as well as an Investment Facilitation cell with Invest India in order to promote further investment. Total inward of FDI in the dairy sector since the last five years terminating 2021-22 is USD 3.54 billion. Under Pradhan Mantri Krishi Sinchayee

Yojana, 52 operation green Parks, 376 projects of cold chain, 79 Clusters of agro-processing, 489 proposals given for Creation and Expansion of dairy Processing & Preservation Capacities, 61 Creation of Backward and Forward Linkages Projects, 41 mega food parks, 183 Food Testing Laboratories projects has been given approval.

According to the Annual Survey of Industries (ASI) 2018-19, being released by Ministry of Statistics and Programme Implementation, in which 40579 food processing units are registered. The ASI does not give any segregated details of Multi-National Companies (MNCs). Estimation of 8.44% revenue will be generated in dairy market sales of e-commerce sector in financial year 2023-24 which showing increasing demand of processed food items. Volume of this market is estimated to grow by 3,150 billion kg till 2028. The dairy sector is estimated to grow by 4.9% in 2024. The volume in the dairy sector per person on an average is expected to be 338kg in 2023.

Reasons for the good prospects of dairy industry

- Urbanization has been increased in last decades and this is giving boost to dairy industries in India.
- Population of India is now working in all the sectors with 24*7 timings which promotes the production of convenient and ready-to-eat products.
- With continuous improvement in education system the living standards also have improved in the country which is

resulting in demand for good and innovative dairy products

- With opening of various supermarkets consumers could be able to choose, evaluate which directly and indirectly boosting all the sectors of food industry right from the storage to packaging industry.

The opportunities in dairy enterprise could be classified in segment like production of milk commodities i.e. farming, processing, production plants, retailer, supplier and the manufacturer of the machinery and feed for the animals. In short one has to understand following point for starting an enterprise are like raw food is having short shelf-life, the varying production volume season wise. Different production and processing systems around the India. Risk of spoilage during transportation. There is great potential in dairy business. Industry is a flexible, where innovations with number experiments in probiotic, fermented, fortified, ready

to cook, ready to serve, ready to eat, ready to pack, dried, retort, UHT products could be generated and could become a key for selling the products. One should see the potential, should understand the chemistry, microbiology and processing of all milk commodities. Wonders could be happened in dairy products industries.

Conclusion

In India dairy Processing Industry sector is showing increasing trends with reference to exports, consumption, production, development or in growth prospects. The processing of food in proper and hygienic manner is a necessity. Also, with great change in life-life, new product development, processing, production of convenient food is high on demand. The government has further granted it a highest priority as a number of financial reliefs and incentives in order to promote propagation and further value addition in agricultural production and further on increase a market share in global market.

* * * * *

An Insight into Preparation of Goat Milk-Based Cheese Using Various Technological Interventions

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Milk and dairy products from animals like cows, buffalo, goats, sheep, donkeys, camel etc are well-known among different age groups as they provide calories (energy), proteins, fat, carbohydrates, vitamins, and minerals as these components are important for our wellbeing. Apart from cow milk, an upward growth in demand and consumption of goat milk and goat milk-based products has been observed. In 2020, goat milk production across the globe was around 20.6 million tonnes whereas in India it was around 5.8 million tonnes. In India, goat milk contributes approximately 3% to the total milk production (FAOSTATS, 2020). Goats have been integral to the livestock sector in developing countries. Goats are one of the oldest domesticated small ruminants, dated 8000 B.C. in Mesopotamia (Middle East) for their milk, meat, skin, hair and fibre products to meet the needs of people in rural areas. Goats are well-known for their easy adaptability towards climatic changes, diverse management practices and geological in arid and semi-arid environments (Hatziminaoglou & Boyazoglu, 2004; Park and Haenlein, 2010). Consequently, goat milk and goat milk-based products have played a significant role socioeconomic development of under-developed and developing countries.

Goat milk is different from cow or human milk for its higher buffering capacity (higher β -casein), easy digestibility (average fat globule size of cow milk fat $\sim 4.5 \mu\text{m}$ whereas goat milk fat globule size $\sim 2.5 \mu\text{m}$), distinct alkalinity and better therapeutic properties. The easy digestibility of goat

milk is mainly attributed to the lower amount of α_1 casein protein and small fat globule size (Haenlein, 2004; Park, 2007; Yangilar, 2013). The detailed composition of goat milk in comparison with cow milk has been depicted in Table 1.

Apart from providing nutrition, goat milk has nutraceutical properties which include the bioactive peptides released upon hydrolysis having potent immunostimulatory, anticarcinogenic, antithrombic, ACE inhibitory, antioxidant, and antimicrobial activities. Hence, with an increase in awareness about the health benefits of goat milk, especially lower allergenicity, several attempts have been made to convert goat milk into goat milk products such as cheese, yoghurt, ice-creams, etc with better bio-functional properties. Among different, goat milk products, cheese second most widely produced and consumed after liquid milk consumption.

In 2017, the global cheese production was around 565,075 tonnes where the majority of produce was soft or unripened cheese varieties (Chevre, Blue cheese, White mold, Feta, Robiola de Capra etc. The low preference towards goat milk-based products was mainly attributed to its 'goaty flavour' which can be overcome to a certain extent by a fermentation process using lactic acid bacteria (LAB). The hard or semi-hard varieties are manufactured in lower quantities due to various known challenges that are faced during its production such as lack of availability of milk, perishable nature of cheese due to high moisture content, lower fat content, difficulty for rennet coagulation, limited start growth, soft-

curd formation, lack of firmness in cheese texture, lower cheese yield and increased hardness during storage etc.

Table 1. Proximate compositional comparison between cow milk and goat milk

Constituent	Goat Milk	Cow Milk
Fat (%)	3.8	3.6
Protein(%)	3.5	3.3
Lactose(%)	4.1	4.6
Ash(%)	0.8	0.7
Solid not Fat(%)	12.1	12.2
Total Solids(%)	12.2	12.3
Calories (Cal)	70	69
Acid value	0.47	0.48
Iodine value	30.44	27.09
Polenske value	1.80	7.06
Saponification value	228.6	232.3
Reichert Meissl value	29.16	24.02
Refractive index	1.450	1.451
Unsaponifiable matter (milk fat)	0.41%	0.41%
Titrateable Acidity (% Lactic acid)	0.11	0.13
pH	6.5-6.9	6.4-6.6
Viscosity (cP)	~1.5	~2.0
Freezing Point (°C)	-0.580	-0.547
Calcium (mg)	134	122
P (mg)	121	1119
Se (µg)	1.33	0.96
Vitamin A (IU)	185	126
Vitamin D (IU)	2.3	2
Total n-6	1.78	2.83
Total n-3	0.44	0.56
Saturated Fatty Acid	68.79	68.72
Mono Unsaturated Fatty Acid	24.48	27.40
Poly Unsaturated Fatty Acid	3.70	4.05
ω-6/ωs-3	5.00	6.01

Hence, advances in techno-functional interventions can be used to overcome the stated challenges such as membrane processing (ultrafiltration, microfiltration), enzymatic modification, non-thermal and thermal processing like high-pressure processing, ultrasound, pulsed electric field etc (Lai *et al.*, 2020).

Recently, technological and biotechnological alternatives to promote ripening, and improve yield and flavour have been explored, which include the application of ultrafiltration, rennet substitutes/alternatives, the addition of exogenous enzymes such as transglutaminase, non-starter lactic culture, high-pressure processing etc (Khattab *et al.*, 2019). Technological development has given an opportunity to standardize milk and improve the yield and textural properties intended for cheese making at the industrial level for certain types of cheese.

Among many membranes processing, ultrafiltration (UF) processing is the most widely used membrane technology for cheese making. UF is a pressure-driven process using a semi-permeable membrane to separate macromolecules or colloids from liquids. Based on molecular weight cut-off (1-200K Da), UF permeates lactose, vitamins, soluble minerals, and non-protein nitrogen and retains fat, colloidal salts, and total protein. This resulted in the application of UF in the production of different cheeses where it has increased yield and improved the textural characteristics (Mistry and Maubois, 2017). The level of UF concentration plays a key role, the concentration can be up to 2-5 folds. The 2 folds concentration has been shown to improve cheese yield in cheeses like mozzarella, cheddar and cottage mainly due to the retention of whey proteins (Guinee *et al.*, 2006; Lipnizki, 2010; Kethireddipalli & Hill, 2015). A reduced-fat Cheddar cheese was prepared

using exopolysaccharide-producing LAB, which resulted in cheese with improved texture, viscoelastic behaviour, melt characteristics, water-holding capacity, and reducing certain cheese defects (Agrawal and Hassan, 2007) and in cow milk Cheddar cheese, UF resulted in increasing total solids concentration, retention of whey proteins and calcium, yield ($\uparrow$ 6-8 %) (Bintis and Papademas, 2018). When the concentration was rising above 2 folds up to 5 folds, it also resulted in similar outcomes however this medium concentration was of not much commercial interest (Kelly *et al.*, 2008; Lipnizki, 2010). Further increase in concentration above 6 and 7 folds, which is pre-cheese where whey proteins were completely trapped and only heat-treated cheese milk was acceptable to manufacture semi-hard and hard varieties (Banks, 2007; Fox *et al.*, 2017). Hence, based on studies, it can be concluded that lower concentration retentate up to 3 folds was acceptable in terms of texture and yield only when heat treatment was given e.g., feta cheese (Hannon *et al.*, 2009). Hence, as a thumb rule, using UF to manufacture cheese needs a detailed analysis of physico-chemical properties to interpret the cheese quality and consumer acceptance and give the expected profitability.

Further, using enzymes such as microbial transglutaminase is a protein-glutamine cross-linker, known as Amine γ -glutamyl transferase (EC: 2.3.2.13) (mTG) which is most commonly found in nearly all prokaryotes and eukaryotes cells. This enzyme catalyses the transfer of the acyl group between the γ -carboxamide group of peptide-bound glutamine residues and several primary amines, including the ϵ -amino group of protein lysine residues resulting in the formation of inter- and intramolecular isopeptide bonds within and between proteins (Zhu *et al.*, 1995; Kuraishi *et al.*, 2001; Jaros *et*

al., 2006). As this enzyme forms cross-links in and within the protein structure, it enhances the functional properties in products such as viscosity, water-holding capacity, texture and rheological characteristics without compromising the nutritional quality. Cohort studies have focused on the application of transglutaminase (TG) to improve the functional properties in cow milk-based products and only limited data is available regarding its application in goat milk-based products (Lauber *et al.*, 2000; Bönisch *et al.*, 2007). However, few studies related to the application of TG in goat milk certain cheeses like halloumi type, goat milk whey cheese, fresh goat cheese, and cheddar have been shown to improve the yield and texture of cheese.

In addition, mTG can be added at different stages of cheese production such as (1) TG could be added to previously pasteurization milk, and thus, the enzyme TG will be inactivated when the coagulant is added; (2) after the curd cutting; and (3) simultaneously with the coagulant. The addition of TG at the above-stated steps has its advantages and disadvantages but the key benefit of adding TG is that it retains whey protein due to cross-linking with curd protein by enhancing nutritive and textural attributes in goat milk Cheddar cheese. However, this depends on various factors like pH, temperature, concentration of enzyme, pretreatment given to milk, presence of any other enzymes, cofactors etc. The main advantage of using TG is that it is calcium-independent, works well at a wide range of pH (5-7) and temperature range between 40-50 °C but loses activity at 70 °C at pH 6 and it has obtained GRAS status from FDA since 1998 (Ando *et al.*, 1989; Yokoyama *et al.*, 2004; Jaros *et al.*, 2006). An experiment conducted by Hu and co-workers (2013) to produce low-fat Cheddar cheese (LFT) from cow milk (0.12 % fat) and outcomes of the study were that

when transglutaminase was added yield increased from around 6.5 (LFT) to ~8.7 (TG added LFT) and compositional low-fat TG added Cheddar cheese has higher protein and fat recovery (%) than the LFT i.e ~64.2 & ~71.7, and ~83.4 & ~71.2, resp. The textural-rheological properties of TG-addedLFC showed that with an increase in time hardness and cohesiveness were increasing and springiness was decreasing slowly but in the case of LFC, Hardness was decreasing, and springiness & cohesiveness were increasing.

Hence, using UF and mTG intervention singly or in combination, a goat milk-based cheese can be developed with better retention of whey proteins, improved yield along rheological properties and better textural characteristics. However, research in this direction of manufacturing hard-variety cheese resulted in limited success. Hence, further investigations are required to develop hard variety cheese using novel approaches singly or in combination with treatments and investigating the effect of these interventions on cheese during ripening and respective metabolite profiling to identify various biomarkers using targeted or untargeted approaches.

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Revolutionizing Dairy Products: Exploring New Value-Adding Techniques

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Dairy products have long been a staple in our diets, providing us with essential nutrients and adding flavor to numerous dishes. However, with evolving consumer preferences and a growing emphasis on innovation, the dairy industry has embraced new techniques to add value to their products. By incorporating novel approaches and technologies, dairy producers have been able to create exciting new offerings that cater to changing consumer demands and enhance the overall consumer experience. The dairy industry is embracing these new value-adding techniques to cater to an increasingly discerning consumer base that seeks health, sustainability, convenience, and delightful experiences. Through these innovations, dairy producers are not only reinventing their products but also redefining the possibilities of what dairy can offer.

In this era of heightened awareness about health, wellness, sustainability, and convenience, the dairy industry is at the forefront of revolutionizing its products. From fortified functional foods to innovative flavors, from customization to sustainable practices, the industry is exploring a multitude of avenues to enhance the value and appeal of dairy products. This article delves into the exciting realm of value-adding techniques in the dairy industry.

1. Functional Dairy Products: One of the significant advancements in value-adding techniques within the dairy industry is the development of functional dairy products. These products are fortified with

additional nutrients, vitamins, minerals, probiotics, or other bioactive compounds, providing added health benefits beyond their basic nutritional value. Examples include yogurts enriched with probiotics for improved gut health, milk fortified with omega-3 fatty acids for heart health, or dairy-based beverages enhanced with vitamins and antioxidants. Functional dairy products not only appeal to health-conscious consumers but also offer a competitive advantage in a market driven by wellness trends.

2. Innovative Flavors and Ingredients: To cater to diverse consumer preferences and create a unique product portfolio, dairy producers are experimenting with a wide range of flavors and ingredients. Traditional dairy products like cheese, yogurt, and ice cream are being infused with unconventional flavors such as exotic fruits, spices, herbs, or even savory combinations. Additionally, there is a growing interest in plant-based dairy alternatives, where ingredients like almond milk, coconut milk, or oat milk are used as the base for creating non-dairy versions of traditional dairy products. These innovative flavors and ingredients not only expand the product range but also capture the attention of adventurous consumers seeking new taste experiences.

3. Sustainable and Ethical Practices: As environmental concerns continue to rise, consumers are actively seeking products that align with their values. Dairy producers are responding to this demand by adopting sustainable and ethical practices throughout their production processes.

This includes implementing environmentally friendly packaging, reducing greenhouse gas emissions, optimizing water usage, and prioritizing animal welfare. By highlighting their commitment to sustainability, dairy companies can differentiate themselves in the market and attract conscious consumers who are willing to pay a premium for products produced with integrity.

4. Convenience and Snackability: In today's fast-paced world, convenience plays a crucial role in consumers' purchasing decisions. Dairy producers are capitalizing on this trend by introducing convenient and snackable dairy products. Single-serving yogurts, pre-portioned cheese snacks, and grab-and-go dairy-based beverages are gaining popularity, providing consumers with on-the-go options that fit their busy lifestyles. Moreover, dairy companies are investing in packaging innovations that enhance product portability, extend shelf life, and ensure optimal freshness, all contributing to improved convenience for consumers.

5. Customization and Personalization: To cater to individual preferences and create a more personalized consumer experience, dairy producers are exploring customization options. Through technological advancements, consumers can now tailor dairy products to their specific dietary needs, taste preferences, or nutritional goals. This can range from personalized yogurt flavors and toppings to customized lactose-free or low-fat milk options. By offering customization, dairy companies foster a stronger connection with their consumers, ultimately building brand loyalty and customer satisfaction.

Need of value-addition

- **Evolving Consumer Preferences:** Consumer tastes and preferences are constantly changing. As consumers become more health-conscious

and adventurous in their food choices, they seek innovative and unique dairy products. Value-adding techniques allow dairy producers to adapt to these evolving preferences and offer products that cater to specific dietary needs, lifestyles, and flavor profiles.

- **Sustainable and Ethical Practices:** Sustainability and ethical considerations are gaining prominence among consumers. Value-adding techniques enable dairy producers to incorporate sustainable practices, reduce environmental impact, and prioritize animal welfare. By aligning their products with these values, producers can attract eco-conscious consumers and address their concerns about the ecological and ethical aspects of dairy production.
- **Convenience and Snacking Culture:** Busy lifestyles and on-the-go consumption patterns have fueled the need for convenient and snackable dairy products. Value-adding techniques allow producers to create single-serving portions, portable packaging, and ready-to-consume options that fit the fast-paced modern lifestyle. These convenient offerings cater to consumers seeking quick and hassle-free dairy products.
- **Market Differentiation:** In a highly competitive market, dairy producers need to differentiate themselves from their competitors. By employing value-adding techniques, they can introduce novel products that stand out and capture consumer attention. These techniques enable producers to create a diverse product portfolio, expanding their market reach and attracting new customer segments.
- **Health and Wellness Trends:** With an increased focus on health and wellness, consumers are

actively seeking dairy products that offer functional benefits beyond basic nutrition. Value-adding techniques allow dairy producers to fortify their products with additional nutrients, probiotics, antioxidants, or other bioactive compounds, meeting the growing demand for functional foods that promote well-being.

- **Personalization and Customization:** Consumers appreciate products that cater to their individual needs and preferences. Value-adding techniques provide opportunities for customization and personalization, allowing dairy producers to offer tailored dairy products. This customization can range from flavors and ingredients to nutritional profiles, catering to specific dietary restrictions or preferences.

By embracing new dairy product value-adding techniques, dairy producers can stay ahead of market trends, meet consumer demands, differentiate their offerings, and create a diverse product range that appeals to a wide range of consumers. These techniques are essential for remaining competitive in the dynamic dairy industry and driving growth and innovation within the sector.

Methods of value addition

The dairy industry employs various methods of value addition to enhance the quality, functionality, and appeal of dairy products. Here are some common methods:

Fortification: Fortification involves adding additional nutrients or bioactive compounds to dairy products to enhance their nutritional value. For example, vitamins, minerals, probiotics, omega-3 fatty acids, or plant sterols can be added to milk,

yogurt, or cheese to provide specific health benefits and meet consumer demands for functional foods.

Flavoring and Ingredient Innovation: Dairy producers experiment with innovative flavors and ingredients to create unique taste experiences and cater to diverse consumer preferences. This can involve incorporating fruits, spices, herbs, or savory combinations into dairy products to expand flavor options. Additionally, the use of alternative dairy bases, such as almond milk, coconut milk, or oat milk, allows for the creation of non-dairy versions of traditional dairy products.

Product Diversification: Dairy companies diversify their product portfolios by introducing new dairy-based products or variations of existing products. This includes developing new types of cheeses, yogurts, ice creams, or beverages with distinct characteristics and flavors. Product diversification helps capture different consumer segments and offers a wider range of options in the market.

Packaging Innovation: Packaging plays a crucial role in product presentation, shelf-life extension, and convenience. Dairy producers employ innovative packaging techniques such as portion-controlled packaging, resealable containers, or single-serve options for on-the-go consumption. Advanced packaging technologies can also help maintain product freshness, extend shelf life, and enhance sustainability by using eco-friendly materials.

Customization and Personalization: Customization allows consumers to tailor dairy products to their specific preferences or dietary needs. Dairy companies offer options such as flavored yogurts with various mix-ins or toppings, lactose-free milk alternatives, or low-fat versions of products. Customization can also involve offering

personalized packaging or portion sizes to meet individual consumer requirements.

Sustainable and Ethical Practices: Value addition in the dairy industry extends beyond the product itself to include sustainable and ethical practices throughout the production process. This includes implementing eco-friendly production methods, reducing carbon emissions, optimizing water usage, prioritizing animal welfare, and adopting transparent supply chains. Communicating these sustainable practices can enhance the value perception of dairy products among environmentally conscious consumers.

Convenience-focused Products: The dairy industry recognizes the demand for convenient and snackable options. Dairy producers create ready-to-consume products like single-serving yogurts, pre-portioned cheese snacks, or dairy-based beverages for on-the-go consumption. These products cater to consumers' busy lifestyles and offer convenience without compromising on taste or quality.

Process Innovations: Advancements in processing techniques can improve product quality, texture, and functionality. Examples include ultra-high temperature (UHT) processing for extended shelf life, homogenization for consistent texture, or novel processing methods for creating innovative dairy-based ingredients or extracts.

By implementing these value addition methods, dairy producers can create unique, nutritious, and appealing products that meet consumer expectations, differentiate themselves in the market, and drive growth within the industry.

Future aspects of Value-Adding Techniques:

Plant-based Alternatives: One prominent aspect of revolutionizing dairy products is the rise of plant-based alternatives. With the increasing demand for

non-dairy options driven by health, environmental, and ethical considerations, manufacturers are investing in the development of plant-based milk, cheese, yogurt, and ice cream. This trend opens up new possibilities for dairy alternatives that cater to various dietary preferences and requirements.

Advanced Processing Technologies: Advancements in processing technologies are revolutionizing dairy product production. Techniques such as microfiltration, nanofiltration, and ultra-high temperature (UHT) processing are being employed to enhance the safety, quality, and shelf life of dairy products. These technologies enable the preservation of nutritional value, reduction of spoilage, and development of innovative textures and flavors, thereby expanding the range of dairy products available to consumers.

Functional and Nutritional Enhancements: Dairy products are being fortified with functional ingredients and nutrients to enhance their health benefits. Probiotics, prebiotics, omega-3 fatty acids, and vitamins are being incorporated into dairy formulations, promoting digestive health, immunity, and overall well-being. Furthermore, the development of dairy products with reduced fat, sugar, and lactose content caters to the growing demand for healthier options without compromising taste and texture.

Smart Packaging and Traceability: In the future, smart packaging technologies will play a significant role in revolutionizing dairy products. Intelligent packaging systems equipped with sensors and indicators will ensure product freshness, monitor temperature fluctuations, and provide real-time information to consumers. Additionally, blockchain technology is being explored to enhance traceability and transparency in the dairy supply chain, allowing

consumers to make informed choices and verify product authenticity.

Customization and Personalization: The future of dairy products lies in customization and personalization. With advances in data analytics and consumer insights, manufacturers can tailor dairy products to individual preferences and dietary needs. Customized flavors, textures, nutritional profiles, and portion sizes will cater to diverse consumer demands, creating a more personalized and enjoyable dairy experience.

Conclusion

The dairy industry is experiencing a wave of innovation through new value-adding

techniques. Plant-based alternatives, advanced processing technologies, functional enhancements, smart packaging, and customization are key areas revolutionizing dairy products. These developments not only meet evolving consumer demands but also offer opportunities for sustainable and innovative dairy solutions. By embracing these techniques, the dairy industry is poised to remain relevant and thrive in an ever-evolving marketplace, providing consumers with a wide array of delightful and tailored dairy products to enjoy.

Value-Added Dairy Products	Description
Probiotic Yogurt	Yogurt fortified with beneficial probiotic cultures for gut health.
Omega-3 Enriched Milk	Milk enhanced with omega-3 fatty acids for heart health.
Flavored Greek Yogurt	Greek yogurt infused with a variety of fruit flavors or natural extracts for a taste twist.
Artisanal Cheese Varieties	Unique and specialty cheeses with distinctive flavors, textures, and aging techniques.
Lactose-Free Milk	Milk processed to remove lactose, suitable for individuals with lactose intolerance.
Plant-Based Ice Cream	Dairy-free ice cream alternatives made from plant-based ingredients like almond, coconut, or soy milk.
Protein-Enhanced Milk	Milk with added protein content, appealing to fitness enthusiasts or individuals seeking protein-rich diets.
Functional Dairy Beverages	Beverages like kefir or probiotic drinks fortified with additional health-boosting ingredients.
Low-Fat Cheese	Cheeses with reduced fat content, catering to health-conscious consumers.
Customized Yogurt Cups	Yogurt cups with customizable toppings, allowing consumers to personalize their snack experience.

Table showcases a range numerous value-added dairy products available in the market that highlight different value-adding techniques such as fortification, flavor innovation, customization, and catering to specific dietary preferences or needs.

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Ready to Reconstitute Kheer/Payasam Mixes

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Payasam and *kheer* forms an integral part of cultural ethos of south and north India, respectively and is an inseparable part of almost every ritualistic ceremony including weddings and religious functions. *Kheer* is a traditional Indian delicacy prepared from the partial dehydration of whole milk from the mixture of whole milk, sugar and cereal grain (rice being the most common), in an open pan over a direct fire (De *et al.*, 1976). The word *Kheer* is derived from the Sanskrit word '*ksheer*' for milk and '*kshirika*' for any dish prepared with milk. It has different names in different parts of India; such as in north western India, it's called as '*kheer*', in south, its named as '*payasam*', in eastern parts of India, its known as '*payas*', in northern region as '*phirni*', '*kheech* in Mewar region and '*payesh*' in Bengal (Aneja *et al.*, 2002).

History of consumption of kheer in Indian

Cereal based dairy desserts have a much-extended history of consumption and are an important segment of milk-based desserts relished by Indian population. Preparation of Indian traditional milk-based puddings include, mixture of cereals, millets, pulses and fruits with milk. Milk based puddings such as *kheer* and *payasam* are mentioned in the great Indian epics, Ramayana and Mahabharata of Hindu mythology. *Payasam* made with vermicelli, termed as *Sarvaligeya payasam* and sago or *sabudana payasam* referred as bead like *payasam* have been quoted in Kannada literature of the 13th century. *Phirni* is known to be introduced to India from Middle East and Persia by Moghuls during 14th century (Kumar *et al.*, 2015).

Classification of Indian kheer types

The milk-based puddings are classified based on the raw material used, process involved in preparation and additives used. The raw material used in preparation plays a major role in the classification of milk-based puddings. The classification of milk-based puddings with respect to the characteristic ingredients used and region-specific terminology is given in Table 1. *Kheer* is majorly prepared using rice whereas, *payasam* is prepared using rice, pulses, millets, fruits and seeds. *Payasam* is similar in preparation to that of *kheer*. The extent of concentration of milk is more in *kheer* as compared to that of *payasam*. However, *dalia* is prepared using wheat and milk (Jha *et al.*, 2012).

Table 1: Classification of Indian traditional milk-based puddings

Type	Characteristic ingredients used	Regional names of the puddings
Cereal based	Rice	<i>Kheer, Palada payasam, Paal payasam, Phirni, Avalakki payasam, Dodol, Chawak ki kheer, Gil-e-Firdaus, Halu kheeru,</i>
	Wheat	<i>Dalia, Vermicelli payasam, Godhi payasam</i>
Pulse based	Green gram Bengal gram	<i>Hesaru bele payasam Kadale bele payasam</i>
Millets based	Finger millet Barnyard millet	<i>Ragi payasam Navane payasam</i>
Seeds based	Poppy seeds	<i>Gasagase payasam</i>
	Bamboo seeds	<i>Bamboo seeds payasam</i>

Tuber based	Tapioca	<i>Sabakki payasam,</i> <i>sabudana payasam,</i> <i>Kaddu ki kheer</i>
Fruits based	Jackfruit	<i>Halasina payasam</i>
	Mango	<i>Mavinahannu payasam</i>
	Apple	<i>Apple payasam</i>
	Bottle guard	<i>Bottle gourd payasam</i>
	Carrot	<i>Carrot payasam</i>
	Pumpkin	<i>Pumpkin payasam</i>

(Unnikrishnan *et al.*, 2000; Sinha, 2017; Jha *et al.*, 2012)

Need for convenience mixes of payasam/kheer

Conventional *payasam/kheer* preparation methods are tedious and time consuming, as product preparation often involves slow cooking of the granules in milk and sugar, until desired product properties are achieved like colour, taste and consistency (Unnikrishnan *et al.*, 2000). Technical solutions in the form of dry mixes in this product category meet the specific consumer demand for convenient products with improved quality and shelf life. In addition, standardization of mechanical unit for process technology provides an opportunity to upgrade process technology for large-scale production in a controlled hygienic environment. Due to rapid urbanization and changing lifestyles, convenience foods are becoming increasingly popular. Convenience mixes for many traditional products have been developed because of their convenience in terms of easy preparation, improved quality, storage and ready availability. Various manufacturing processes are used for instant dry mixes such as dry blending method, dry blending method cum spray coating method, extrusion cooking method, spray drying method, tray drying method and dry crystallization method. Further, recently, consumers are becoming more inclined towards the convenience, ready to eat and ready to reconstitute instant dry mixes.

Approaches for development of convenience mixes of payasam/kheer

The different methods used for preparation of convenience mixes of kheer are listed in Table 2. Instant mixes have been formulated using dry-blending technique, which is one of the most acceptable methodologies offering industry friendly solutions. The technique involves mixing of solid or powdered ingredients in optimized proportions which reduce labour, increase convenience and provide easy adaptation. The instant *kheer* mix based on pearl millet was optimized by Bunkar *et al.*, (2014). In this process, pre-treated *pearl* millet grains were prepared from hulled and washed grains, which were dried under the sun for 1 hour, followed by autoclaving (121°C/15 min) to soften the grains. The satisfactory quality instant RTR blend was formulated by dry blending pre-treated pearl millet seeds (20g), powdered sugar (15g) and dairy whitener (30g). Kashyap *et al.*, (2018) developed the technology to produce a dried *kheer* mix based on kodo millet. The dry blending approach has certain limitations such as the final reconstituted product is not very similar to traditionally prepared *kheer/payasams*.

There is another approach of dry crystallization, which helps in developing instant convenient dry mixes. The resulting reconstituted product prepared by this method is very similar to the traditionally prepared *kheer/payasam* (Deshmukh *et al.*, 2020). This process is commonly used to create sugar-rich milk-based instant mixes. It involves using thermal energy to mix the ingredients and concentrate them into a uniform mass, followed by cooling, seeding and crystallization by cooling. The desired particulates are obtained by this process, which retains their shape even after reconstitution, thereby resulting in an acceptable quality

kheer/payasam (Deshmukh *et al.*, 2020). Some of the *payasams* developed by the dry crystallization approach include *palada payasam* dry mix (Unnikrishnan *et al.*, 2003), *gasagasa payasam* dry mix (Nath *et al.*, 2004), *avalakki payasam* dry mix (Nath *et al.*, 2008) and *pal payasam* dry mix (Aisha, 2019).

Conclusion

Milk based pudding are being currently prepared in domestic level with regional and seasonal importance. The nutritional properties of the milk-based puddings lead commercial manufactures to explore technologies for the production on a commercial scale with improved shelf life. Combination of characteristic ingredients in the milk-based puddings, enhances the nutritional profile of the product with enhanced bioavailability and digestibility. The method of manufacture employed, enhances the sensory and rheological properties of the milk-based puddings. There is a huge scope for development of convenience mixes for millet based *payasam* or *kheer*. Among the various approaches used for preparing instant mixes, dry crystallization is expected to yield good quality product in terms of better appearance, reconstitution and sensory attributes. The process also extends shelf life of dry mix with a possibility of mechanization and scale up.

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Table 2: Methods of kheer mix preparation

S. No	Method of preparation	Important features
1	Dry blending	Ingredients are dried and then mixed together to obtain the ready to reconstitute mixes. This technology would make the product much cheaper, less laborious, convenient, and easily available at all places.
2	Drying - cum-instantization technique	In this approach, first the raw material is cooked or semi-cooked and later it is dried to attain an instant powder formulation. It involves the use of novel techniques such as roller drying, tray drying (both atmospheric and under vacuum), spray drying, dry-blending and drying-cum-instantization processes to convert dairy products to shelf stable dry mixes.
3	Dry-crystallization process	Dry crystallization is a concentration process that has recently been reported to produce quick dry mixes of dairy confections such as <i>payasam/kheer</i> . The process involves the concentration of the solid food ingredient along with milk and sugar to the supersaturation stage and then cooling, so that the sugar crystallizes over the surface of the solid food ingredient. The importance of using this method stems from its better reconstitution, easier manufacturing, mechanized manufacturing and higher shelf life.

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Bactofugation: Revolutionizing Dairy Production for Safer and Fresher Milk

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In recent years, the dairy industry has witnessed remarkable advancements aimed at ensuring the production of safer and higher-quality dairy products. One such innovation is bactofugation, a breakthrough technology that has revolutionized milk processing. Bactofugation involves the removal of bacteria from raw milk, resulting in longer shelf life and enhanced product safety. This article delves into the principles behind bactofugation, its advantages over traditional methods, and its impact on the dairy industry.

Bactofugation is a separation process that focuses on eliminating bacteria from milk. The technique employs centrifugal force to separate microorganisms and suspended particles from the milk, leaving behind a significantly reduced bacterial load. The process works by subjecting the raw milk to high centrifugal forces, causing the denser bacteria and impurities to migrate towards the outer edge of the separator. The purified milk is then extracted from the inner chamber, resulting in a product with substantially reduced bacterial count.

Bactofuge: Specialized Equipment

A bactofuge, a specialized piece of equipment used in the dairy industry, plays a vital role in reducing the microbial load of milk, particularly when the milk is of poor quality and intended for cheese production. This high-speed centrifuge is specifically designed to remove bacterial spores from milk, operating at elevated temperatures. During the bactofugation process, the milk is subjected to high centrifugal forces, typically around $9,000 \times g$, for a

very short duration of less than 1 second, while maintaining temperatures between 55 to 60°C (Ribeiro-Júnior et al., 2020). This rapid and controlled centrifugation causes the denser bacterial spores and impurities to migrate towards the outer edge of the separator, forming a concentrated bactofugate. The bactofugate is then removed, effectively eliminating a significant portion of bacterial spores from the milk.

Advantages of Bactofugation

Bactofugation offers several advantages over conventional milk processing methods. Firstly, it enhances the shelf life of dairy products. By removing bacteria, bactofugation significantly reduces the microbial load in milk, preventing spoilage and extending the product's freshness (Griep-Moyer et al., 2022). This allows for longer storage times, reducing wastage and ensuring a more consistent supply of safe dairy products to consumers. Secondly, bactofugation improves the safety of dairy products. Bacteria, such as harmful pathogens, are effectively removed during the process, minimizing the risk of foodborne illnesses associated with consuming contaminated milk. This is particularly crucial for vulnerable populations, such as children, pregnant women, and the elderly. Furthermore, bactofugation preserves the natural flavor and nutritional value of milk. Unlike traditional heat-based methods, which can lead to undesirable flavor changes and nutrient loss, bactofugation gently separates bacteria without altering the milk's composition. The result is a

product that retains its original taste and nutritional content, providing consumers with a more wholesome dairy experience.

Bactofugation has had a profound impact on the dairy industry, transforming the way milk is processed and marketed. Firstly, it has enabled the production of extended shelf-life milk (ESL), a product that remains fresh for an extended period without the need for preservatives. ESL milk has gained popularity among consumers due to its convenience and enhanced safety, driving market growth and diversification.

Moreover, bactofugation has facilitated the production of specialized dairy products, such as lactose-free milk and dairy-based beverages. By removing bacteria and impurities, bactofugation helps eliminate lactose-digesting bacteria, allowing lactose-intolerant individuals to enjoy dairy products without discomfort. This has expanded the target market for dairy companies, opening up new avenues for product innovation and consumer engagement.

Additionally, bactofugation has contributed to improved food safety regulations and standards in the dairy industry. With its ability to remove harmful bacteria effectively, bactofugation aligns with the industry's commitment to ensuring the production of safe and wholesome dairy products. It has prompted stricter quality control measures and regulatory requirements, promoting consumer confidence and fostering industry-wide best practices.

The Bactotherm Process

The Bactotherm process incorporates additional steps to enhance the effectiveness of bactofugation and offers various advantages in the dairy industry. To begin, clarified and standardized milk is subjected to heat treatment in a plate heat

exchanger, reaching temperatures between 60-75°C. This preheated milk is then directed to the bactofuge, where the centrifugal acceleration is intensified to 10,000g. The denser slurry of bacteria, known as bactofugate, is continuously expelled through specialized nozzles due to its higher specific weight. Typically constituting approximately 3% of the original feed volume, the bactofugate stream achieves a significant reduction in total bacterial count, typically around 50-60%.

To ensure complete inactivation of spores, the bactofugate stream undergoes ultra-high temperature (UHT) processing, typically utilizing temperatures of 130-140°C for 3-4 seconds. This time-temperature profile effectively sterilizes the bactofugate, eliminating any remaining spores. The sterilized bactofugate is then re-chilled in the plate heat exchanger and can be reintroduced back into the de-aerated milk stream or separately utilized for other suitable applications. By continuously recycling the sterilized bacterial concentrate into the milk, product losses are minimized, contributing to improved resource utilization and cost efficiency.

Advantages of the Bactotherm Process

The Bactotherm process offers several advantages in dairy applications. For example, the use of bactofuged milk in cheese production can prevent swelling in certain cheeses that may occur due to heat-resistant butyric acid bacteria. By selectively removing bacteria without subjecting the milk to pasteurization, cheddar cheese can develop a more characteristic and desirable flavor profile. In the production of powdered dairy products, the Bactotherm process effectively reduces microbial counts and allows for significant removal of heat-resistant bacteria. This not only enhances product safety but also extends the shelf life of powdered

dairy products, providing benefits in terms of storage and distribution. Furthermore, the severity of heat treatment can be reduced when employing the Bactotherm process in sterilized milks. By efficiently eliminating heat-resistant *Bacillus cereus* and associated defects, cream products can maintain their quality and sensory attributes.

The versatility of the Bactotherm process extends beyond dairy applications. It can also be utilized for butter oil separation, high-fat cream processing, and other non-dairy applications. The adaptability of the bowl's geometry allows for customization to suit the specific requirements of each product, further expanding the potential applications of the Bactotherm process.

Future Prospects

Looking ahead, bactofugation holds immense potential for further advancements in the dairy industry. Ongoing research and development efforts aim to optimize the bactofugation process, making it even more efficient and cost-effective. Advancements in technology may lead to the development of more compact and automated bactofuges, making it accessible to a broader range of dairy producers, including smaller-scale operations. Another exciting prospect is the integration of bactofugation into the production of a wider variety of dairy products. As the technique continues to demonstrate its ability to preserve the natural properties of milk, it may find applications in the processing of other dairy-based items, such as yogurt, butter, and cream. This could result in a more diverse range of high-quality dairy products for consumers to enjoy.

Challenges and Considerations

However, the adoption of bactofugation in the dairy industry may also face challenges. One

significant obstacle is the initial investment required to acquire bactofuge equipment and set up the necessary infrastructure. For smaller dairy farms or businesses with limited financial resources, this initial cost may be prohibitive. Additionally, ensuring consistent and uniform bactofugation performance across different batches of milk is essential for maintaining product quality and safety. Striving for standardization in bactofugation processes, operator training, and quality control measures will be vital to overcome this challenge.

Lastly, raising awareness and educating consumers about the benefits of bactofugation may be necessary to foster broader acceptance and demand for dairy products processed using this technique. Clear communication about the technology's advantages in terms of safety, nutrition, and flavor preservation can help build consumer trust and loyalty.

Conclusion

In conclusion, bactofugation has revolutionized the dairy industry by providing an effective method for removing bacteria from milk. Its ability to extend the shelf life of dairy products, improve safety, preserve flavor and nutrition, and enable the production of specialized products has had a significant impact on the industry. As research and development continue, bactofugation holds promise for further advancements and applications in the dairy sector. Overcoming challenges such as initial investment costs and ensuring consistent performance will be crucial for the widespread adoption of this innovative technology. By embracing bactofugation, the dairy industry can continue to meet the evolving demands of consumers while ensuring the production of safe, high-quality dairy products.

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Effects of Cold Plasma Technology on Physical and Nutritional Properties of Milk and Milk Products

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Cow's milk is consumed worldwide and its composition includes water, lactose, fat, proteins, and vitamins/minerals. To ensure food safety and extended shelf-life, traditional methods like pasteurization and sterilization have been used for a long time. However, these methods can negatively affect milk quality by causing browning, vitamin loss, and flavor changes. As a result, consumers are now interested in less processed dairy products that retain maximum nutrition, safety, and long shelf-life without extensive heating. Novel food preservation technologies such as high hydrostatic pressures, pulsed electric fields, ultrasounds, and cold atmospheric plasma have gained attention. Cold plasma is a non-thermal technique that uses ionized gas to pasteurize milk, effectively eliminating microorganisms while maintaining milk quality. It can be optimized to reduce bacteria without significant quality loss, but non-optimized processes can lead to issues like lipid oxidation, protein aggregation, and off-flavors. Cold plasma offers advantages such as short processing times, effectiveness at room temperature (beneficial for heat-sensitive products), and low-energy requirements in the food industry.

Mode of action of cold plasma:

The effectiveness of cold plasma treatment is based on the production of various reactive species, including ultraviolet radiation, reactive oxygen species (such as ozone, hydrogen peroxide, singlet oxygen, peroxy radicals, and hydroxyl radicals), and

reactive nitrogen species (such as nitric oxide, peroxy nitrite, and peroxy nitrous acid). These reactive species have significant effects on the physical, chemical, and microbiological properties of milk and dairy products. One important change caused by cold plasma treatment is the deformation of microbial cell surfaces, damage to intracellular genetic material, and ultimately cell death through lysis. Additionally, the plasma-reactive species, including free radicals, have the potential to inactivate enzymes by modifying amino acids through oxidation, sulfonation, and hydroxylation reactions. Cold plasma specifically targets the secondary structure of enzymes, inhibiting their binding and catalytic activities. Plasma-produced reactive oxygen species can also interact with lipids in foods and cause lipid oxidation. This can lead to undesirable changes, especially in dairy products with high fat content, such as cream and butter. Reactive oxygen species primarily target the methyl groups of fatty acids, with fatty acids containing double bonds being more sensitive to oxidation.

There is a possibility of an increase in product acidity due to chemical interactions between reactive species like hydrogen peroxide and nitric acid formed during plasma production. However, studies have shown mixed results, with some observing no change in acidity. These discrepancies may be attributed to differences in the plasma source used and the specific process parameters applied in different studies.

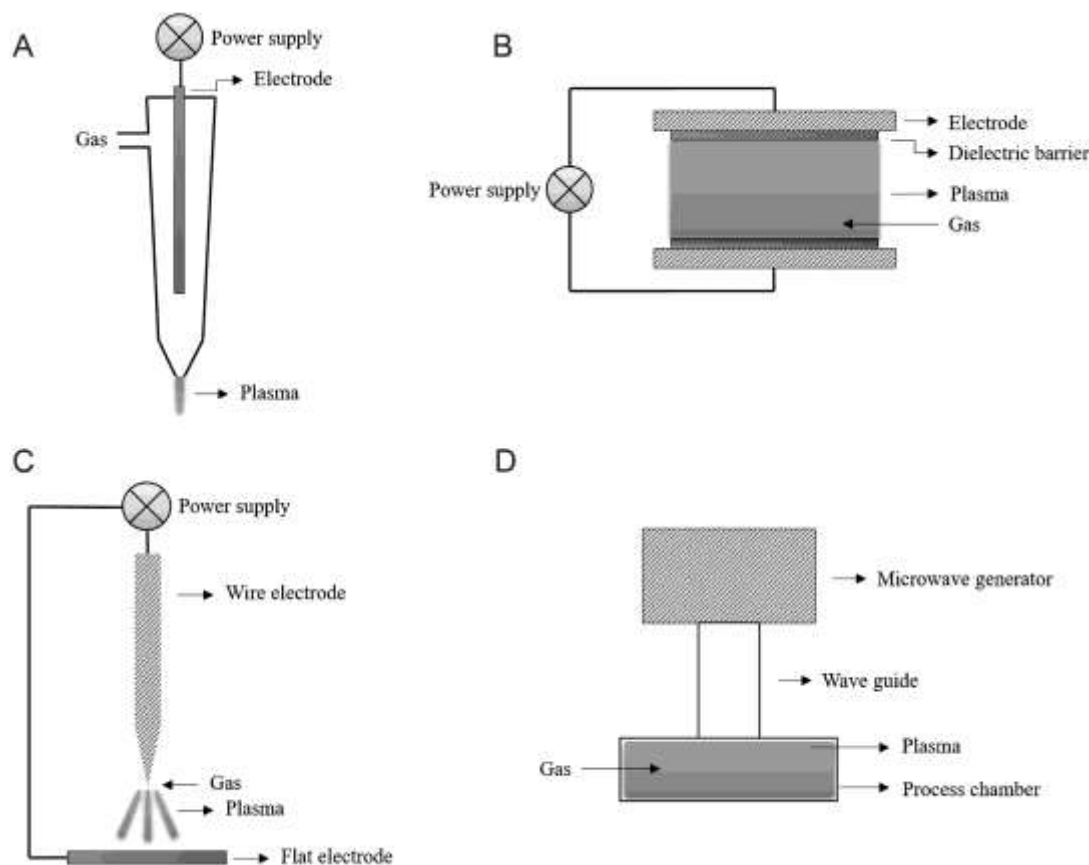


Fig.1. Different Cold Plasma Systems: (A) Plasma Jet, (B) Dielectric Barrier Discharge, (C) Corona Discharge, and (D) Microwave Disc

Physical Properties

Milk is an emulsion containing fat and protein compounds in a watery environment. Its viscosity, which affects mouthfeel and is used as a quality control measurement, depends on its composition and processing conditions. Research has shown that viscosity decreases with higher temperature and moisture content, and increases with higher fat, lactose, protein, and mineral contents. Factors such as pasteurization temperature, pasteurization time, and homogenization pressure also influence viscosity. Skim milk has a viscosity of about 1.56mPas at room temperature, while whole milk has a viscosity of about 2.00mPas. Cold plasma

treatment has been observed to slightly reduce milk viscosity, likely due to protein and lipid oxidation. Studies have shown that mild plasma treatment can lead to lower viscosity and flow consistency index in milk. However, the effect of cold plasma on viscosity can vary depending on factors such as treatment time, voltage, and flow rate. Longer treatment times, higher voltages, and

higher flow rates can result in increased viscosity. The optimization of viscosity can be achieved by adjusting the plasma conditions.

The color of milk is an important sensory characteristic that influences consumer preferences and is closely linked to the quality of dairy products. The total color difference (ΔE) is a commonly used metric to quantify the visual perception of color differences between two samples. In a study, plasma-treated milk exhibited ΔE values of 0.91 and 1.58 when treated at flow rates of 6 and 3 ml/min, respectively. However, another study reported no significant change in color after plasma treatment of raw milk for up to 15 minutes. In a separate investigation, milk samples treated with DBD at 80 V for 120 seconds showed ΔE values ranging between those of UHT (36.02) and pasteurization. Similarly, for milk powder, ΔE values were below 1.5 after 120

seconds of plasma treatment. To minimize color changes in dairy products, it is recommended to keep the treatment time below 5 minutes. Additionally, to prevent nonenzymatic reactions in milk that result in increased yellowness, it is suggested to use working gas with low oxygen concentration to avoid oxidation of fat and proteins.

The size of particles, particularly fat globules, in milk plays a significant role in determining its flavor, mouthfeel, and emulsion stability. When whole chocolate milk is subjected to cold plasma treatment for 5 minutes, the resulting milk particles exhibit increased surface areas and reduced volume diameters compared to untreated milk. The presence of reactive oxygen species (ROS) in cold plasma processing can lead to mild oxidation of proteins, resulting in increased carbonyl groups and surface hydrophobicity, as well as a reduction in free SH groups. This protein oxidation can cause protein aggregation. Similar findings were observed in a study on whey beverages treated with cold plasma processing. However, if cold plasma treatment exceeds 5 minutes, it can lead to further protein oxidation due to the increased generation of ROS, resulting in larger particle sizes. On the other hand, a higher flow rate (30 ml/min), which increases gas velocity, can cause smaller particle sizes. In summary, cold plasma treatment of milk can impact particle size by influencing protein oxidation and gas velocity. Treatment times longer than 5 minutes can result in protein oxidation and larger particle sizes, while higher flow rates can lead to smaller particle sizes due to increased gas velocity.

Nutritional Properties

Milk proteins, which make up about 32 g/L to 38 g/L in whole milk, play a crucial role in determining the physical, chemical, and sensory

characteristics of milk products. When subjected to a 70 kV DBD atmospheric cold plasma treatment for 15 minutes, there was a mild oxidation of proteins, as indicated by an increase in protein-bound carbonyl groups compared to the control sample. This oxidation was measured using a spectrophotometer and resulted in approximately 3 AU2 Abs, whereas the control sample had an approximate value of 0.25 AU Abs. In the case of non-fat dry milk, a study showed that there were no significant changes observed in the amino acid profile when subjected to cold plasma treatment. However, it should be noted that if low pressure (16Pa) or nitrogen gas is used in the treatment, which does not generate reactive oxygen species (ROS), there may be no significant impact on the proteins. On the other hand, if air, high voltage (60 kV), and long treatment times exceeding 30 minutes are applied, there can be mild oxidation or significant protein aggregation due to the higher concentration of generated ROS. Therefore, to minimize changes in proteins during cold plasma treatment, it is important to tailor the treatment conditions accordingly.

In a study it was found that using an encapsulated DBD plasma source on milk resulted in a change in the concentration of butyric acid (0.6 g/L of milk) compared to the control (0.7 g/L of milk) after a 10-minute treatment. In another study by Korachi et al. evaluated fat oxidation in milk using an atmospheric plasma discharge system. They reported a one percent decrease in the concentration of short-chain fatty acids (63.6%) during the first 5 minutes of treatment, which increased to 65.8% after 10 minutes. When milk was treated with a low-pressure (16Pa) plasma system, there was a loss of fat during the plasma processing. Higher levels of reactive oxygen species (ROS), including OH radicals and atomic oxygen, are associated with

increased fat oxidation. To minimize fat oxidation, it is suggested to lower the voltage and limit the treatment time to below 10 minutes, as this reduces the concentration of ROS. Additionally, using a working gas with a lower concentration of oxygen, such as pure nitrogen, can also help decrease fat oxidation.

There is limited research available regarding the effects of cold plasma treatment on lactose in cow's milk. In one experiment, a DBD-type plasma system was applied to raw milk, and the lactose content was measured. The results showed a significant reduction in lactose content, specifically 44.8 g/L at a flow rate of 3 ml/min, compared to the control sample which had a lactose content of 46.4 g/L. This reduction in lactose content is believed to be a result of the interaction between the OH radical present in the plasma and lactose molecules. The OH radical abstracts a proton from the lactose disaccharide, leading to the formation of a sugar-free radical and subsequent reduction in lactose content.

Conclusion

Cold plasma technology is a relatively new non-thermal technique that holds great potential for processing milk and dairy products. It offers several advantages over thermal methods. When optimized, cold plasma treatment can achieve non-thermal pasteurization or sterilization of milk while minimizing quality changes. However, existing studies on cold plasma have primarily focused on its antimicrobial effects, and there is a lack of comprehensive research addressing the physical, chemical, and sensory properties of the final products. The effects of cold plasma on milk and dairy products are diverse, encompassing microbiological, physicochemical, biochemical, and sensory properties. The type and concentration of

reactive species present in the plasma can vary based on factors such as the gas or gas mixtures used, the configuration of the plasma source, and the applied voltage and treatment time. Consequently, different results have been observed in various studies, depending on the method of plasma generation, process parameters, and the specific microorganism species being investigated. Overall, further research is needed to fully understand the changes that occur in milk and dairy products due to cold plasma treatment. More studies are required to elucidate the complex processes involved and to gain a comprehensive understanding of the potential benefits and limitations of cold plasma technology in the dairy industry.

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A sustainable approach: Production and Processing of whey

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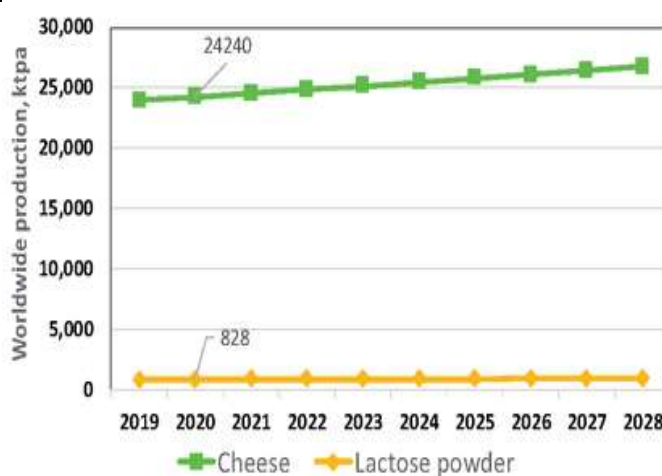
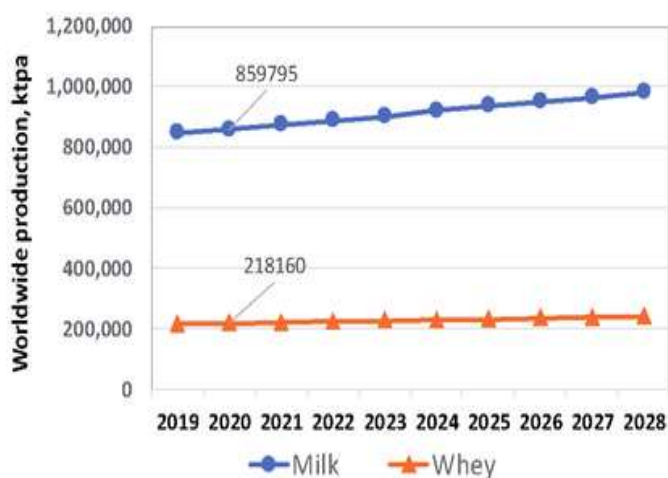
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Sustainable development is of utmost importance because it results in managing the natural resources for the generations to come along with the species that live worldwide. Our future is driven by sustainability, which impacts every aspect of life and will influence it in the future. Cheaper, more accessible, and clean energy are required by Sustainable Development Goals (SDG). To put it another way, by 2030 it will be required to provide energy efficiency and reduce carbon dioxide emissions to produce goods and services. More significantly, it decreases the cost of economy and lowers the demand for imported energy. Furthermore, energy efficiency benefits the construction, transportation, industrial, and energy

Sustainability of dairy industry:

The proper handling of food waste materials and by-products poses a concern for the agriculture and food production sectors, as they must manage greater commercial costs for their treatment, process, recycle or dispose due to the rise in food consumption as well as strict environmental restrictions. As the dairy industry advances, enormous quantities of by-products are produced, primarily whey. In this regard, the concept of whey has transformed from being a waste to a dairy by-product, and numerous studies have been carried out to identify workable, ecologically acceptable whey usage alternatives rather than simply dumping of the whey in the field.



generating sectors. 'Transforming our World', was the agenda for Sustainable Development UN summit which was held in New York, 2015. The 17 SDGs, which are broken down into 169 closely related sub-goals, which are related to the handling of waste in every part of the cycle, lowering the emissions to the three major resources such as air, water and soil. Also, reducing the amount of waste with higher rate of reuse and recycling.

Fig.1. Worldwide production of milk, whey and cheese(in metric kilo-tonnes per annum)

Annually, the dairy industry generates millions of tonnes of by-products, cheese whey (CW) is one among the most important product, which is the net fraction left after milk coagulation while cheese processing. As depicted in the Fig.1. several millions of tons of whey are produced each year as a by-product as a result of the consistent increase in

milk and cheese production around the world in recent years. For every kg of cheese produced, around 9–10L of whey are produced. So, what happens if the whey without being treated is let to blend in the ecosystem? It results in a serious environmental issue. CW is high in the COD (Chemical Oxygen demand) and BOD (Biochemical Oxygen Demand). In similar to CW, second cheese whey (SCW), the liquid that remains after whey cheese separation containing 90% of the original whey or more. SCW is regarded as a significant source of pollution, having high BOD and COD values (an approximate amount of 50 and 80 g L⁻¹, respectively), with lactose (35–50 g L⁻¹) because it is relatively rare to process it, and also it turns out to be challenging to use as feed ingredient since animals lack the ability to breakdown lactose in high quantities.

Valorisation of whey

An ideal ecological and cost-effective option for using whey is the simultaneous incorporation of multiple working units into a single process, which minimizes the environmental impact of whey. Let us see how the cheese whey can be valorised, what technologies are being used and the methodologies for valorisation. The food industry has benefited from the development of membrane separation techniques as they are relatively simple to scale up and are less expensive than preparative chromatographic methods. The benefit of using membrane separation techniques is that the bioactive chemicals do not undergo excessive heat treatments during processing. Proteins from various whey-based ingredients have been concentrated and separated using a variety of techniques, which includes Ultrafiltration (UF), Diafiltration (DF), Nanofiltration (NF), Ion exchange chromatography, precipitation, electrophoresis, and crystallisation.

In fact, fermented whey can be used to extend the shelf life of some foods in addition to fortifying them. For instance, when some authors added fermented whey to poultry feed as a supplement, they saw an increase (2–4-fold) in the antifungal activity when compared to the control diet. Also, it was discovered that using whey powder that had undergone lactic acid fermentation caused *Penicillium expansum*, a toxigenic fungus, to be slightly inactivated (0.5–0.6 log cfu/g) in bread loaves. There are numerous approaches to sustainable whey management, most of which are focused on the creation of value-added products such lactic acid, bioethanol, bioplastics, biogas, whey powder, and functional foods and beverages. While whey in large quantities can be converted to bioethanol, whey in smaller amounts is most effective when utilised to make fermented or unfermented beverages.

Another method used is the generation of bioethanol from whey. According to estimations, raw products such wheat, sugar, beets, and oil seeds are fermented to produce 93% of the world's ethanol (biodiesel), known as first generation bioethanol. The production of bioethanol from second and third generation sources, which primarily consist of agricultural residue, has shown to be an essential approach in minimizing the food-related issue connected with first-generation bioethanol, which seeks to address the food and energy paradox. Therefore, different microorganisms and enzymes are used for fermentation to generate bioethanol. It can also be produced from cheese whey as well as in combination with organic matter.

The liquid whey can be made into whey powder, a most commonly used method. It comprises of the processing steps: whey clarification,

cream separation and pasteurization, concentration of whey, lactose crystallisation and the drying of whey (mostly spray drying is used). Whey contains over half of the vitamins (A,D,E,K) and minerals along with 70% lactose of the total solids found in whole milk and contains 20% protein. Whey proteins and peptides, has most advantageous applications for dealing with chronic diseases, nutritional deficiency, and for body mass gain, as well as in elderly people to address loss of muscle mass due to age caused by sarcopenia. Thus, it is a ground breaking additive in food supplements.

Whey protein films emerges as a biodegradable replacement to the commonly used polyester films and nylon due to their highly effective oxygen barrier qualities. Additionally, compared to films made from polysaccharides, proteins from whey can generate transparent films as well as coatings with better barrier properties, and they could possibly provide surface sterility. Such films and coatings also biodegrade quickly in addition to having superior barrier qualities. However, whey proteins must be combined with glycerol, xylitol, mannitol, or any appropriate plasticizers, in order to create new environmentally friendly food packaging that are flexible and resistant to moisture transfer.

Conclusion

In conclusion, the Sustainable Development Goals are applicable in the field of food industries by reusing and recycling the by-products, proper treatments of the effluents, etc., In the case of whey, it can be used in numerous fields as raw materials, various products, additive in pharmaceuticals and food, and so on. At the same time, over processing of a product can damage its properties, thus the quality of the processed whey should be analysed before

introducing it to the market. Awareness should be created regarding SDG's not only in the field of whey processing but also in other food products also which can be helpful for achieving the SDGs in shorter period of time.

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Novel Heat Transfer Fluids for Efficient Energy Dissipation in Dairy Industry

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The dairy industry has noticed a notable trend towards sustainable energy practices in recent years. The study of non-conventional or novel heat transfer fluids (HTFs) has drawn a lot of attention as the push for cleaner and more effective energy sources develops. These cutting-edge HTFs provide a number of advantages, including increased thermal conductivity, increased heat transfer effectiveness, and little environmental impact. In this article, the in-depth examination of emerging novel HTFs and their potential uses in the dairy industry is being discussed.

Traditional heat transfer system

Traditional heat transfer systems have been widely used in various applications, including heating and cooling systems, industrial processes, and domestic appliances. They often rely on well-established engineering practices and technologies that have proven to be effective and reliable over time.

Conventional heat transfer fluids

One of the leading causes of poor performance and escalating energy costs in various industries, including the dairy and food sector, stems from the prevalent usage of conventional heat transfer fluids. Examples of such fluids include water, steam, propylene glycol, ethylene glycol etc. These outdated fluids, although once considered the norm, are now proving to be inadequate in meeting the demands of modern energy efficiency and sustainability practices.

Hurdles faced with usage of conventional heat transfer fluids

Conventional heat transfer systems have limitations in terms of efficiency and control. They

require larger amounts of energy or have slower response times compared to more advanced and innovative heat transfer technologies. The other problems associated with their application are:

- Corrosion: These fluids corrode the surfaces of heat exchangers which further leads to leakages and equipment failure.
- Scaling: The usage of water causes scaling on the heat exchanger surfaces which reduces heat transfer efficiency
- Toxicity: Few fluids such as ethylene glycol and propylene glycol are toxic in nature and can pose a health risk
- Maintenance cost: The scaling and corrosion problems further leads to higher maintenance cost and processing cost as well.

Emerging heat transfer fluids

As businesses strive to optimize their operations and minimize their environmental impact, the adoption of emerging non-conventional heat transfer fluids has emerged as a viable solution. The enhancement in performance of heat exchanger systems can be obtained using emerging fluids like NFs, phase change materials, thermal oils etc. These advanced HTFs offer a multitude of benefits, ranging from enhanced thermal conductivity to reduced energy consumption, making them an ideal choice for overcoming the limitations of conventional fluids. By transitioning away from conventional HTFs and embracing the potential of novel HTFs, the dairy industry can pave the way for improved performance, reduced energy costs, reduced processing time and a greener future.

Desired characteristics of heat transfer fluids

The desirable properties of heat transfer fluids are mentioned below:

- Low viscosity
- Cost-effectiveness
- Chemical stability
- Wide temperature range
- High thermal conductivity
- High specific heat capacity
- Low toxicity
- Non-flammability
- Low environmental impact
- Compatibility with materials
- Ease of handling and maintenance

Novel heat transfer fluids:

Advancements in materials, design, and engineering have led to the development of more efficient and optimized heat transfer systems, offering improved performance, energy savings, and enhanced control.

Nanofluids

Nanofluids (NFs) are those fluids that contain suspended nanoparticles (NPs), typically with sizes ranging from 1 to 100 nm. These NPs can be made from a variety of materials, including metals, metal oxides, and carbon-based materials. The properties of NFs depend on the type of NPs used like metal-based NPs exhibits excellent thermal conductivity whereas polymer- and carbon-based NPs shows good mechanical properties, and due to this property, they are often used in biomedical applications.

Potential and drawback of using nanofluids for heat dissipation

NFs have potential benefits of using in various processes, such as milk pasteurization, sterilization, and refrigeration. NFs can improve the thermal conductivity of the fluid, leading to more efficient heat transfer and lower energy

consumption. They can also enhance the antimicrobial properties of the fluid i.e., Ag NPs. An increment of 1.6 and 9.4% was observed for heat transfer rate and convective heat transfer coefficient, respectively by incorporating 0.3% volume concentration of Al-Ag NPs in propylene glycol-water (20:80) hybrid NFs. The production and processing of NPs, as well as their dispersion in the base fluid, can contribute to the overall cost of NFs. The stability and settling issues of NFs pose challenges in their long-term use and can impact their reliability in heat transfer applications.

Phase change materials

Phase change materials (PCMs) are substances that exhibit the ability to store and release large amounts of thermal energy during phase transitions, such as melting or solidification, while maintaining a nearly constant temperature (Fig. 1). The examples of PCMs include Paraffin waxes, fatty acids, and salt hydrates. Paraffin waxes have high heat storage capacities and low costs, while fatty acids have a high thermal conductivity and can withstand high temperatures. Salt hydrates are commonly used as PCMs due to their high melting and freezing temperatures.

A more advanced form of novel heat transfer fluid is NPs incorporated PCM. These NPs, which are frequently formed of metals, oxides, or compounds derived from carbon, give the PCMs special features like higher heat conductivity and increased stability.

Benefits and disadvantages of employing phase change materials for energy transport

Using PCMs, which has the following advantages, one can harness latent heat for increased energy efficiency.

- Greater energy efficiency: Because PCMs can store and release significant amounts of energy,

the quantity of energy required for heating may be reduced.

- Better temperature regulation: PCMs can maintain a constant temperature, lowering the possibility of temperature changes and resulting in high-quality products.
- Smaller equipment: By storing thermal energy in PCMs, the size of the equipment required for heating can be reduced.

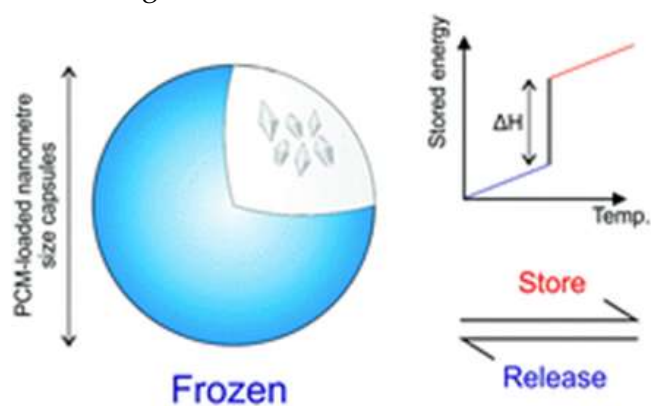


Fig. 1: Phase change materials

The inclusion of NPs in the PCM matrix improves the efficiency of heat transport and permits quick and effective energy storage and release during phase transitions. These fluids are ideally suited for a wide range of applications, including thermal energy storage, electronics cooling, and heat exchangers, thanks to the synergy between the NPs and PCMs, which results in improved thermal management capabilities.

An effective method for increasing overall system performance and optimising energy use in a variety of industries is the use of PCMs with NPs included (NePCMs). Researchers developed a stable and cost-effective NePCM (TiO_2 NPs in water) with 14.75% enhancement in thermal conductivity as compared with pure PCM. The wt.% fraction of 0.60% was optimized for safer storage of milk in cold chains. The main disadvantage of using these fluids is their higher production cost and higher pumping power required for recirculation.

Thermal oils

Thermal oils, also known as heat transfer oils, are specially formulated fluids designed to transfer heat efficiently in various industrial processes and systems. The primary function of thermal oils is to absorb heat from a heat source, such as a burner, electric heater, or heat exchanger, and transport it to a heat sink or heat-using process. They are often supplemented with additives to enhance their

performance, such as antioxidants to inhibit oxidative degradation and anti-wear agents to protect equipment surfaces. Thermal oil-based NFs are advanced heat transfer fluids that combine a base thermal oil with NPs, such as metal

oxides or carbon nanotubes. Thermal oil-based NFs also exhibit better stability at elevated temperatures, reducing the risk of thermal degradation and enhancing overall system performance.

Types of thermal oils

Thermal oils are specifically designed to withstand high temperatures and provide efficient and reliable heat transfer. Some commonly used thermal fluids include mineral oils, synthetic oils, silicone oils etc.

The various types of thermal oils with their properties are given in Table 1 and the choice of fluid depend on the specific applications and operating conditions.

Prospects and Limitations of Utilizing thermal oils for thermal migration

Thermal oils are often used in systems that operate at temperatures near 300°C . It has a high boiling point and low vapor pressure, making it a safer and more efficient to use. The use of thermal oils for heating applications in place of conventional

HTFs possess many benefits, major ones are (i) high thermal stability, and (ii) better heat transfer properties.

Table 1. Different properties of different types of thermal oils

Sr. No	Type of oils	Properties
1	Mineral oil	Most commonly used thermal fluids Cost-effective High thermal stability Non-toxic Temperature range: 20°C to 350°C Suitable for most heating applications in the food and dairy industry. Example: Shell heat transfer oil S2
2	Synthetic oils	Higher thermal stability Temperature range: -80°C to 400°C Preferred for high-temperature applications Example: Dowtherm A, Therminol 55
3	Silicone oils	Low-temperature heating applications Temperature range: -50°C to 200°C Chemically inert, and non-toxic High thermal stability Example: Silatherm® S

They can sustain their performance across a wide temperature range thanks to their high thermal stability. It qualifies them for use in high-temperature processes like pasteurization, frying, and baking. Due to their high boiling point and low vapour pressure, thermal oils provide excellent thermal stability, preventing fluid deterioration and lowering the possibility of heat exchanger fouling.

Because of their high thermal conductivity and heat capacity, thermal oils can move heat fast and effectively. This makes them the perfect option for processes like sterilization, homogenization, and freeze-drying that call for quick heating or cooling.

The dairy industry benefits from employing thermal oil-based NFs due to their improved heat transfer properties, which enable more effective processing and lower energy consumption. Faster heating and cooling rates are made possible by NPs' high thermal conductivity, which boosts productivity and shortens processing times in the food industry. These NFs have more thermal stability than water, enabling applications requiring precise temperature control during milk processing. The dairy industry can employ NFs in applications demanding high temperatures since their use can increase heat exchanger efficiency and reduce fouling and maintenance needs.

The use of thermal oil-based NFs is not without significant drawbacks, though. One significant drawback is their higher cost compared to traditional fluids like water. Another potential concern is the increased complexity in NFs handling and maintenance, as NPs may settle over time and require periodic agitation or mixing. Due to their higher viscosity, thermal oil-based NFs may require modified or specialized equipment for efficient circulation and heat transfer. Proper disposal and waste management protocols need to be followed for NFs to minimize any potential environmental impact.

Comparison between traditional and novel heat transfer fluids

After analysing the pros and cons of using emerging novel heat transfer fluids, comparison can be made between traditional and novel heat transfer fluids as shown in Table 2.

Table 2. Comparison between traditional and novel heat transfer fluids

Differences	Traditional Heat Transfer Fluids	Novel Heat Transfer Fluids
Examples	Water, Glycols	Nanofluids, phase change materials, thermal oils
Thermal conductivity	Moderate to high	High
Viscosity	Moderate to high	Low
Specific heat capacity	Moderate to high	Moderate to high
Operating temperature range	Limited	Wide
Chemical stability	Good	Good
Toxicity	Low	Low
Flammability	Non-flammable	Non-flammable
Material compatibility	Compatible with common materials	Requires compatibility testing
Cost	Low to moderate	High
Environmental Impact	Less	High, requires evaluation
Ease of handling and maintenance	Easy	Require additional measures

Conclusion

The usage of emerging non-conventional (novel) heat transfer fluids in place of conventional heat transfer fluids presents promising opportunities and challenges for the dairy industry. These innovative fluids, such as thermal oil-based NFs or other advanced formulations, offer advantages such as enhanced heat transfer efficiency, improved temperature control, and reduced energy consumption.

In the dairy industry, the application of these novel fluids can lead to more efficient milk processing, faster heating and cooling rates, improved productivity, and enhanced heat exchanger performance. However, it is imperative to address the problems brought on by their increased cost, the potential for NP settling, and health and safety concerns. Continued work should also concentrate on determining their compatibility with food-grade materials, guaranteeing regulatory compliance, and analysing their environmental impact. By taking care of these issues, the dairy sector can improve its operations and contribute to the sustainable and effective production of food by taking advantage of the potential advantages provided by newly developed novel heat transfer fluids.

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From Waste to Wonder: Unleashing the potential of milk processing by-products

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The dairy industry plays a pivotal role in the global food sector, providing a wide array of essential products that form an integral part of people's diets worldwide. From milk and cheese to butter and yogurt, dairy products are rich sources of vital nutrients, contributing significantly to human nutrition and health. But apart from production of these primary products, dairy industries are known for the generation wastes in food sector. In this article, we will explore the importance of the dairy products in the food sector and unveiling the potential of milk processing by products/wastes to utilizing them as edible nutritious food.

Dairy products being the nutritional powerhouse, provides an excellent source of calcium, protein, vitamin D, and other essential minerals and vitamins. These nutrients are crucial for the development and maintenance of healthy bones, teeth, and muscles. The dairy industry's offering forms an essential component of a balanced diet, especially for growing children, pregnant women, and older adults. It provides versatility in culinary applications. Dairy products add depth, flavor, and richness to a wide variety of dishes, making them an indispensable part of culinary traditions across the globe. For example, cheese enhances the taste of pizzas, pasta, and sandwiches, while yogurt is used in sauces, dressings, and smoothies. Butter is a staple in baking, contributing to the texture and taste of cakes, cookies, and pastries. The dairy industry has a profound impact on the global economy too. It provides livelihoods for millions of farmers, dairy processors, and distributors around the world. In rural areas, dairy farming is a crucial source of income and employment, supporting local economies and contributing to poverty reduction. Moreover, the dairy industry is a significant

contributor to the GDP of many countries, fostering economic growth and stability. The dairy industry's importance in the food sector cannot be overstated. Its nutritional value, versatility, economic impact, and contribution to sustainable agriculture make it an essential pillar of the global food supply chain.

The dairy industry, while being a vital component of the food sector generates a variety of waste or by-products during the processing of milk as well as other dairy products. These by-products are secondary products that are obtained alongside the main dairy product manufacturing process. While the primary focus of the dairy industry is to produce milk, cheese, yogurt, butter, and other dairy staples, the by-products that emerge present additional economic opportunities and contribute to sustainability efforts. From the initial stages of milk collection and processing to the production of dairy products, waste is inevitable. Moreover, dairy processing generates other organic waste, such as trimmings, peels, and scraps from the production of dairy products like butter and cheese. The disposal of such organic waste can create environmental issues if not handled properly. Additionally, cleaning and sanitizing processes in dairy plants result in wastewater containing chemicals and detergents, adding to the waste generated by the industry.

One common dairy by-product is whey, a liquid remaining after milk coagulation during cheese or yogurt production. Among the various waste products generated by the dairy industry, whey stands out as a significant concern due to its potential adverse effects on the environment and human health (Chandra et al., 2018). Whey is rich in protein, lactose, vitamins, and minerals, making it a valuable resource for various applications. Despite of

being considered as dairy waste, it has been utilized in the production of protein supplements, infant formula, and as an ingredient in the baking and confectionery industries. Another essential dairy by-product is buttermilk, obtained during butter production. Buttermilk contains residual fats, proteins, and water-soluble vitamins, and it is widely used in the bakery industry to enhance the texture and taste of baked goods. It is also used as a base for various beverages, dressings, and marinades. Dairy industry by-products also include cream, which is separated during milk processing, and it is widely used in the production of ice cream, whipped cream, and various desserts. Moreover, dairy by-products like casein and lactose are used in pharmaceuticals, food additives, and industrial applications.

Dairy wastewater contains high amount of dissolved organic components, (lactose, casein, inorganic salts, and N, P, K, fat and whey protein), that is commonly characterized by is normally characterized by high amounts of biological oxygen demand (BOD) and chemical oxygen demand (Ahmad et al., 2019). The main by-product of dairy industry is whey, which is produced during cheese and casein manufacturing. Milk whey contains lipids, carbohydrates, soluble vitamin, minerals as well as protein. The proper utilization of dairy industry by-products is of utmost importance, not only for economic reasons but also from a sustainability perspective. By optimizing the use of these by-products, the dairy industry can reduce waste and its environmental footprint while maximizing the value obtained from the milk processed. The waste water generated cannot be directly expelled into the river water, but must undergo some treatments.

Advancements in technology have opened up vast opportunities for the creation of novel channels to utilize the by-products generated during dairy processing. Dairy waste and related by-products can be purified and used in other industries by development of some technologies such as reverse osmosis (RO), drying, hydrolysis, ion exchange, nano filtration (NF), ultrafiltration (UF) and electrodialysis (Ryan and Walsh, 2016), which can then safely be disposed into water streams. Thus, a number of by-products of great value from milk processing can be obtained and further utilized for human consumption. Therefore, milk processing by-products are essentially products of commercial value that arises as a by-product during the production of the main products.

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Trans Fatty Acids in Milk Fat and Hydrogenated Oils

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The presence of *trans* unsaturated fatty acids in milk fat and hydrogenated oils are of greater concern nowadays because of health-related issues. *Trans* fatty acids in milk fat are the result of incomplete biohydrogenation of the unsaturated dietary lipids in the rumen. Partial hydrogenation process of vegetable oils also produces *trans* type fatty acids for use in semi-solid fat products, such as margarine and confectionery to increase the shelf life of the product. Processed foods and oils provide approximately 80 % of *trans* fats in the diet, compared to 20 % that occur naturally in food from animal sources. These fatty acids have attracted attention because of their adverse nutritional effect on health. As suggested by observational studies and clinical trials artificial *trans* fats may increase the risk of heart disease by significantly varying the ratio of lipoproteins LDL and HDL levels in the blood. The American Heart Association recommends that less than 25 to 30 % of daily calories come from total fats and *trans* fats should be less than 1 %. An average 2,000 Calorie daily diet should include less than 2 grams of *trans* fats. This article presents the detailed chemistry of *trans* fatty acids, their composition, status, and health effects, which are sourced from milk fat and hydrogenated vegetable oils.

Cis and trans fatty acids

All fats and oils are the esters of fatty acids and glycerol, which are chemically named as triacylglycerol, the major type of fats or oils. Fatty acid composition of fats and oils differ w.r.t the ratio of saturated and unsaturated carbon atoms, denoted

by the absence or presence of double bonds, respectively. Unsaturated fatty acids exhibit two different geometric isomeric forms namely '*cis*' and '*trans*'. The *trans* fats or *trans*-fatty acids (TFA) in foods come from two major sources either naturally (ruminant animals) or artificially (industrial/processed/ hydrogenated oil).

An important structural difference between *cis*- and *trans*-unsaturated fatty acids is that the *cis* configuration of the double bond puts a significant "kink or bend" in the hydrocarbon chain, whereas the *trans* configuration causes only a slight distortion (Fig 1). This difference has a major impact on the way in which triacylglycerols pack in crystal lattices when they solidify (Fox and McSweeney, 2006).

Cis- and Trans-Fatty Acids

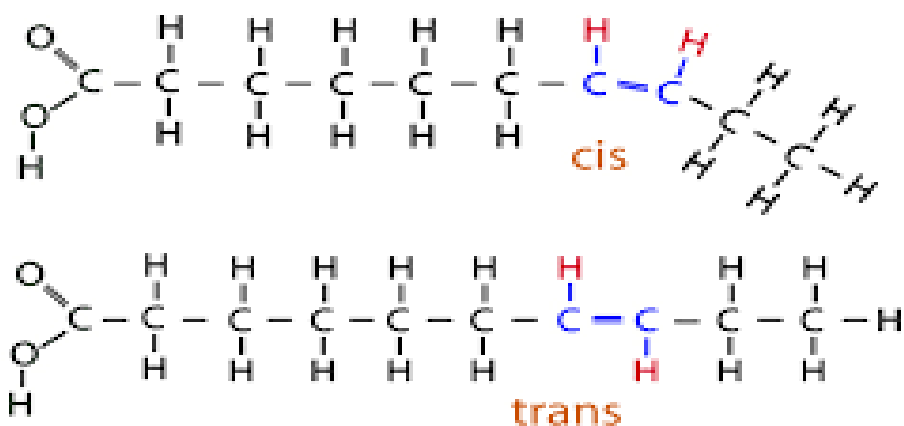


Fig. 1: Structure of '*cis*' and '*trans*' unsaturated fatty acids

Trans fats in Ruminant milk fat and hydrogenated vegetable oils

The primary dietary *trans* fatty acids (TFA) are vaccenic acid and elaidic acid. Vaccenic acid (C18:1, *trans*-11) is the major ruminant TFA, whereas elaidic acid (C18:1, *trans*-9) is the main TFA isomer in

industrial hydrogenation. The TFA content of industrially hydrogenated fats varies widely and may account for up to 60 % of the fatty acid content, whereas the TFA content of beef and dairy products is considerably lower and accounts for 2-5 % of the fatty acid content. In the case of special dietary choices, this allows for a daily intake of up to 10 times more industrially produced TFA than from ruminants (Mensink, 2005).

In milk fat, unsaturated fatty acids having single double bond (C18:1) and two double bonds (C18:2) may exist both in *cis* and *trans* forms. Vaccenic acid (11t-C18:1) is the most important *trans* isomer having *trans* double bond at 11th carbon atom of the fatty acid from carboxyl end, with values ranging from about 30 to 60 % of the total *trans*-C18:1. The concentration of *trans*-C 18:1 varies considerably from about 2.0 to 6.0 %, with mean values for milk fats from several European countries in the range 3.3 to 4.4 %. The higher values are for milk fat samples that were obtained from cows fed on summer pasture, whereas the lower values were associated with the feeding of concentrates and silage to cows in the winter. The feeding of fresh grass to cows appears to reduce the efficiency of the biohydrogenation reactions in the rumen, which leads to higher amounts of *trans* fatty acids (Precht and Molkenin, 2000).

The best-known ruminant *trans*-fat is conjugated linoleic acid (CLA), which is found in dairy foods, butter, lamb and beef. C-18:2 (9c, 11t) is the principal isomer of the CLA in bovine milk fat, accounting for about 80-90 % of the total. The term CLA refers to a mixture of positional and geometric isomers of octadecadienoic acid (C18:2) with conjugated double bonds (e.g., 10t, 12c-C18:2, 10t, 12t-C18:2). The CLA content of milk fat is derived from two related sources. First, C18:2 (9c, 11t) is an intermediate product of the biohydrogenation of

fatty acids in the rumen. In addition, 11t-18:1 can be converted to 9c, 11t-18:2 in the mammary gland by the enzyme stearoyl-CoA desaturase (SCD), which normally catalyses the conversion of 18:0 to 9c-18:1. The concentration of C18:2 unsaturated fatty acids (linoleic acid) in milk fat, which contain *trans* form fatty acids are given in the Table 1 (Precht and Molkenin, 1997).

Table 1: Concentration of *trans*-octadecadienoic acids in bovine milk fat

<i>Trans</i> -C18:2 isomers	Mean (n)	Range
C18:2(9c,11t); Conjugated linoleic acid; CLA	0.85 (100)	0.25-1.95
C18:2 (9c, 12t)	0.10 (100)	0.05-0.16
C18:2 (9t, 12c)	0.07 (100)	0.02-0.48
C18:2 (9c, 13t) and C18:2 (8t, 12c)	0.11 (11)	0.07-0.16
C18:2 (11t,15c)	0.33 (100)	0.04-0.68
C18:2 (9t, 12t)	0.09 (11)	0.06-0.12

Conjugated linoleic acid (CLA) isomers are excluded from definition of *trans* fats for labelling purpose. Some food manufacturers are fortifying foods with extra CLA and marketing them as functional foods. The health implications of CLA have widened to include inhibition of carcinogenesis, atherosclerosis, diabetes, and weight loss induced by immune stimulation; and increase in the percentage of lean body mass (Parodi, 1999). These studies have shown that CLA can be regarded as unique, because it appears to provide numerous positive health effects unlike other *trans* fatty acids (Fox and McSweeney, 2006).

However, artificial *trans* fats (industrial *trans* fats or partially hydrogenated fats) are proven hazardous to health. These fats occur when vegetable oils are chemically altered to stay solid at room temperature, which gives them a much longer shelf life. Partially hydrogenated vegetable oils were the

largest source of artificial *trans* fats in the diet because they were used in many foods such as crackers, cookies, snack cakes and other snack foods. Very commonly found processed foods in the market which are rich in *trans* fats are microwave popcorn, French fries, cheese burger, pies, chicken nuggets, vanaspati, donuts etc. The major sources of *trans* fats that are found in several modern processed diet is presented in Table 2 (Vandana *et al*, 2011).

Table 2. Contribution of several foods in the diet as *trans* fat

Food groups	Contribution of <i>trans</i> fat consumed (%)
Cakes, Cookies, Crackers, Bread	40
Animal products	21
Margarine	7
Fried potatoes	8
Potato chips, Corn chips, Popcorn	5
Household shortening	4
Breakfast cereals etc	5

Health risks

TFA has unique effects on serum lipid levels. Clinical trials have shown that *trans*-octadecenoic acids (C18:1), relative to the *cis* isomer, can increase the LDL (bad cholesterol) and decrease the HDL (good cholesterol), thus producing an unfavourable effect on the LDL: HDL ratio (Mensink and Katan, 1993). Mozaffarian *et al*. (2006) reported that saturated fat and TFA had similar effects on LDL on a calorie basis. However, when compared with either saturated or unsaturated fat, TFA reduced HDL and increased the ratio of total cholesterol to HDL. TFA consumption also increased serum triglyceride and lipoprotein levels and reduced LDL particle size in controlled trials indicating higher risk of coronary heart disease. Consumption of excess artificial *trans* fats in the diet are similarly linked to other illnesses such as long-term inflammation, insulin resistance,

and even some kind of cancer (breast cancer), especially for people with obesity or excess weight (Joe, 2023).

The Food and Drug Administration (FDA) banned the use of partially hydrogenated oil in most processed foods in the US in 2018. Intake of these fats has declined in recent years can be related to consumer awareness and action of legal regulatory bodies. In India, Food Safety and Standards Authority (FSSAI) also has reduced the levels of *trans* fatty acids (TFA) in oils and fats to 3 % for 2021 and 2 % by 2022 from 5 % limit. Commercial fat and oils samples can be analysed with advanced technology methods using Fourier transform infrared (FTIR) spectroscopy technique, which can determine *trans*-fats with greater accuracy as compared to Gas Chromatography.

Conclusion

Fats and oils are required in the diet (min. 20 % of daily calorie intake) as a source of essential fatty acids and vitamin E. Avoiding fats and oils in the diet is not a fair option to reduce *trans*-fat consumption. Industrial production of processed foods which contain hydrogenated oils should be discouraged and consumer awareness regarding the ill effects on health can bring down the use of *trans* fats in the diet.

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Microbial Inactivation by Engineered Water Nanostructures for Enhanced Food Safety

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In the field of food safety and quality, there is a growing need to develop innovative and sustainable approaches that do not involve chemicals, in order to combat foodborne illnesses. Among the various types of food, fresh produce has garnered increased attention from regulatory authorities, producers, and consumers, demanding stricter measures to ensure safety and quality. Fresh produce has been identified as a significant source of harmful microorganisms and has been associated with serious outbreaks of foodborne diseases. As the global trend towards healthier lifestyles continues, the consumption of fresh produce is on the rise. However, existing methods for disinfecting fresh produce heavily rely on the use of chemicals or irradiation, which are both flawed and face objections from consumers. Recently a new and innovative approach has emerged for eliminating microorganisms from surfaces such as fresh produce and stainless steel, as well as from the air. This method utilizes nanotechnology and does not require the use of chemicals. It involves the creation of engineered water nano-structures (EWNS) through the process of condensation, electrospraying, and ionization of water vapor present in the atmosphere. (Pyrgiotakis *et al.*, 2015).

Engineered water nano-structures (EWNS):

EWNS are nanosized water droplets carrying a strong electric charge and filled with free radicals, are produced by transforming atmospheric water vapor through electrospray. These engineered water nano-structures exhibit unique physical, chemical, morphological, and biological

characteristics. With an average size of 25 nm, they contain reactive oxygen species (ROS) such as hydroxyl and superoxide radicals. Additionally, EWNS possess a high electrical charge of around 10 electrons per particle on average. They are highly mobile and have an extended lifespan. When applied to food surfaces, EWNS have the ability to deactivate microorganisms responsible for foodborne diseases, making them a promising environmentally friendly method for disinfecting food (Pyrgiotakis *et al.*, 2015; Pyrgiotakis *et al.*, 2014).

Synthesis of EWNS:

A single “needle” EWNS generation system was developed to understand the EWNS synthesis processes. The process involves condensing atmospheric water vapor onto a Peltier element, which is then directed through tubing to a stainless steel needle (metal capillary). The metal needle is connected to a high voltage source and positioned above a grounded electrode, with the distance between them adjustable. By applying a high voltage (~6.5 kV) between the metal capillary and the counter electrode, two distinct phenomena occur: electrospraying and water ionization (Fig.1)

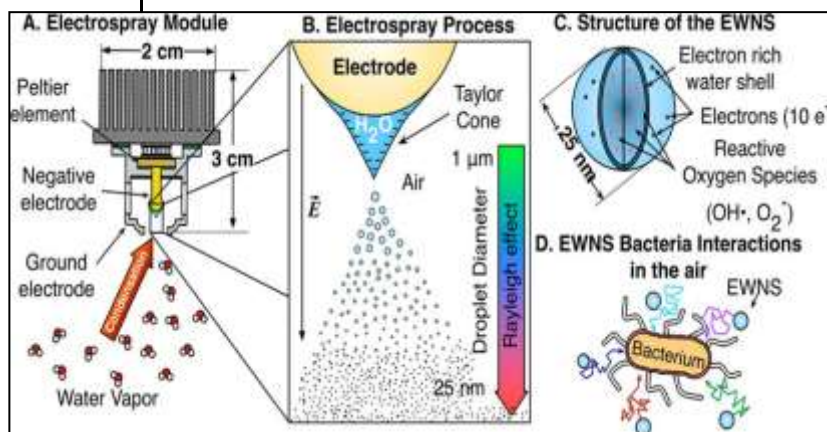


Fig.1. Synthesis of EWNS

Under the influence of the strong electric field between the electrodes, negative charges accumulate on the surface of the condensed water at the tip of the needle, resulting in the formation of a Taylor cone. This leads to the production of highly charged water droplets that continue to break into smaller particles according to the Rayleigh theory. Simultaneously, the high electric field causes some water molecules to undergo ionization, where electrons are stripped off. This process generates a significant number of reactive oxygen species (ROS). The ROS produced are encapsulated within the forming water droplets, resulting in the formation of EWNS. These engineered particles have a diameter of only 25 nanometers, making them 4,000 times smaller than the width of a human hair. Due to their high electric charge, they can remain suspended in the air for hours under indoor conditions. The small size of these nanoparticles enables them to be highly mobile, acting like tiny bombs that can move around and interact with microorganisms. By delivering the encapsulated ROS payload, EWNS can effectively deactivate microorganisms they come into contact with. Two different ways of delivering EWNS on surfaces were developed. In one method, EWNS were delivered to surfaces via diffusion by simply allowing EWNS to move around and find bacteria on surfaces; in another method high surface charge of EWNS facilitates the targeted delivery of the EWNS on the surface of interest using an electric field thus maximizing their efficiency.

Mechanism of Bacterial Inactivation by EWNS

Since EWNS contain ROs, the mechanism of inactivation is believed to be ROs mediated. ROs can cause cell membrane destruction, DNA damage and oxidation of cell proteins. Out of these mechanisms, cell membrane destruction was found to be the primary mechanism. EWNS exposed bacteria showed destruction of cell membrane and cell wall

resulting in loss of membrane integrity and shape of bacteria.

Application of EWNS in food safety

Antimicrobial potential of EWNS was assessed on a representative panel of food-related microorganisms. The researchers sprayed the surfaces of prewashed organic grape tomatoes and stainless steel chips with three lab strains of bacteria related to common food-borne pathogens: *Escherichia coli*, *Salmonella enterica*, and *Listeria innocua*. The researchers then exposed tomatoes to the EWNS at concentrations of 24,000 to 50,000 particles per cm³ in an enclosed chamber, for time periods ranging from 30 to 90 minutes. Steel surfaces were exposed for 15 to 45 minutes. Depending on the bacterial species and type of surface, the exposure could achieve inactivation up to 4 logs (99.99% reduction) without compromising sensory quality of food or leaving chemical traces making it an ideal technology for chemical free applications (Pyrgiotakis *et al.*, 2016). Role of EWNS in air disinfection was also reported. It was found that it can kill 70-100% airborne bacteria like *Mycobacteria* and *Serratia* in 30 min. Besides, it is energy efficient and has been shown by an acute in-vivo inhalation toxicological study that apparently possesses no health side-effects when EWNS are inhaled (Pyrgiotakis *et al.*, 2014). The antimicrobial potency of the EWNS can be further enhanced by integrating electrolysis, electrospray and ionization of de-ionized water in the EWNS synthesis process resulting in three times increase in ROS content and increased antimicrobial activity (Vaze *et al.*, 2018). Huang *et al.*, in 2021, introduced a new and innovative method for disinfecting leafy vegetables using a "dry" nano-aerosol-based antimicrobial technology. This approach involves the use of engineered water nanostructures (EWNSs) as nano-sanitizers. The EWNSs are created through a

combination of electrospray and ionization processes using aqueous solutions containing active ingredients that are generally recognized as safe. Very recently Vaze *et al.* (2022) reported the efficacy of EWNS technology as a nano-carrier for delivering a minuscule dose while inactivating human corona virus, making this an attractive technology against SARS-CoV-2.

Advantages of EWNS in food application:

- Chemical free, organic disinfection method
- Can be used across the food production and distribution chain
- Against Gram positive and Gram negative bacteria
- No effect on sensory quality
- No toxicological effects
- Can be used at normal temperature and pressure
- Cost-effective

Disadvantages of EWNS in food application:

- Only surface disinfection
- Needs smooth surface
- Cannot inactivate endospores of bacteria

Conclusion

In conclusion, the development of a novel, chemical-free method using engineered water nanostructures (EWNS) for food decontamination shows great promise. As researchers refine and scale up this technology, they aim to determine optimal conditions for maximum pathogen destruction and expand its application to various food pathogens and spoilage microorganisms. Furthermore, the versatility of this method opens doors to other potential applications such as wound healing, air disinfection, virus inactivation, and preservation of art and artifacts. While no method can guarantee complete eradication of microflora, this

environmentally friendly intervention offers a "green" alternative to conventional disinfection methods, holding significant potential for the food industry and beyond.

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Unveiling the Remarkable Nutritional Benefits of Donkey Milk

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When it comes to milk, we often think of cows or goats as the primary sources. However, there's a lesser-known milk that has gained attention for its impressive nutritional profile and health benefits – donkey milk. Although it may sound unusual, donkey milk has been consumed and valued for centuries. In this article, we will explore the unique nutritional benefits offered by donkey milk and delve into the reasons why it has been hailed as a hidden gem of the dairy world. Donkey milk is a nutrient powerhouse, packed with a variety of essential vitamins and minerals. It contains vitamins A, B1, B2, B6, C, D, and E, as well as important minerals such as calcium, magnesium, potassium, and phosphorus. These nutrients are vital for maintaining overall health and supporting various bodily functions, including bone health, immune system function, and cellular regeneration.

Production and consumption in the world

Italy has a long history of donkey milk production, particularly in regions like Sardinia and Sicily. The country is known for its high-quality donkey milk products, including milk for direct consumption and the production of cosmetics. It is often consumed as a standalone beverage or used in the production of dairy products like cheese and gelato. In recent years, China has seen a significant rise in donkey milk production. The demand for donkey milk in China is primarily driven by its use in traditional medicine and the cosmetic industry. It is often consumed as a tonic or used as an ingredient in health foods and supplements. France has a small but notable donkey milk industry, particularly in regions like Provence and Corsica. Donkey milk is often used in the production of luxury skincare

products. The milk is valued for its skin-nourishing properties and is used in the production of high-end beauty products. Spain has a long tradition of donkey milk production, particularly in the Andalusia region. Donkey milk farms in Spain cater to both local and international demand. Countries such as Serbia, Romania, and Bulgaria have a history of donkey milk production, with a focus on traditional uses and local consumption. Donkey milk production exists to a lesser extent in other countries, including Greece, Turkey, Morocco, and some South American countries. While donkey milk consumption is less prevalent, it can be found in smaller quantities in other countries where it is either locally consumed or utilized in specialized products like cosmetics and natural remedies. Overall, the consumption of donkey milk remains a niche market.

Nutritional properties

For those seeking a low-fat and low-cholesterol alternative to traditional dairy products, donkey milk is an excellent choice. It contains significantly less fat than cow's milk while providing similar levels of protein. Moreover, the milk's lower cholesterol content makes it a suitable option for individuals aiming to manage their cholesterol levels or reduce their intake of saturated fats. Donkey milk is renowned for its exceptional digestibility, making it an ideal option for people with lactose intolerance or sensitive digestive systems. It contains a unique protein profile that is structurally different from cow's milk, making it easier to digest. Additionally, the smaller fat globules in donkey milk can contribute to better digestion and absorption of nutrients. Donkey milk boasts immunological properties that can enhance immune system function

and support overall health. It contains high levels of lysozyme, lactoferrin, and immunoglobulins, which possess antimicrobial and antibacterial properties. Donkey milk exhibits higher antibacterial activity against *Listeria monocytogenes* and *Staphylococcus aureus* bacteria, making it potentially effective in the treatment of listeriosis and staphylococcosis. (Madhusudan et al., 2017). These components help protect against infections and boost the body's immune response. For individuals allergic to cow's milk or soy-based products, donkey milk can serve as a safe and nutritious alternative. It lacks the proteins (e.g., casein) and sugars (e.g., lactose) found in cow's milk that commonly trigger allergies. Its hypoallergenic nature makes it an appealing option for infants, children, and adults with known milk allergies or sensitivities. Donkey milk has a long-standing reputation for its positive effects on the skin. The milk's rich vitamin and mineral content, coupled with its gentle nature, make it a sought-after ingredient in various skincare and cosmetic products. Donkey milk-based soaps, lotions, and creams are known for their moisturizing, anti-aging, and soothing properties, helping to nourish and revitalize the skin. The bioactive and immune-supportive properties of donkey milk make it a beneficial fortifier for formula-fed infants. (Souroullas et al., 2018)

Role in Brain development

The role of donkey milk in brain development of humans is an area that requires further research and scientific investigation. While donkey milk is known for its nutritional composition and potential health benefits, limited studies have specifically examined its effects on brain development in humans. However, based on the nutritional profile of donkey milk, it can be inferred that it may have some positive contributions to brain health and development. Some of the key factors are Omega-3

Fatty Acids particularly docosahexaenoic acid (DHA), Essential Vitamins and Minerals, Bioactive Compounds: such as lactoferrin and immunoglobulins and Allergen-Friendly Nature.

Shelf life

Donkey milk, like other types of milk, has a shelf life that can vary depending on various factors such as the processing methods, packaging, and storage conditions. Generally, donkey milk has a shorter shelf life compared to cow's milk or goat's milk. Fresh donkey milk typically has a shelf life of around 1 to 3 days when stored in a refrigerator at a temperature of 4°C (39°F) or below. However, it is important to note that this timeframe can vary depending on the initial quality of the milk and the specific conditions during milking, handling, and storage. To extend the shelf life of donkey milk, various preservation techniques can be employed. One common method is pasteurization, which involves heating the milk to kill harmful bacteria and increase its shelf life. Pasteurized donkey milk can last for several weeks when refrigerated properly. It's worth mentioning that there are also powdered forms of donkey milk available on the market. Powdered donkey milk has a significantly longer shelf life, typically ranging from 12 to 24 months or more, depending on the manufacturer and storage conditions.

Donkey Milk Based Products available in world market

While donkey milk products may not be as widely available as those made from cow or goat milk, there are some brands and products that specialize in utilizing donkey milk. Some of the examples are ASINARA skincare products, Asinus Adoramus cosmetics, Mulier SRL dietary supplementation, El Greco Cosmetics, Nanibio facemask, lotions and serums, etc. It's important to note that the availability of these brands and

products may vary depending on your location and local retailers. Additionally, new brands and products may emerge as the demand for donkey milk-based items continues to grow. Checking online marketplaces, specialized retailers, or contacting local distributors can help in finding specific brands and products in your region.

Adverse effects or hazards

Some individuals may have allergies or sensitivities to donkey milk, just like with other types of milk. Allergic reactions can include symptoms such as hives, itching, swelling, difficulty breathing, or digestive issues. If you have known allergies to milk or any other animal products, it's important to exercise caution when consuming donkey milk. Like any raw milk, donkey milk can potentially be contaminated with harmful bacteria such as Salmonella or E. coli. These bacteria can cause foodborne illnesses, especially if the milk is not properly handled or stored. Additionally, maintaining proper refrigeration and storage temperatures is crucial to prevent spoilage and bacterial growth. Donkey milk contains certain proteins and enzymes that may interact with certain medications. If you're taking any medications or have specific health conditions, it's advisable to consult with a healthcare professional before consuming donkey milk to ensure there are no

potential interactions. It's important to note that donkey milk is not a substitute for medical treatments or formulas for infants with specific nutritional needs.

Conclusion

Donkey milk may be an unconventional choice, but its nutritional benefits are undeniable. With its impressive array of essential nutrients, easy digestibility, immunological properties, and potential as an allergen-friendly alternative, donkey milk has carved a niche for itself in the world of dairy products. Whether consumed for its health benefits or applied topically for skincare purposes, donkey milk continues to fascinate and captivate those seeking natural and wholesome options

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Hydrodynamic Cavitation- Overview and Application in Dairy Sector

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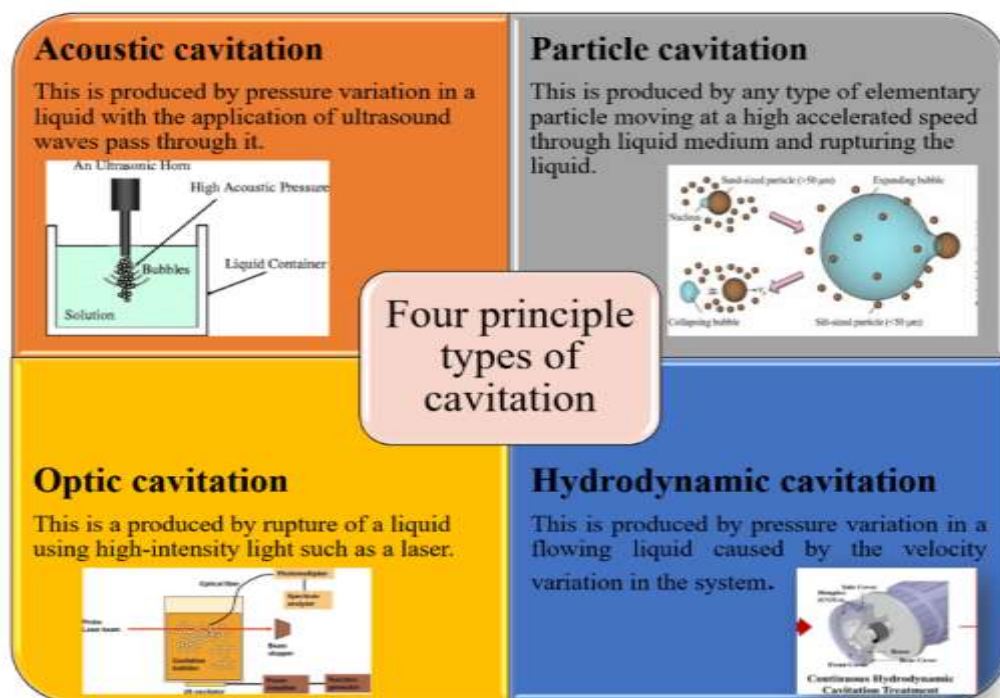
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Cavitation is a rapid phase-change event where bubbles form, develop, and burst in a liquid. It can be produced through acoustic, hydrodynamic, optical, and particle mechanisms. Cavitation has various applications in disinfection, cell disruption, sludge treatment, biodiesel synthesis, nano-emulsion production, and degradation of organic compounds. It releases high pressure and temperature, generates reactive free radicals, and enhances mass transfer. Cavitation offers energy-efficient and cost-effective operations when combined with other wastewater treatment techniques, reducing chemical usage. Optic cavitation (OC), particle cavitation (PC), acoustic cavitation (AC), and hydrodynamic cavitation (HC) are four different types of cavitation that may be categorised based on the mechanism of formation as shown in figure 1. Optical cavitation occurs when laser light converges in a liquid, causing localized energy deposit and bubble formation. Particle cavitation refers to cavitation induced by elementary particle beams. Acoustic cavitation utilizes ultrasound to induce pressure changes and chemical alterations. Hydrodynamic cavitation arises from pressure conversion to kinetic energy and flow separation in constrictive parts or irregular geometries.

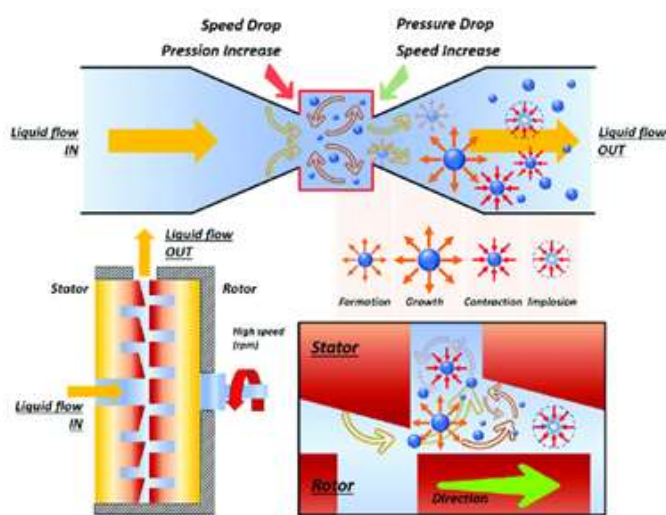
Figure 1: Four principle types of cavitation
Hydrodynamic Cavitation Mechanism

HC can be generated by pressure and flow changes using specific structures such as venturi tubes, nozzles, orifice plates, and rotating-type devices with rotor and stator designs. These structures act as throttle valves, causing an increase in flow rate or kinetic energy at the expense of pressure. Turbulence and boundary layer separation occur, resulting in energy loss. HC is produced by forcing liquid through a small orifice, increasing its kinetic energy. The process involves bubble nucleation, expansion, and implosion. At the vena contracta, the flow area is minimized, leading to a drop in liquid pressure according to the Bernoulli equation.

The flow area is minimized at the vena contracta, leading to a pressure drop as per the Bernoulli equation. Cavities form and expand when the local pressure falls below the cavitation threshold. The size of cavitation bubbles varies based on flow conditions. Throttling causes the pressure at the vena contracta to drop below the threshold,



resulting in the release of numerous cavities. These cavities collapse as the pressure further decreases, releasing a sharp shock wave of energy. This shockwave helps control rotor and liquid friction, providing scale-free heating.



(Source: Verdini *et al.*, 2021)

Figure 2: Cavitation mechanism (a) Venturi system (b) Rotor-Stator system

Effect of bubble collapse

A cavitation bubble becomes unstable and starts to collapse once it reaches its maximum size or comes into contact with a significant amount of pressure. Large amounts of energy are released into the surrounding liquids during the collapse in the form of thermal, mechanical, and chemical energy, as depicted in figure 4 (Gogate *et al.*, 2006).

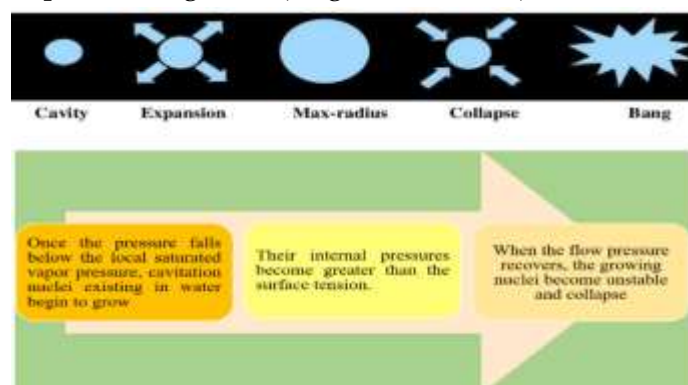


Figure 3: Phenomena of bubble formation and collapse

Mechanical Effect: High shear stress from the collapse of liquids causes shock waves, microjets, and other very damaging mechanical (physical) effects of HC. Rapid changes at the vapor-liquid interface can cause adiabatic compression of bubbles, which can result in shock waves. When the bubble wall reaches the point of maximum compression, it stops expanding and rapidly shrinks. At the start of the emission, high-pressure shock waves with significant nonlinear propagation properties are produced by contracting fluids reflecting back from the bubble interface. The velocity of a shock wave propagating in water is much faster than the speed of sound in water (roughly 1500 m/s), and it can reach pressures of up to 6000 or 7150 GPa, while travelling at speeds of almost 4000 m/s or 2000 m/s on average.

Thermal Effect: The cavitation bubble's gas and vapour are compressed by an implosion or collapse, which produces extreme heat and a local hot spot by raising the temperature of the liquid immediately around the bubble. The little hot spots raise the heating and cooling rates above 1010 K/s within milliseconds and are several thousand Kelvin in temperature. According to Suslick *et al.*, (1999), the heating effect, which is the cause of homogenous sonochemistry, is strongly dependent on the distance from the centre. There are three areas along the line: (i) inside the bubble, where the gas phase can reach its highest temperature of 4600 ± 200 K; (ii) at the interface, where the thin liquid layer immediately surrounding the collapsing bubble can reach a temperature of 1900 K (Suslick *et al.*, 1999); (iii) The temperature of the bulk medium is not immediately impacted by bubble collapse, though.

Chemical effect: Extreme bubble collapse conditions at the gas-liquid and gas-phase interface can break down dissolved oxygen (O_2) and water (H_2O)

molecules into reactive species such hydrogen atoms ($\bullet\text{H}$), oxygen atoms ($\bullet\text{O}$), hydroperoxyl radicals ($\text{HO}_2\bullet$), and other species. If there is no solute, these main radicals can produce H_2O , $\bullet\text{O}$, and O_2 . Hydrogen peroxide (H_2O_2) is created by the recombination of $\bullet\text{OH}$ and $\text{HO}_2\bullet$ either outside of the hot bubbles or at the cooler interface. Additionally, H and OH species can interact with H_2O_2 to produce HO_2 and OH .

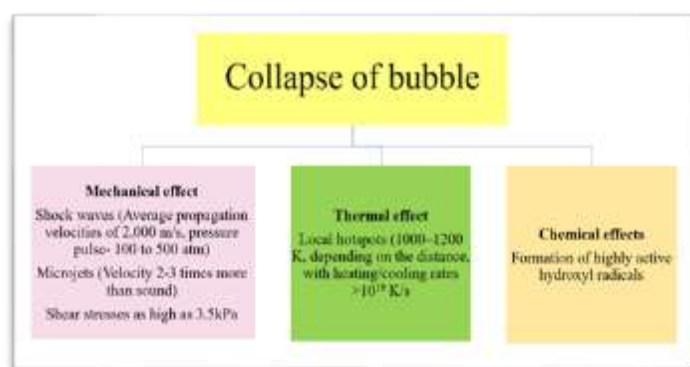


Figure 4: Effect of collapse of bubble

Applications in Dairy industry

HC was used by Milly et al. (2007) to pasteurise and sterilise liquid foods such tomato juice, apple juice, and skim milk by inactivating food spoilage microorganisms. According to their findings, HC introduced into the food chain effectively rendered yeast and lactic acid bacterium spores inactive. In the dairy processing industries, particularly in the production of milk powder, HC has various uses. The efficiency of HC in the inline application for fast rehydration of high protein milk powders for semi-industrial pilot size plant was examined by Pathania et al., (2018); they made a powder dispersion of milk protein concentration and ran it through the HC reactor. The end findings showed that, in comparison to samples that had undergone conventional treatment, the milk protein powder dispersion had a particle size distribution for full rehydration with higher stability to

sedimentation. Instant solubilization, wetting, dissolving, and immersion of protein milk powders dramatically reduced the apparent viscosity of the dispersion for HC samples

In the APV Cavitator, the characteristics of milk were examined, including protein interactions, heat stability, acid gelation, casein micelle particle size, and rennet coagulation of skim milk. They stated that the casein micelle particle size of the HC milk drastically changed from the control, and they also discovered that the gel strengths of the HC and conventional milk were comparable. Additionally, the impact on renneting characteristics was favourable. This demonstrated the possibility of HC as an alternative method for heating milk without forming scales in order to make yoghurt with little impact on other crucial milk qualities (Dahiya et al., 2015). According study done by Li et al., (2018), using HC improved the rheological and functional properties of milk protein concentrate while also having no effect on solubility. They recommended HC as an alternative to spray drying process with a positive effect on the rheological properties, such as a reduction in viscosity and elastic modulus of milk protein concentrate.

The ability of HC to recover cheese waste brines while almost eliminating the majority of natural microorganisms has also been demonstrated. The study examined how used brines from cheese production would react to (High Pressure Homogenizer Reactor) HPH at 150 MPa. There was a noticeable decrease in the microbial flora with each pass through the homogenization valve, both with and without temperature control. This lethal impact was caused by the product's exposure to the combined physical and mechanical stresses created by the homogenization valves. Five passes through the homogenization valve were sufficient to

completely inactivate native pollutants, and spiked brines treated with the same method also effectively eliminated spoilage and harmful microbes. The effects of HPH on brines used in cheese production are outlined in the paper in explicit terms.

For the first time, the CHC (continuous hydrodynamic cavitation) processing technology was created and effectively used by Sun et al. (2021) to inactivate microorganisms in milk. The CHC treatment temperature was lower (70°C) and the treatment time was shorter (1-2 s) than HTST (71-74 °C, 15-40 s). For *E. coli*, *S. aureus*, and *B. cereus*, respectively, log reductions of 5.89 (100%), 5.53 (100%), and 2.99 0.08 (99.85%) were attained under ideal circumstances, with a production rate of 4.2 L/min and a cost of \$0.00268/L. While the safety features of the CHC milk were equivalent to LTLT milk and lower than HTST and UHT milks, the effect of CHC on the nutritional content of milk was comparable to that of HTST. Milk, as well as other liquid food items with "fresh-picked" flavour, may be produced safely, healthily, and nutritionally using CHC as a viable replacement or supplementary technology. Future study is required to better understand how CHC affects bacteria, nutrient levels, and safety, as well as how to optimise CHC devices and procedures.

Conclusion

Hydrodynamic cavitation (HC) technology is an energy-efficient and cost-effective technique with practical industrial applications. It has the potential to enhance and preserve the functional properties of food and beverages in large-scale businesses, as well as in laboratories and pilot scales. However, not all types of cavitators yield favorable results, as the final product depends on the cavitator design and food composition. Further improvements are needed to

achieve higher quality products with extended shelf lives. Collaborative research in the food and dairy sector can leverage HC technology for energy-efficient and rapid advancements.

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Lactic Acid Bacteria (Lab), Classification, Desirable Characteristics and Its Role

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The term LAB refer to a taxonomically diverse group of Gram positive, facultative anaerobic, non-spore forming, non-motile and acid-tolerant cocci, coccobacilli or rods that appear as single cells or pairs, tetrads or long chains with common metabolism and physiology capable of fermenting sugars primarily into lactic acid. LAB are found in two phyla, the Firmicutes and the Actinobacteria. Firmicutes include genera of LAB such as Lactobacillus, Streptococcus, Leuconostoc, Enterococcus, Pediococcus that are low in G + C with 31–49 %, belonged to the Bacillus class and the Lactobacillales order, while the Bifidobacterium genus with a high G + C content (58–61 %) belonged to the Actinobacteria phylum. LAB are a group of Gram-positive bacteria which produce lactic acid as a main fermentation product into the medium. The main groups include Lactobacillus, Leuconostoc, Pediococcus and Streptococcus. Lactic acid bacteria are the most commonly used starters in fermented milk products like curd, yogurt, cheese and so on.

Classification of starters LAB

The starters used in fermented milk product preparation are classified as mesophilic and thermophilic based on optimum growth temperature. Mesophilic starters include Lactococci, Pediococci, Leuconostoc, Lactobacillus brevis, while *Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus*, *Lb. acidophilus* belong to thermophilic starters. Based on fermentation, starters may be homofermenters or heterofermenters or miscellaneous fermenters. Homofermenters like

Lactococci, *Streptococcus thermophilus*, *Lactobacillus delbrueckii* ssp. *bulgaricus*, *Lb. acidophilus* that produce only lactic acid; heterofermenters include Leuconostoc, *Lb. brevis*, *Lb. fermentum*, *Bifidobacterium* spp that produce lactic acid, other acids like acetic acid or ethanol with or without carbon dioxide; *Propionibacterium freudenreichii* ssp. *shermanii*, *Kluveromyces*, *Torula* are included under the miscellaneous starters that yield other acids (propionic acid, acetic acid) or ethanol with carbon dioxide.

LAB can be mainly divided into two groups based on the end products formed during the fermentation of glucose. Homofermentative LAB such as *Pediococcus*, *Streptococcus*, *Lactococcus* and some *Lactobacillus* produce lactic acid as the major or sole end product of glucose fermentation. Homofermentative lactic acid bacteria use the Embden-Meyerhof-Parnas pathway to generate two moles of lactate per mole of glucose and derive approximately twice as much energy per mole of glucose as heterofermentative lactic acid bacteria. Heterofermentative lactic acid bacteria such as species of *Weissella*, *Leuconostoc* and some 13 *Lactobacillus* produce equimolar amounts of lactate, CO₂ and ethanol from glucose via the hexose monophosphate or pentose pathway.

The classification of LAB into different genera is largely based on morphology, mode of glucose fermentation, growth at different temperatures, configuration of the lactic acid produced, ability to grow at high salt concentrations,

and acid or alkaline tolerance. The LAB group is currently classified in the phylum Firmicutes, class Bacilli, and order Latobacillales. LAB are classified based on cellular morphology, mode of glucose fermentation that include Lactobacillus, Lactococcus, Leuconostoc, Pediococcus Streptococcus, Aerococcus, Alloiococcus, Carnobacterium, Dolosigranulum, Enterococcus, Oenococcus, Tetragenococcus, Vagococcus and Weissella with Lactobacillus being the largest genus, including more than 100 species

that are abundant in carbohydrate rich substances.

Desirable characteristics of LAB

LAB are rod shaped bacteria as lactobacilli while cocci shaped bacteria include Lactococcus, Streptococcus, Leuconostoc and Pediococcus under LAB. Lactic acid bacteria are prokaryotic in nature having the following general characteristics: they are non-spore formers, do not produce catalase and cytochrome oxidase. Most are non-pigmented. They are facultative anaerobic to microaerophilic in nature. They ferment sugar with lactic acid as major end product or other acids and/or may be gases. These are nutritionally fastidious bacteria requiring specific growth factors such as vitamins, amino acids and minerals. They are unable to use complex carbohydrate like starch and cellulose.

The desirable characteristics of lactic acid bacteria include:

- It should be non-pathogenic in nature.
- Should produce desirable characteristics in milk required for fermented milk products (flavour & textural changes).
- Should dominate competitive microflora.

- Should be easily propagated, easily preserved, should be stable during culturing and storage.
- Probiotic cultures used in FMP should be of human origin and resistant to HCl of stomach and bile of intestine.
- Able to colonize in intestine and bring beneficial properties like inhibition of putrefactive bacteria, produce anticholesterolemic, anticarcinogenic properties, bacteriocin production, calcium absorption and vitamin synthesis.

Function	Changes	Effect
Primary	Lactic acid production	Inhibit undesirable bacteria like Pseudomonas, Micrococci
Secondary	Acid coagulation of milk	Curdling effect on milk
	Flavor production of diacetyl; acetaldehyde by aroma producing LAB	Curdling effect on milk
	Bacteriocins are polypeptides synthesized by LAB, example - Nisin - Lactococcus lactis ssp. lactis NIZO2218, Acidophilin from Lactobacillus acidophilus	Suppress potential pathogens and spoilage organisms - S. aureus, Micrococci & bacterial spores.
	Some LAB, example Lactobacillus helveticus produce exopolysaccharide	Improves texture by increasing the viscosity of fermented milk products.

Role of LAB

Species of *Lactobacillus*, *Leuconostoc*, *Lactococcus* and other LAB are the most frequent microbes found in fermented milk products. LAB can be found in a variety of genera within the *Lactobacillaceae* family. They are potential microorganisms that have been frequently used in food fermentation around the world because of their well-known GRAS (Generally recognized as safe) status. They are also known for their fermentative abilities, which help to improve food safety, organoleptic qualities, nutrient enrichment and health advantages.

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CFD Simulation of Transport Phenomena in Dairy Processing Applications

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Computational fluid dynamics (CFD) is a powerful tool for simulating fluid flow and heat transfer in various industries. It combines fluid mechanics, mathematics, and computer science to solve governing equations using computer software. Its application has gained global attention since the emergence of digital computers. CFD

simulations offer advantages over empirical experiments. It allow exploration of any location in the region of interest and interpretation of performance using multiple thermal and flow parameters. Simulations are cost-effective compared to traditional experiments, as they provide engineering data for design without the need for costly physical testing. CFD enables modeling of various process conditions and simulation of difficult-to-test flow and heat transfer processes. It provides control over the physical process, allows isolation of specific phenomena for research, and can be performed more quickly than laboratory tests. Simulations facilitate early modifications in the design process.

Understanding transport phenomena in dairy processing is crucial for process analysis, prediction and design. CFD is a valuable tool for solving complex problems related to momentum, heat, and mass transfer. Visualizing simulation results through attractive color figures and animations aids in interpreting physical phenomena, improving process and product quality.

2. Stages in performing a CFD analysis

To conduct a CFD analysis, the analyst formulates the problem mathematically, utilizes

CFD software to represent the problem scientifically, and performs calculations using the computer. The resulting data is then examined and interpreted by the analyst. Three key steps are involved in CFD simulation.

Pre-processing: All the tasks that take place before the numerical solution process are called pre-processing. This includes problem thinking, meshing and generation of a computational model.

1. **Problem thinking:** Before committing to practice, it is worth thinking about the physics of the problem that is faced. In this stage, the analyst should consider the flow problem and try to understand as much as possible about it.
2. **Meshing:** In this stage, the analyst creates the problem domain shape using a CAD program. The domain is divided into cells or volumes using meshing, which can be done within the CFD package.

Defining Boundaries: The problem domain boundaries and their corresponding boundary conditions are established in the initial stage of a CFD simulation. This information, along with fluid parameters and physical properties, defines the specific flow problem to be solved. Advanced CFD software packages provide tools for grid generation, boundary definition, application of conditions, specification of initial conditions, setting fluid properties, and controlling numerical parameters.

Processing: Processing involves solving fluid flow equations using a computer. Meshing is followed by specifying input values and solving equations for each cell until convergence. This iterative process is

the core of CFD software with limited visibility, but time-consuming.

Post-processing: The CFD post-processing program evaluates generated data, enabling numerical and graphical analysis of model results. It includes 2-D and 3-D visualizations like mesh sections, velocity vector plots, and scalar variable contour plots using color for differentiation. Results analysis ensures solution satisfaction and extraction of required flow data.

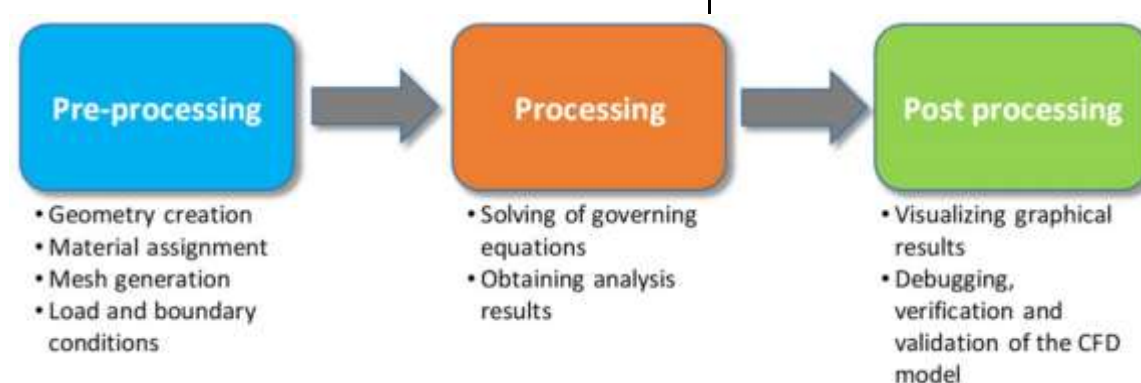


Figure 1: Stages in performing CFD analysis

Applications in simulations of transport phenomenon in the dairy processing:

Sterilization and pasteurization

Heat treatment equipment can be categorized into direct and indirect systems. Any heat treatment focuses on temperature, time, and the chemical and physical properties of the products, including the slowest heating zone. Ghani *et al.*, (2000) used CFD to simulate the process of sterilization. In the study, natural convection that occurs during sterilization in a pouch heated from all sides was simulated. The results showed different temperature profiles during sterilization process which highlight the migration of the slowest heating zone. Moreover, the dependency of concentration of alive bacteria on the temperature distribution was shown. The work assumes that the rate of bacterial inactivation is consistent with the first-order kinetics. The reaction rate constant is a

function of temperature and is usually described by Arrhenius equation.

$$K_T = A \exp (-E/RT)$$

Accurate kinetic parameters such as reaction rate constants and activation energy were required to predict quality changes during food processing. Decimal reduction time is most commonly used. The relationship between the reaction rate constant and the decimal reduction time (D) is calculated according to following equation.

$$k_T = (2.303/D)$$

In the simulation, the value of the decimal reduction time at 121°C for Clostridium botulinum was

0.1 min, and the value of activation energy was $30 \times 10^4 \text{ J mol}^{-1}$. The reaction rate constant k_T was calculated using above equation. Further, above equation is used to calculate the 'A' constant of Arrhenius equation ($A = 2.5 \times 10^{11} \text{ s}^{-1}$).

Anand Paul *et al.*, (2011) developed a CFD models for low and high temperature pasteurisation of canned milk for the first time and validated with the experiments. Moreover, the effect of can rotation (5, 50 and 100 rpm) on processing time and pasteurization value was investigated. A uniform heating (due to absence of slowest heating zone) of milk with reduced processing time was achieved in the rotated canned milk processing. Further, the study indicated that rotation process helps in maximum inactivation of microbes in shorter processing time.

Cooling and refrigeration

CFD simulations are extensively utilized for air flow calculations in designing refrigeration and freezing systems in the food industry. Temperature is a key parameter in determining the microclimate around food products. CFD enables optimization of cooling and freezing processes, including classic refrigeration devices and innovative freezing methods, to enhance efficiency, time, and energy utilization.

In ice cream manufacturing, freezing is a critical step that influences ice cream crystallization. Factors such as multiphase flow, ice crystal nucleation and growth, phase change, and viscous shearing impact the process. Miller *et al.*, (2011) conducted a study simulating ice crystallization in ice cream manufacturing. They focused on the dynamic freezing of sucrose solutions in a scraped-surface heat exchanger, examining the effects of multiphase phenomena, phase change, and shear on ice crystal nucleation and growth kinetics. Alvarenga *et al.*, (2021) utilized CFD simulations to analyze the maturation conditions of traditional sheep cheeses, specifically studying the effects of environmental factors such as humidity and temperature on the physicochemical and microbiological properties of the product.

Mixing

Mixing is a crucial process in dairy processing, ensuring homogeneity of different particles and components. CFD serves as a powerful tool for modeling mixing processes, including homogenization, solid mixing, and mixing of Newtonian and viscoelastic fluids. Additionally, CFD has been used in designing industrial mixers for fluid foods.

Homogenization

Homogenization is essential in food and dairy industries for creating emulsions and improving product quality. Understanding the valve's flow structure is crucial for optimizing homogenization devices in terms of energy efficiency and performance. CFD provides insights into turbulent structures in homogenizer valves, including velocity, pressure, and turbulent kinetic energy. Previous research used k- models with RANS equations for valve flow field analysis, yielding satisfactory results. However, limited studies focused on two-dimensional models with different k- models. Håkansson *et al.*, (2012) studied a three-dimensional valve and found inaccuracies near the gap exit and in reproducing turbulent kinetic energy at the gap entrance. The main understanding of flow structure in homogenizer valves are based on RANS approaches, exhibiting general information on the flow inside the valve with the time-averaging scheme. The "steady-state" RANS cannot reflect a detailed picture of instantaneous velocities or fluctuations that vanish due to the averaging process.

Mixing tank

Mixing tank is a device used for mixing one or more phases of matter with same or different physical and chemical characteristics, through the application of mechanical force. With the help of CFD, the phenomena in an agitated vessel can be predicted.

During mixing, a common method of enhancing the process is to use some kind of stirrer or paddle. CFD codes have been applied to optimize mixing by minimizing energy input and processing time. Previous research focused on energy distribution and mixing quality based on stirrer position, which was previously impossible to

predict. CFD modeling of mixing in stirred tanks by Sahu et al. (1999) addressed impeller-vessel geometry, energy balance, and flow-field design linkage. The predicted mixing time values showed good agreement (within 5-10%) with published experimental data, using a 3D unsteady, pressure-based solver with a K-epsilon (RANS) turbulence model.

Designing of heat exchangers

CFD has found application in many areas of research of different types of heat exchangers: improper distribution of fluid flow, contamination, pressure drop and thermal analysis in the design and optimization phase. In simulations of processes with the use of heat exchangers, various turbulence models are used, e.g. standard k- ϵ , realizable k- ϵ , RNG k- ϵ and SST k- ω . Speed-pressure coupling schemes such as Semi-Implicit Method for Pressure Linked Equations (SIMPLE), Semi-Implicit Method for Pressure Linked Equations-Consistent (SIMPLEC), Pressure-Implicit with Splitting of Operators (PISO) are used to perform the simulation. In most cases, simulations give results in good agreement with experimental studies in the range of 2% to 10%.

The reliability of CFD results has reached the point where it has become an integral part of all design processes, leading to the elimination of the need for prototyping. The studies conducted by Piepiórka-Stepuk and Diakun (2014) shown that the design of the plate surface is a key issue in the development of heat exchangers. This work allowed simulating the distribution of fluid flow velocity in the channel between heat exchanger plates with different surface shapes. The results showed that the velocity field and streamlines favour the use of panels with a corrugated surface. The velocity

distribution in the duct between the heat exchanger plates is an important parameter of the cleaning efficiency of a damaged system.

Spray Drying

CFD simulations are crucial for understanding and enhancing the spray-drying process, as obtaining measurements of air flow, temperature, particle size and humidity in large-scale dryers is challenging and costly. Advanced techniques like particle image velocimetry (PIV) and temperature/humidity sensors can complement CFD simulations to provide detailed insights into the flow pattern and conditions inside the drying chamber. Submodels in CFD simulation include particle tracking, droplet drying (heat and mass transfer), and particle quality. Accurate heat dose selection and process optimization are crucial for nutritional value preservation and avoiding harmful compound formation. Optimization using CFD offers economic benefits by reducing energy consumption (Kuriakose & Anandharamakrishnan, 2010).

(i) Drying fluid flow simulation in the drying chamber

The air-flow pattern in the chamber affects the movement of the particles, which subsequently effects the residence time of the particles, drying rates (i.e. heat and mass transfer) and whether the particles are deposited on the chamber wall or escape through the outlet pipe. Hence, getting an accurate prediction of the flow field in the drying chamber is a prerequisite for the subsequent modelling effort. Most spray dryer CFD simulations are performed using commercial codes such as FLUENT, CFX and STAR-CD software tools.

Turbulence modeling

Selecting an appropriate turbulence model is crucial for spray-drying simulation, considering accuracy and computational requirements. The standard $k-\epsilon$ model is commonly used due to its robustness, low computational demand, and reasonable accuracy. While effective for simple flows, it struggles to capture complex flow patterns, like swirling flows in counter-current spray dryers, where swirling effects are not considered. Thus, an optimal turbulence model should be chosen to accurately simulate fluid flow in spray dryers.

Bayly *et al.*, (2004) reported that the RSM can give better results for turbulent swirling flows in a counter-current spray dryer. The shortcoming of the standard $k-\epsilon$ model is attributed to its assumption of isotropic turbulence. Other $k-\epsilon$ related models, such as the renormalized $k-\epsilon$ (RNG) and realizable $k-\epsilon$ (RKE), accommodate the swirling flow model and mathematical function to ensure positivity in turbulence stresses.

Chamber design and flow configuration

The effect of different chamber geometries (cylinder-on cone, lantern, hour-glass and pure cone) on the drying performance and the particle residence time was studied by Huang *et al.*, (2003). They suggested that it is possible to change the chamber geometry for better utilization of the dryer volume. The use of CFD to obtain uniform flow distribution in a plenum chamber with a single, off-axis, inlet pipe was studied by Southwell *et al.*, (2000). The flow distribution was investigated and the result was confirmed by experimental data for selected configurations. They concluded that CFD can be used for several design alternatives for overcoming poor flow distribution. Apart from the conventional vertical design of the spray dryers, the use of horizontal design is gaining importance nowadays.

Studies revealed that use of good chamber design and incorporation of fluidized bed will improve the drying performance. In spray drying, the majority of works of CFD simulations have been performed on co-current flow.

Conclusion

CFD is a powerful tool used in the food industry for understanding physical phenomena in 2D and 3D geometries. It has wide applications in the dairy industry, from processing to packaging. CFD simulations optimize flows, temperature distribution, and mechanical changes, leading to process optimization and cost reduction. In the future, CFD will be indispensable for enhancing process efficiency in the dairy and food industry.

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Shelf-Life Prediction of Cheese

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Consumers are increasingly concerned about the safety and quality of the food they consume, and they prioritize products that meet strict safety guidelines. Shelf life and food safety are two interlinked concepts, where proper shelf-life assessment is required to ensure food safety. According to Institute of Food Science and Technology (1993), the shelf-life of a food product is described as the period it will remain safe, retain intended sensory, chemical, physical, and microbiological properties, and conform with any label declaration of nutritional data when it is stored under the specified conditions. Thus, the shelf-life of a food is the period upto which the primary characteristics of a food remains acceptable to the consumers in view of its safety and organoleptic quality.

Shelf-life prediction in the food industry holds immense significance as it enables manufacturers to make decisions about product formulation, packaging, storage, and distribution. By accurately estimating the duration for which a food product can retain its quality and safety, businesses can minimize waste, optimize inventory management, and enhance consumer satisfaction. Predicting shelf life allows manufacturers to establish appropriate storage conditions, determine expiration dates, and implement effective quality control measures. It also aids in complying with regulatory requirements, reducing financial losses due to spoilage, and building consumer trust by ensuring consistent product quality. Ultimately, reliable shelf-life prediction serves as a valuable tool

for ensuring food safety, minimizing waste, and maximizing efficiency across the food supply chain.

Cheese is the most diverse dairy product, often comes under fermented milk product. It is a perishable commodity due to the dynamic microbiological and biochemical changes that occur throughout manufacturing, ripening, and marketing (Jafarzadeh *et al.*, 2021). Cheese production consist of perfectly coordinated series of sequential and concurrent biochemical events during the manufacturing and ripening phases.

Factors affecting shelf life of Cheese

The storage stability of various cheese varies from low (e.g., Camembert, Cottage cheese) to high (e.g., Parmesan). The shelf life of product is controlled by intrinsic and extrinsic factors. Intrinsic factors that affect the shelf life of cheese are the microbiological profile and indigenous enzymes of cheese milk; the gross composition of curd and cheese, that is, residual lactose, salt, protein and fat content; physiochemical conditions of cheese, that is, pH, water activity (a_w) and redox potential (E_h). Salt, pH, water activity and redox potential prevent the growth of pathogens in cheese and minimize spoilage. Extrinsic factors of shelf life of cheese are related to processes and treatments applied during cheese making and throughout ripening and storage, that is, temperature/time combinations, hygiene, storage and distribution conditions are very important (Moschopoulou *et al.*, 2019).

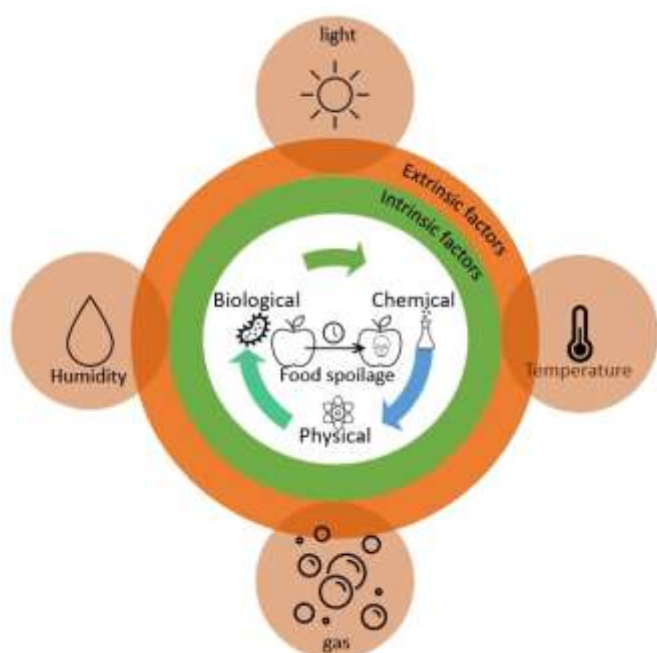


Fig. 1 General factors affecting shelf life of food
(Source: Choachamnan, 2022)

Shelf-life Assessment of Cheese

Shelf-life assessment considers the specific characteristics of the food product, packaging, and anticipated storage conditions to ensure accurate and reliable shelf-life predictions. It involves three steps: preliminary step, testing and modelling (Nicoli, 2012). Deterioration of food can be due to physical, chemical or biological reactions. In the preliminary step, the factor which has most impact on the quality of food is identified along with the critical indicator which shows the deteriorative event. The acceptability limit of the critical indicator is also described, which distinguish the acceptable product from that having quality changes. The quality indicators can be determined using instrumental analysis (e.g., spectrophotometer, colorimeter etc.), sensory evaluation (Descriptive analysis, consumer acceptance testing, triangle test, hedonic scaling) or by analytical methods (peroxide value, thiobarbituric acid index, GC-MS etc.).

During testing, which can be real time or accelerated, the packed food product is monitored for decay in quality under simulated storage conditions. The shelf life of a food product is a result of complex interaction between intrinsic food features, packaging-related factors, and environmental factors (Calligaris *et al.*, 2019). Practically, testing under actual condition is possible only when it has low storage life i.e., highly perishable food. Shelf-life estimation can be done using real time testing while it is predicted with accelerated testing conditions. In accelerated shelf-life testing, the intrinsic and extrinsic factors are kept constant and the environmental conditions (temperature, %RH, light etc.) are set to accelerate the deterioration of food. Accelerated shelf-life testing is conducted when the quality depletion rate grows as a function of the intensity of the preferred accelerating factor. To that end, the selected quality indicator should be monitored during storage at various degrees of accelerating factor intensity.

Different types of cheese have varying shelf life due to their unique compositions, manufacturing processes, and ageing requirements. Soft and fresh cheeses, such as mozzarella and cottage cheese, have shorter shelf lives, typically ranging from a few days to a few weeks. Semi-hard and hard cheeses, like cheddar and Parmesan, can have significantly longer shelf life, often extending from several months to years. The ageing process and proper storage conditions contribute to the development of desirable flavors and textures in aged cheeses. Shelf-life testing of cheeses is an important aspect of ensuring their quality and safety throughout their expected storage period. Several studies have been conducted to evaluate and predict the shelf life of cheeses using various methods. Park *et al.*, (2014) conducted accelerated shelf-life study of cheese and

found a shelf life of 0.2 months at 35°C. Studies on sliced vacuum-packaged fresh cheese used accelerated shelf-life testing to predict its shelf life. These studies include monitoring of the changes in quality attributes, such as microbial counts and sensory properties, and researchers developed models to estimate the remaining shelf life based on the accelerated testing data. Gürsoy and Altuntas (2020) studied shelf life of Halloumi cheese using sensory and microbial analyses. They evaluated the sensory attributes and microbial quality of the cheese during storage and determined the shelf life based on the changes observed in these parameters. Near infrared spectroscopy is used to predict the shelf life and sensory quality of protected designation of origin (PDO) cheeses. The developed models based on the spectral data to estimate the remaining shelf life of the cheeses and assessed their sensory quality throughout the storage period. Further, to predict the shelf life and to study the changes in quality attributes over time in cheese, statistical models and accelerated testing are used.

Shelf-life modelling uses mathematical or statistical models to predict the changes in quality of food product over time. These models can estimate the shelf life under different storage conditions without the need for extensive real-time testing. The use of a mathematical model is substantially less expensive, faster in execution, and allows for simulation. That is, multiple shelf-life estimations can be obtained by adjusting one or more model parameters, evaluating the effects of various components, and making predictions about the behaviours in various settings (Piergiovanni and Limbo, 2019). Predictive modelling combines data from different sources to make predictions about product quality and safety over time. Schmidt and Bouma (1992) used Weibull hazard analysis

technique to fit shelf-life data (pH, microbial count, sensory characteristics, percent free whey) of cottage cheese to various statistical models. Favati *et al*, (2007) employed predictive modelling to evaluate the shelf life of Provolone cheese packed under protective atmosphere. Kamleh *et al*, (2012) estimated the shelf-life of stored Halloumi cheese using survival analysis with consumer rejection as a failure index. Goyal and Goyal (2012) used Linear Layer (Design) and Multiple Linear Regression models for predicting the shelf-life of processed cheese stored at 7-8°C. Dalzini *et al*, (2017) used predictive models to check the growth of *Listeria monocytogenes* during storage life Gorgonzola cheese. Diblan and Kaya (2023) reported the shelf-life modelling of kaşar cheese packaged with potassium sorbate, nisin, silver substituted zeolite, or chitosan incorporated active multilayer plastic films.

Conclusion

Accurate prediction of the shelf life of cheese is a vital aspect of ensuring food safety, quality, and consumer satisfaction. Researchers and manufacturers are continuously improving their ability to estimate the optimal storage period for different types of cheese. The development of data-driven approaches further enhances the precision and reliability of shelf-life predictions. Through these advancements, we can minimize waste, optimize inventory management, and guarantee that consumers enjoy cheese at its peak freshness. The ongoing efforts to predict the shelf life of cheese contribute to a more sustainable and efficient food industry.

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Encapsulation of Probiotic Cultures for Dahi using Spray and Freeze Drying

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In recent years, the demand for functional probiotic foods has increased worldwide due to the rising awareness of consumers regarding their health and the beneficial effects of probiotics. As a result, food producers have begun to place a greater emphasis on creating functional and probiotic foods. Probiotics are "live microorganisms that, when administered in sufficient amounts, confer a health benefit on the host," according to FAO/WHO (2001). For a product to provide the claimed health benefits, the amount of live probiotic bacteria in it at the time of intake should be greater than 10 CFU/100 g, according to the Food Safety Standards Authority of India (FSSAI). Prebiotics, on the other hand, are food ingredients that stimulate bacterial development and favour helpful bacteria in the stomach over unfavourable ones. About 30 live microorganisms and 16 compounds have received FSSAI approval for use as probiotics and prebiotics in food. The 10-100 trillion bacteria that make up the human body are mostly found in the gut and are generally referred to as the microbiota. Due to its potential to increase the viability and stability of these advantageous microorganisms, the encapsulation of probiotic cultures has attracted substantial attention in the field of food science and technology. Live bacteria and yeasts known as probiotics have a variety of positive health effects when taken, especially in fermented dairy products like *dahi*.

Probiotics *dahi* culture

The balance of gut health is maintained in large part by probiotic culture. They enhance the

host's intestinal microbial balance, which benefits the host's health. Lactobacillus, Streptococcus, Enterococcus, Bifidobacterium, Saccharomyces, and other probiotic species are examples. Probiotic strains can protect the GI tract and epithelial cells, reduce inflammation in the gut, control antibodies, reduce lactose intolerance, prevent colorectal cancer, and inhibit the growth of harmful bacteria like *Helicobacter pylori*, among other benefits to human digestive health. According to Roobab *et al.* (2020) and Sharif *et al.* (2020), probiotics aid in the treatment of food allergies and the prevention of acute diarrhoea. The intestinal microbial equilibrium is preserved with the aid of probiotic microorganisms. Probiotic products improve human immunity and guard against oxidative damage to proteins and lipids, and reduce pathogens in the body.

Benefits

Probiotic *dahi* culture offers numerous health benefits due to the presence of live bacteria that promote a healthy gut and overall well-being.

- Improved Digestive Health
- Enhanced Immune Function
- Alleviation of Diarrhoea and Irritable Bowel Syndrome (IBS)
- Management of Lactose Intolerance

Microencapsulation

There are several different microencapsulation procedures, including spray drying, coacervation, fluidized bed coating, and emulsion-based techniques. The preferred characteristics of the encapsulated substance and the

intended application determine the technology to use. The active component or core material is initially disseminated or dissolved within a covering substance known as the shell or matrix during the microencapsulation process. Depending on the demands of the application, different core-shell combinations may be used. Lipids, proteins, natural or manufactured polymers, or a combination of these, may make up the shell material.

The heat-sensitive probiotic could, however, be vulnerable to heat inactivation while drying. To avoid cellular damage and improve the survival of probiotics, thermal and cryoprotectants can be utilised during spray and freeze drying. The most widely used protectants include skim milk, sucrose, trehalose, maltodextrin, whey protein concentrate (WPC), and whey protein isolate (WPI). By forming hydrogen bonds with biomolecules and interacting with components of the cell wall, these protectants play a crucial function in shielding probiotic cells from cold shock and thermal stress. They have control over the temperature at which the bacterial cell membrane transitions to glass.

Using a variety of characterisation approaches, the size, shape, and surface morphology of dried probiotic cultures can be determined. Techniques like differential scanning calorimetry (DSC), Fourier transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), etc. were applied. These methods of characterisation provide an insight into the nature of probiotic culture encapsulation.

Spray drying

Spray drying is a widely employed technique for the encapsulation of probiotic cultures. The process involves atomizing a liquid mixture of probiotics and carrier material into a hot drying

chamber. The carrier material, typically a carbohydrate-based matrix, acts as a protective shield around the probiotics, preventing their exposure to adverse environmental conditions. The atomized droplets quickly dry, forming microspheres or powder particles containing the encapsulated probiotic cultures.

Spray drying has the benefit of rapid as well as continuous encapsulation of probiotics, even though it provides rather poor survivability due to high drying temperature. It is an economic process with high production rate. Spray drying is also used to encapsulate probiotic cultures in the dairy and pharmaceutical industry. In this process, the suspension solution of microbial cells with wall material is atomized into the drying chamber, followed by rapid evaporation of water (Corcoran *et al.*, 2004). The atomized spray droplets come in contact with hot dry air inside the drying chamber. Water is evaporated by the heat in drying air, and the probiotic cells are dried into powder. The dried solid particles are separated from the drying air and are collected at the bottom part of the drying chamber. It is a rapid and cost-efficient method that produces spherical powder particles with desired properties such as specific residual moisture content, uniform shape and size. The dried solid particles are separated from the drying air and are collected at the bottom part of the drying chamber. It is a rapid and cost-efficient method that produces spherical powder particles with desired properties such as specific residual moisture content, uniform shape and size.

Freeze drying

Freeze drying, also known as lyophilization, is another popular method for probiotic encapsulation. In this process, the probiotic cultures

are first frozen and then subjected to vacuum conditions. This causes the frozen water within the culture to sublime, bypassing the liquid phase and transforming directly into vapor. The resulting product is a dry powder with the probiotics encapsulated within, offering enhanced stability and extended shelf life.

Low temperature attainment and cold harm to microorganisms are drawbacks of freeze drying, however these are overcome by the benefits of cryoprotectants utilised in the process. Therefore, probiotics are frequently encapsulated through freeze drying. Freeze drying, in contrast, is based on sublimation, in which water in the solid state instantly transforms into a vapour state. Three processes make up the process: freezing, primary drying, and secondary drying. When samples are frozen, any water present crystallises at extremely low temperatures and separates away. During primary drying, the water in the frozen form is eliminated by sublimation. Desorption-based secondary drying is used to remove any remaining non-frozen water. Low freezing temperatures have the potential to alter the physical state of membrane lipids if handled carelessly.

Electrospinning

Electrospinning is a versatile technique used for the encapsulation of probiotic cultures, offering unique advantages in terms of structure and functionality. This method involves the use of an electric field to create ultrafine fibres from a polymer solution or melt. When applied to probiotic encapsulation, electrospinning provides several important benefits like biocompatibility, enhanced protection that contribute to the viability and stability of the cultures.

Comparison between spray and freeze drying techniques

The specific characteristics and outcomes of spray drying and freeze drying can vary depending on the specific parameters and conditions used in each process. The comparison between spray and freeze drying techniques for probiotic encapsulation is given in Table 1.

Table 1. comparison between spray and freeze drying techniques

Differences	Spray Drying	Freeze Drying
Process	Atomization of liquid feed inside a hot chamber	Freezing and sublimation under vacuum
Viability and survival rate	Lower due to high temperature drying process	Potentially higher due to processing at lower temperature
Moisture sensitivity	Offers better resistance to moisture due to case hardening	More susceptible to moisture absorption during storage
Cost and scalability	More economical and scalable approach	Complex and costly equipment with limiting scalability
Particle size	Wide particle size distribution	More uniform particle size distribution
Shelf life	Shorter shelf life	Extended shelf life due to superior stability

Conclusion and future trends

Microencapsulation is used to enhance the resistance of probiotics to unfavourable conditions. In encapsulation, the microbial cells are enclosed within a membrane to reduce cell injury, protect them from external stresses and to increase their viability and shelf-life.

Owing to the increasing awareness of consumers to probiotics and their health benefits, there is increasing demand for probiotic foods in India and worldwide. Food producers have therefore focused their efforts on the development of functional and probiotic foods. The viability of probiotic microorganisms is very important to realize their intended beneficial effects on health. They must stay alive in the recommended population until they reach their site of action so that their health benefits are realized. Probiotics are often destroyed in the stomach due to the harsh digestive conditions. Salt, sugar and pH in foods and the microenvironment have been found to adversely affect the viability of probiotics in foods. Therefore, protecting the probiotics and converting them into more resistant and stable forms are very important. The prominent technique to protect the probiotics in the food matrix is encapsulation, which isolates the probiotics from external influences. Viability, controlled and targeted release, handling

convenience and applications in food are enhanced by encapsulating probiotics. Common technologies for encapsulating probiotic bacteria are freeze and spray drying.

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High Pressure Processing in Dairy Industry

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High-pressure processing (HPP) is a “non thermal” food preservation technique that inactivates harmful pathogens and vegetative spoilage microorganisms by using pressure rather than heat to effect pasteurization. HPP utilizes intense pressure (about 400–600 MPa) at mild process temperatures (<45°C), allowing most foods to be preserved with minimal effects on taste, texture, appearance, or nutritional value. Also known by the name of Pascalization, bridgmanization, hydrostatic-pressure processing (HHP) or ultra-high-pressure processing (UHP).

Regardless of its nomenclature, the technology has been cited as one of the best innovations in food processing in 50 years (Dunne, 2005). It provides food processors an opportunity to preserve foods with a “cleaner” ingredient label, and it is the process of choice for applications where heat pasteurization would adversely affect product quality. Pressure treatments of 400 MPa for 15 min or 500 MPa for 3 min at room temperature achieves microbiological reductions similar to thermal pasteurization but it is not used commercially because long pressure processing times are not financially viable. HPP treatments (586 MPa for 3 and 5 min) at moderate temperature (55°C) extend the refrigerated shelf life of milk to over 45 days while retaining milk volatile profiles similar to those observed after conventional HTST treatments. Finally, ultra high temperature (UHT) processing (135–150°C for 3–5 s) yields milk that is stable at room temperature for 6 months; however, this process induces strong ‘cooked’ off-

flavour notes thus limiting its consumer acceptance in important markets.

The most attractive feature, which made the process worldwide acceptable, is its uniform processing ability, independent of mass and time. The HHP can be used to process both liquid and solid (water-containing) foods and adds advantages to the foods such as (i) Kills bacteria in the raw food, (ii) Extends shelf-life, (iii) Ponders additive free and fresh food, (iv) Manipulates the texture and (v) Enhances desired attributes (digestibility). A newer concept of Pressure-Assisted Thermal Processing Technology (PATP) is coming into role giving a synergistic effect with combination of high pressure and high temperature

The operating principles behind this technology are as follows:

- *Le Chatelier's principle*: Any phenomenon in equilibrium chemical reaction, phase transition and/or change in molecular configuration is accompanied by decrease in volume, which can be enhanced by pressure.
- *Isostatic principle*: The transmittance of pressure is uniform and instantaneous (independent of size and geometry of food).

General Description of HP Equipment

For Food Industry The main components of an HP system are a pressure vessel, a pressure generation system, a temperature control device and a material handling system. Most pressure vessels are made from a high tensile steel alloy ‘monoblocs’ (forged

from a single piece of material), which can withstand pressure of 400-600 MPa. For high pressures, prestressed multilayer or wire-wound vessels are used. In operation, after all air has been removed, a pressure transmitting medium (either water or oil) is pumped from a reservoir into the pressure vessel using a pressure intensifier until the desired pressure is reached. Temperature control in commercial operations can be achieved by pumping a heating/cooling medium through a jacket that surrounds the pressure vessel. This is satisfactory in most applications as a constant temperature is required but if it is necessary to change the temperature regularly, an internal heat exchanger is fitted. There are two methods of processing foods in high pressure vessels: in-container processing and bulk processing. There are two main types of High pressure equipments:

1. Batch type: A batch press can be used for any kinds of food in flexible packages, such as pouches, cups, or bulk bags. With the food already packed in the final consumer package at the processing stage, the risk of contamination is eliminated. The food packaged, are placed in the pressure vessel where they are isostatically compressed
2. Continuous type: Continuous systems can be used for pumpable food. The system is installed with other equipment, and in the end the liquid food reaches an aseptic or clean filler. Thus, any kind of consumer package can be used. Top of-the-line, high quality juice may be perceived as more valuable if sold in glass bottles, rather than PET or other plastic that would require for batch cycling.

The volume in a pressure vessel for continuous use is better utilized than in a batch press,

where there is dead space between the food packages. Thus the output volume is large despite the fairly small dimensions of the vessels used.

Advantages of HPP

- Retention of flavour and texture of the product
- Increase in Microbiological safety and shelf-life
- Low energy consumption
- Minimal heat input
- Minimal effluent and losses
- Uniform isostatic pressure & adiabatic temperature distribution
- Combination with heat gives better effects

Application of HPP in Dairy Industry

Milk treated at pressures of up to 500 MPa for few minutes has been shown to have a shelf-life at least equivalent to HTST pasteurized milk. Most vegetative cells, including non-spore forming thermotolerant, can be eliminated. HHP treatment (200 MPa, 10 min) after acidification (rise of acidity after acidification) in yogurt, increases the water binding capacity of whey proteins. The cheese yield is not influenced when milk treated at pressure ≤ 250 MPa, but at 600-800 MPa, it gets increased by up to 25% with increase in moisture content in curd and decrease in protein content in whey.

Cheese Ripening can be accelerated by using the High-Pressure treatment, which avoids the usage of elevated temperatures, addition of cheese slurries or exogenous enzymes or by the use of adjunct starters. Cheddar cheese, when exposed to HP from 5 to 300 MPa for 3 days at 25°C, shows free amino acid levels of 26.5 mg/g at 50 MPa compared to 21.3 mg/g in the 6-month-old cheese (which had not been HP treated). The taste of both the cheese were described as "excellent". This shows a considerable

reduction in the ripening times of the cheese, attained through the application of HPP.

Conclusion

The HPP is a 'novel' non-thermal technology has the potential for use as an alternative to thermal processing. Several researches have been done on HP treatment on milk and milk products. These have

provided a detailed understanding about the complex changes that take place in milk under high pressure like the dissociation of caseins micelles from the colloidal to the soluble phase, influence turbidity of milk etc. However, it cannot be denied that the dairy industry has been comparatively slow to adopt HP processing, as compared to product meat and sea-foods, jams, juices.

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Application of Machine Learning in the Dairy Industry

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Machine learning has become a buzzword in recent years as it is being used in various industries to gain insights and make predictions based on copious amounts of data. The dairy industry has not been left behind, and its adoption of machine learning has led to numerous benefits such as improved milk yield, disease diagnosis, and enhanced breeding programs. In this article, we will discuss the application of machine learning in the dairy industry and how it is transforming the industry.

Machine learning techniques used in the dairy industry

The dairy industry is leveraging various machine learning techniques to analyse vast amounts of data generated from various sources such as milking robots, health sensors, and breeding records. These techniques include:

Supervised learning

Supervised learning is a technique where the machine is trained on a labelled dataset. In the dairy industry, this technique is used for tasks such as predicting milk yield, disease diagnosis, and identifying optimal breeding programs. For instance, by analysing data from various sensors installed in milking robots, machine learning models can predict milk yield, detect abnormal milk compositions, and identify cows with mastitis or other diseases.

Unsupervised learning

Unsupervised learning is a technique where the machine is trained on an unlabelled dataset. This technique is used in the dairy industry to identify

patterns in data that may not be visible to the human eye. For example, by analysing breeding records, machine learning models can identify patterns in the genetic makeup of cows that lead to higher milk yield or better resistance to diseases.

Reinforcement learning

Reinforcement learning is a technique where the machine learns from its environment by receiving feedback in the form of rewards or punishments. In the dairy industry, this technique is used in automated milking systems, where the machine learns to recognize the udder of each cow and adjust the milking process accordingly. By continuously learning from its environment, the machine can optimize the milking process, resulting in improved milk yield and quality.

Applications of machine learning in the dairy industry

Milk yield prediction

Milk yield prediction is one of the most common applications of machine learning in the dairy industry. By analysing data from various sources such as milking robots, health sensors, and breeding records, machine learning models can predict the milk yield of each cow with high accuracy. This information can be used to optimize the feeding regime, monitor the health of each cow, and plan for future milk production.

Disease diagnosis

Disease diagnosis is another application of machine learning in the dairy industry. By analysing data from various sensors installed in milking robots,

machine learning models can detect early signs of diseases such as mastitis or lameness. Early detection of these diseases can help farmers take preventive measures, such as adjusting the feeding regime or administering medication, to prevent the spread of the disease.

Breeding programs

Breeding programs are essential in the dairy industry as they determine the genetic makeup of cows and their offspring. By analysing breeding records, machine learning models can identify patterns in the genetic makeup of cows that lead to higher milk yield, better resistance to diseases, and other desirable traits. This information can be used to select the best cows for breeding, resulting in improved offspring and enhanced breeding programs.

Automated milking systems

Automated milking systems are becoming increasingly popular in the dairy industry as they can optimize the milking process and reduce labour costs. By using machine learning techniques such as reinforcement learning, these systems can learn to

recognize the udder of each cow and adjust the milking process accordingly. This results in improved milk yield and quality, as well as reduced labour costs for farmers.

Conclusion

In conclusion, the application of machine learning in the dairy industry has transformed the industry in numerous ways, from milk yield prediction to disease diagnosis and automated milking systems. By leveraging various machine learning techniques, farmers can analyse vast amounts of data generated from various sources to gain insights and make informed decisions. However, the implementation of machine learning in the dairy industry is not without challenges, and farmers must address these challenges to fully benefit from this technology. Despite the challenges, the adoption of machine learning in the dairy industry is expected to continue growing, and we can expect more innovations in the future that will revolutionize the industry even further.

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Unveiling The Future of Dairy: Exploring Animal - Free Alternatives

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The dairy industry has undergone a remarkable transformation in recent years. With growing concerns about animal welfare, environmental sustainability, and health, there has been a rising demand for dairy products that do not rely on animal sources. This shift in consumer preferences has paved the way for a new era of dairy: one that explores and embraces animal-free alternatives. Unveiling the future of dairy means delving into the innovative realm of animal-free alternatives that are revolutionizing the way we perceive and consume dairy products. These alternatives, ranging from milk to cheese and yogurt, are crafted without the need for traditional animal-based ingredients. Instead, they harness the power of science and technology to replicate the flavors, textures, and nutritional profiles of traditional dairy, all while minimizing the impact on animals and the environment. These products are often developed using plant-based ingredients such as soy, almonds, oats, or coconuts. These ingredients are carefully selected and processed to create a milk-like base that can be transformed into a variety of dairy substitutes. Through advancements in food science and manufacturing techniques, these alternatives have achieved remarkable resemblance to their conventional counterparts, both in taste and functionality.

These alternatives offer a cruelty-free solution that allows consumers to enjoy the creamy goodness of dairy without compromising their values. Furthermore, these products can be suitable for a wide range of diets, including vegetarian,

vegan, and plant-based lifestyles. Beyond ethical considerations, these alternatives also contribute to environmental sustainability. Many traditional dairy products contain high levels of saturated fats and cholesterol, which can contribute to various health issues such as heart disease. Animal-free alternatives are lower in saturated fats and zero cholesterol, which is a healthier option for individuals seeking to improve their diet and overall well-being. One of the key advantages of these alternatives is their versatility. These products can be seamlessly incorporated into a wide range of recipes and culinary creations. Whether it's a creamy plant-based milk for your morning cereal, a delectable vegan cheese for a pizza topping, or a refreshing dairy-free yogurt for a post-workout snack etc.

Food scientists and researchers are continuously working to enhance the taste, texture, and nutritional profiles ensuring that they not only rival their traditional counterparts but surpass them in certain aspects. This commitment to innovation ensures that consumers can enjoy high-quality, delicious dairy alternatives that meet their dietary needs and preferences. Furthermore, the adoption of these alternatives has significant implications for the global food system. By reducing the reliance on animal agriculture, we can alleviate the strain on resources, mitigate the environmental impact, and promote a more sustainable and resilient food supply chain. This shift towards a more plant-centric approach to dairy production can contribute to a greener future and help address pressing issues such

as deforestation, water scarcity, and biodiversity loss.

Market analysis

The market for dairy products without animal ingredients had a value of USD 24.53 billion in 2021 and is projected to grow at a rate of 10.4% during the forecast period. The constant rise in consumer choice for a vegan diet might be linked to the market revenue growth of animal-free dairy products. Based on Rakuten's 2021 worldwide consumer survey, 81% of those surveyed had tried plant-based milk, 48% had tried various dairy substitutes, 44% had tried vegan meat alternatives, and 25% had tried vegan eggs. NSF surveyed professionals in the food sector worldwide in 2021, and 88% of them said they anticipated a rise in the demand for plant-based products. Another element boosting market revenue growth is the nutritional advantage provided by plant-based dairy substitutes. Due to issues like lactose intolerance and milk allergies brought on by the use of cow's milk, the demand for plant-based alternatives to milk has surged significantly. In response to these demands, the food industry has developed a variety of milk beverages that are advertised as plant-based substitutes.



Source: <https://omdfortheplanet.com/blog/5-reasons-plant-based-milk/>

Application

Animal-Free Dairy and Dairy Products

These innovative alternatives have the potential to make a significant impact in various

industries and sectors. Let's explore some of the key applications of animal-free dairy and how they are transforming different areas:



Food Service and Hospitality Industry: These alternatives have become a staple in the food service and hospitality industries. Restaurants, cafes, and hotels are incorporating these products into their menus to increase demand for plant-based options. From animal-free milk for coffee beverages to vegan cheeses for gourmet dishes, these alternatives offer chefs and culinary professionals a versatile range of ingredients to create delicious, inclusive, and environmentally friendly meals.

Food Manufacturing and Processing: Food manufacturers and processors are utilizing these alternatives in the production of a wide range of dairy-based products. Whether it's vegan ice cream, yogurts, spreads etc, animal-free dairy alternatives provide manufacturers with a way to meet the needs of consumers who are looking for healthier, more sustainable, and cruelty-free options.

Nutritional Supplements and Functional Foods: These products are fortified with essential nutrients, vitamins, and minerals, making them a viable choice for individuals seeking a convenient and sustainable source of nutrition.

Research and Development:

The development is an ongoing area of research and development. Scientists, food technologists, and biotechnologists are continually exploring new methods and technologies to improve the taste, texture, and nutritional profiles. This research contributes to the advancement of food science by offering insights into ingredient formulation, product optimization, and new production techniques that can further enhance the quality and acceptance of animal-free dairy alternatives.

Sustainability Initiatives: Companies and organizations committed to sustainability are actively seeking and promoting these alternatives as part of their eco-friendly practices. These initiatives of animal-free dairy contribute to lower greenhouse gas emissions, reduced water usage, and preservation of natural resources.

International Aid and Food Security: These alternatives have the potential to address global food security challenges. In regions where traditional dairy production is limited or unsustainable, plant-based dairy alternatives offer a viable solution. These alternatives can be produced using locally available plant resources, reducing dependence on imported dairy products, promoting self-sufficiency in food production, improving nutrition, addressing food accessibility and affordability issues in vulnerable populations.

Preparation techniques

Preparation of peanut milk

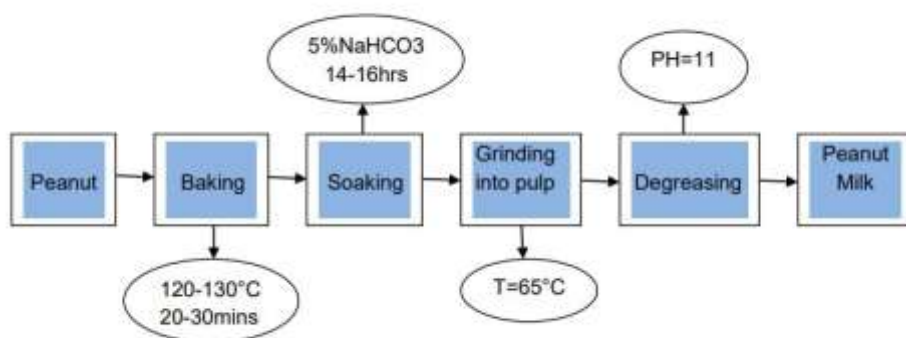


Fig 1: Steps used for preparation of peanut milk

The development of products involves combination of scientific expertise, culinary innovation, and technological advancements. These preparation techniques aim to improve flavors, textures, and nutritional profiles.

Plant-Based Milk Production: The production of plant-based milk involves various techniques, depending on the source ingredient. For example, soy milk is made by soaking and grinding soybeans, followed by straining the mixture to obtain a smooth, creamy liquid. Almond milk, on the other hand, involves blending soaked almonds with water and straining to remove solids.

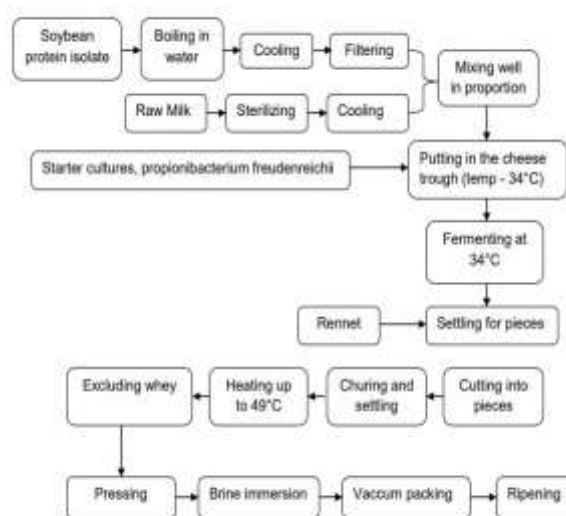


Fig 2: Process flow chart showing the production of mixed soybean cheese

Fermentation and Culturing: These techniques play a crucial role in creating animal-free dairy products with complex flavors and textures. Yogurt can be made by fermenting plant-based milk using specific strains of bacteria. These bacteria convert the sugars in the milk into lactic acid, resulting in the characteristic tanginess and thick consistency of yogurt. Similarly, plant-based cheeses can be crafted using fermentation techniques, allowing for the development of unique flavors and textures reminiscent of traditional dairy cheeses.

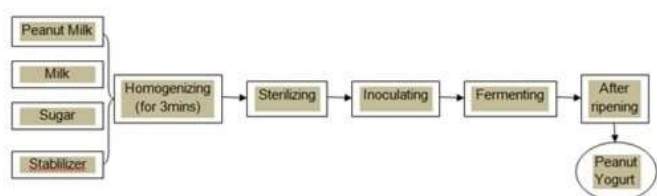


Fig 3: Steps used for preparation of peanut yogurt

Emulsion and Stabilization: These are employed to create stable and creamy textures. Emulsifiers, such as lecithin or gums like xanthan gum or carrageenan, are often added to plant-based milk to prevent separation and improve mouthfeel. These ingredients help to bind fats and water together, resulting in a smooth and cohesive product.

Texture and Mouthfeel Enhancement: These alternatives strive to mimic the texture and mouthfeel of their conventional counterparts. Ingredients like agar-agar, carrageenan, tapioca starch can be added to provide the desired thickness and creaminess. Additionally, blending and homogenization techniques help create smooth and velvety textures in products like plant-based ice cream and yogurts.

Flavor Development: Natural flavorings, such as vanilla extract, cocoa powder, or fruit purees, are commonly used to enhance the taste of plant-based dairy products. Fermentation and aging processes

are employed to develop complex flavors in cultured products.

Nutritional Fortification: These are often fortified with essential nutrients to ensure their nutritional value. Calcium, vitamin D, and vitamin B12 are commonly added to plant-based milk and other dairy substitutes to match or exceed the nutritional content of traditional dairy and provide comparable health benefits to their animal-based counterparts.



Source:

https://www.pinterest.com/pin/436286282661249498/sent/?invite_code=bb1902f4d7b94baf9874c15c02aa3d6b&sfo=1

Advantages of preparation techniques

Healthier Options: These products are often lower in saturated fats and cholesterol compared to traditional dairy products. The preparation techniques allow for the creation of products that are more aligned with health-conscious lifestyles, providing consumers with healthier choices that can contribute to improved cardiovascular health and weight management.

Allergen-Friendly: Products can be suitable for individuals with common food allergies or intolerances. By utilizing plant-based ingredients

and avoiding common allergens like lactose and dairy proteins, these alternatives offer a viable option for those who are lactose intolerant or have dairy allergies.

Environmental Sustainability: Animal-free dairy production has a lower environmental impact compared to traditional dairy production. By reducing the need for animal agriculture, these techniques help conserve natural resources, reduce greenhouse gas emissions, and mitigate deforestation associated with the dairy industry.

Ethical Considerations: The preparation techniques allow for the creation of dairy alternatives without relying on animal exploitation, thereby providing consumers with cruelty-free options that align with their values and ethical beliefs.

Disadvantages of preparation techniques

While animal-free dairy alternatives offer numerous advantages, there are also some challenges and limitations associated with their preparation techniques.

Taste and Texture Variations: Despite significant advancements in preparation techniques, achieving the exact taste and texture of traditional dairy products can still be a challenge. Many animal-free dairy closely resemble their counterparts, some individuals may have subtle differences in taste and mouthfeel.

Ingredient Selection and Processing: The selection and processing of plant-based ingredients can impact the nutritional composition and overall quality of products. Careful consideration and optimization of ingredient choices and processing methods are necessary to ensure that these alternatives offer a well-rounded nutritional profile and desirable sensory characteristics.

Processing Complexity: Some alternatives require more complex processing techniques compared to traditional products. The use of emulsifiers, stabilizers, and fortification processes may involve additional steps and require specific expertise, equipment, and resources. This complexity can impact the scalability and cost-effectiveness of production, especially for small-scale producers.

Market Availability and Accessibility: While animal-free dairy alternatives have gained popularity, they may still be less readily available compared to traditional dairy products in certain regions or establishments. Limited market availability and accessibility can pose challenges for consumers who wish to incorporate these alternatives into their daily lives or rely on them as viable options in various culinary settings.

Conclusion

The idea of "animal-free dairy" has come to light as a potentially effective response to the myriad moral, environmental, and health issues raised by the manufacture of traditional dairy products. Modern scientific techniques, such as cellular agriculture, which includes raising animal cells in a lab setting to make milk and dairy products, are used to create animal-free dairy products. First off, it does away with the necessity for conventional methods of raising animals, which frequently involve cruelty, squalor, and environmental harm. Production of dairy products without the use of animals greatly decreases animal suffering and encourages a more humane approach to food production. Furthermore, dairy products made without animals have the potential to solve issues with traditional dairy consumption that are related to public health. Traditional dairy production is associated with significant greenhouse gas emissions, land and water

usage, and deforestation. Many people find it challenging to consume dairy products because they are lactose intolerant or have dairy allergies. Dairy made without animals offers a practical substitute that is free of allergies and can be adjusted to satisfy particular dietary needs. In summary, the development of dairy products free of animal products is a key step towards a food system that is more moral, sustainable, and diverse. The production and consumption of dairy products could be revolutionized by animal-free dairy by utilizing cutting-edge technologies, providing a prospective substitute that is better for humans, the environment, and animals.

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Overview on Importance of the Donkey Milk and Its Nutritive Value

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Donkeys belong to the Equidae family, which also includes horses and zebras. Various breeds of domesticated donkeys live all over the world, and like many other mammals, female donkeys, known as jennies, have been raised for thousands of years for their milk (Elisabetta Salimei et al., 2012). Donkey milk has a long history of medicinal and cosmetic uses. Hippocrates reportedly used it as a treatment for arthritis, coughs, and wounds. Cleopatra is said to have maintained her soft, smooth skin with donkey milk baths (Osman Swar M. 2011). It has antimicrobial properties and is used as a folk medicine treatment for infections, including whooping cough, as well as viruses in parts of Africa and India (Osman Swar M. 2011). Compared with milk from other dairy animals like cows, goats, sheep, buffalo, and camels, donkey milk most closely resembles human breast milk. In fact, it was first used in the 19th century to feed orphaned infants (Maria Aspri et al., 2016). Donkey milk has a growing interest due to its composition similar to human milk, with good tolerability and palatability. Many pediatricians suggested donkey milk in the infant's diet as a valid alternative in terms of nutritional adequacy for subjects affected by allergy to cow milk proteins. It is rich in lactose and whey proteins, contributing to the intestinal absorption of calcium, essential for bone mineralization. Additionally, due to the low-fat

content and favorable lipid composition, donkey milk and derived products are also valuable foods for elderly consumers. The presence of endogenous bioactive compounds increases some other alleged health benefits, as the antibacterial activity, the stimulation of immune system, the prevention of inflammatory diseases, and antiaging properties. The attractive characteristics of donkey milk, also defined as a nutraceutical product, seems to meet the growing consumer's demand for natural and health-promoting foods.

Milk composition

Milks from nontraditional animal species (i.e., donkey, camel, and buffalo) are recently gaining momentum mainly due to the fact that they are considered suitable to supplement the needs of special population groups (i.e., infants, the elderly). Research on donkey milk has dramatically increased over the past few years. Donkey milk is gaining a growing interest for human nutrition because of some other alleged health benefit. It shows antibacterial activity toward a wide range of Gram-positive and Gram-negative bacteria, stimulates immune system in convalescence, regulates gastrointestinal flora, and prevents inflammatory and autoimmune diseases.

Most of the protein in dairy milk comes from casein and whey. Casein is the protein most people with an allergy to cow's milk react to. Donkey milk

is similar to human breast milk in that it's low in casein and higher in whey. The whey protein in donkey milk is notable for its antimicrobial properties. It contains compounds that can prevent the growth of viruses and bacteria *in vitro*. In lab studies, it prevents the spread of bacteria, including *Listeria monocytogenes*, *Escherichia coli*, and *Staphylococcus aureus*. (Diana Brumini et al., 2016). Donkey milk may be a suitable dairy substitute for people with a cow's milk protein allergy, although it still contains casein and lactose. In addition, it might offer other benefits, including supporting a healthier immune system and reducing blood pressure.

Table.1 Nutritive value of comparison between Donkey milk, cow's milk and human breast milk

	Donkey milk	Whole, vitamin-D-fortified cow's milk	Human breast milk
Calories	49	61	70
Protein	2 grams	3 grams	1 gram
Carbs	6 grams	5 grams	7 grams
Fat	2 grams	3 grams	4 grams
Cholesterol	3% of the	3% of the DV	5% of the DV
Vitamin D	23% of the DV	9% of the DV	1% of the DV
Calcium	7% of the DV	11% of the DV	3% of the DV
Riboflavin	2% of the DV	13% of the DV	2% of the DV

* Daily Value (DV) (Mina Martini et al., 2017; Li L et al., 2017)

Clinical Importance

Experimental data on animal models observed that donkey milk affects glucose metabolism in a manner more similar to human milk than cow milk and that might have beneficial effects by changing energy homeostasis in favour of fatty acid oxidation, thereby reducing fat storage. As a

result of its clinical tolerance, palatability, and nutritional suitability, donkey milk is particularly beneficial for kids with cow's milk protein allergies (CMPA). Donkey milk consumption exerts anti-inflammatory properties by normalizing antimicrobial peptides levels in Paneth's cells, so the authors speculate about its possible use as dietetic intervention in patients with Crohn's disease. The lactoferrin content in donkey milk is intermediate between the value reported in cow's milk and the highest value reported in human milk. Lactoferrin inhibits the growth of iron-dependent bacteria present in the gastrointestinal tract. Lactoferrin also protects against viral diseases, including those caused by coronavirus. Moreover, recent data suggest that donkey colostrum and mature milk inhibit the growth and metastasis of mouse 4T1 tumors by inducing apoptosis. Thus, anticancer properties could be hypothesized for the future as well (Enrico Bertino et al., 2022)

Other uses of donkey milk

Donkey milk is more than a food item. It's just as well known for its use as an ingredient in cosmetics. In fact, you'll probably have much better luck finding donkey milk skin moisturizers and soaps than donkey milk beverages. The proteins in donkey milk have the ability to attract and hold water, which makes it an excellent moisturizer. Some of the proteins in donkey milk also function as antioxidants. They help protect cells from oxidative damage, including that caused by sun exposure, thus providing anti-aging benefits. Cosmetic products that may have donkey milk as a major ingredient include skin creams, face masks, soaps, and shampoos (Cosentino, C et al., 2015).

Limitations of Donkey milk

The biggest downside of donkey milk is its price and availability. Because both the number and size of donkey dairy farms are limited, it's expensive to produce and sell. Europe has some larger manufacturers who sell the milk in powdered form, but it can be expensive to ship overseas. The prices of donkey milk, along with its low casein content, also make it very expensive and difficult to use for cheese making. Another potential downside is that most small farms only sell raw donkey milk, and drinking unpasteurized milk carries a risk of foodborne illness. Although donkey milk has antimicrobial properties, and tests usually find it to be free of harmful pathogens, there's always a risk that raw milk contains bacteria or other harmful toxins. That can be dangerous if fed to infants, older adults, or anyone with a compromised immune system. If you want to try donkey milk in liquid or powder form, look for one that has been pasteurized. Alternatively, heat the raw milk to at least 161°F (72°C) for 15 seconds before drinking it to kill any pathogens. (Conte F et al ., 2019) Finally, if you have lactose intolerance and experience symptoms like gas, bloating, and diarrhea after drinking milk, donkey milk will likely cause these same symptoms due to its lactose content. Thus, people with lactose intolerance should avoid or limit donkey milk.

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Exploring the Potential of Yak Milk: Composition, Nutrition Properties, and Applications

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Yaks, large, long-haired mammals native to high-altitude regions of Central Asia, are vital for their livelihoods and cultural heritage (Wiener et al., 2003). Yak milk, a valuable resource, is essential for the diets and economies of yak-rearing communities. Traditionally, yak milk is recognized as a highly nutritious and therapeutic food, providing essential sustenance for human and animal consumption. Studies have explored its macro- and micronutrient profiles, highlighting its rich content of proteins, fats, vitamins, and minerals. Yak milk's unique characteristics, including high-fat content and rich flavour, make it suitable for the production of dairy products, such as butter, cheese, and yoghurt (Guo et al., 2014).

Traditional methods of yak milk processing, such as fermentation and churned-butter production, have been practised for centuries. The economic significance of yak milk extends to the production of products like butter, cheese, and yoghurt, providing opportunities for income generation and local economic development (Dong et al., 2003). However, challenges persist in genetic improvement, optimal feeding and management practices, and product diversification opportunities. Addressing these challenges and exploring the untapped potential of yak milk will contribute to scientific knowledge, sustainable agriculture, and economic growth in yak-rearing regions.

Yak Milk Composition

Yak milk, a unique and valuable dairy product, possesses a distinct composition that sets it



apart from other types of milk. It is known for its rich content of essential macronutrients and micronutrients. The composition of yak milk is influenced by factors such as breed, diet, and environmental conditions. The unique environment in which yaks graze, characterized by high altitudes and harsh climates, contributes to the distinct composition of their milk (Li, 2011). The comparative milk composition of yak milk and other species of milk is depicted in Table 1.

Yak milk typically contains a higher proportion of fat compared to cow's milk, making it creamier and imparting a distinctive flavour. The fat content in yak milk can range from 6% to 7.5%, contributing to its creamy texture and mouthfeel. It contains lactose about 4.0–5.9%. While, it contains a higher amount of protein than cow's milk, with an average protein content of 4.5% to 5.5%. These proteins are composed of various essential amino acids necessary for human nutrition. The amino acid profile of yak milk is characterized by a balanced ratio of essential and non-essential amino acids,

making it a valuable source of high-quality protein (Ma et al., 2013).

Table 1 Average comparative composition per 100 g of milk of yak, camel, cow and human milk (modified from Kalwar et al., 2023)

Component (gm/100 gm of milk)	Yak	Camel	Cow	Human
Fat	6.5	4.5	4.0	4.0
Protein	5.1	3.5	3.4	1.9
Lactose	4.4	4.4	4.8	6.5
Minerals	0.8	0.7	0.7	0.2
Solid-Not-Fat	10.4	8.6	9.0	7.3
Total solids	16.9	12.8	13.3	12.1

Yak milk is also a good source of vitamins and minerals. It contains higher levels of certain vitamins such as vitamin A, vitamin E and vitamin B₆ compared to cow's milk (Singh et al., 2023). Yak milk has 32.8 mg/L of vitamin C, and this quantity rises with altitude (Cui et al., 2014). The vitamin D content is also high in yak milk compared to cow milk. this can be due to longer UV exposure as yaks live in high-altitude areas. These vitamins play crucial roles in maintaining overall health and supporting various physiological functions. Yak milk's mineral content is influenced by environmental factors, with higher altitudes resulting in higher Mn and Fe content, which is beneficial for infants. It also contains more calcium and phosphorus than human milk, and has the highest zinc content, making it suitable for infant diets. (Ma et al., 2017). It provides essential amino acids necessary for growth, repair, and maintenance of body tissues, while the higher fat content in yak milk serves as an energy source and contributes to fat-soluble vitamin absorption (Kalwar et al., 2023).

Yak milk contains sphingolipids, phospholipids, and oligosaccharides, which benefit yak calves and humans. It also contains beneficial probiotics like *Lactobacillus rhamnosus*, *Lactobacillus plantarum* strain As21, and *Kluyveromyces marxianus* PCH397, with significant potential for human health (Wang et al., 2023).

Yak Milk Products in Traditional and Modern Era

Yak milk serves as a versatile raw material for the production of various dairy products, both traditional and modern, offering a range of culinary delights and economic opportunities. In traditional contexts, yak milk has been used to produce revered products such as yak butter and churpi. Yak butter, made through churning yak milk, holds cultural significance and is widely used in cooking, tea preparation, and religious rituals (Ma et al., 2013, Silk et al., 2014). Churpi, a fermented cheese-like product, is another traditional delight derived from yak milk. Churpi is known for its long shelf life, and nutritional richness, and is consumed as a snack, grated over dishes, or incorporated into soups and stews (Wiener et al., 2003).

In modern times, yak milk has expanded its applications to include a broader range of dairy products. Yak milk powder, obtained through the spray-drying of fresh yak milk, provides a convenient and shelf-stable form of yak milk, preserving its nutritional properties and enabling easy storage and transport (Silk et al., 2014). Yak cheese, with its unique flavour profile and nutritional attributes, has gained popularity among consumers. Yak cheese production involves curdling and ageing yak milk to achieve a firm and savory cheese, which can be enjoyed on its own, grated over dishes, or used in various culinary creations (Silk et al., 2014, Ma et al., 2017).

Yak yoghurt, a fermented dairy product, has also emerged as a modern application of yak milk. Yak yoghurt offers a tangy flavour, smooth texture, and probiotic benefits. It is produced by fermenting yak milk with specific bacterial cultures, providing a source of beneficial bacteria for digestive health and offering a delightful snack or ingredient in desserts and smoothies (Silk et al., 2014).

The diverse range of traditional and modern yak milk products not only contributes to culinary enjoyment but also supports economic growth in yak-rearing regions. These products provide opportunities for value addition, income generation, and cultural preservation, fostering sustainable agricultural practices and promoting local economies.

Therapeutic properties of yak milk

Yak milk has been found to possess therapeutic properties, including antimicrobial, immunomodulatory, anticarcinogenic, antihypertensive, antioxidant, anti-hypoxic effects, etc. Potential health benefits of yak milk on human health are shown in Figure 2.

The antimicrobial peptides present in yak milk have demonstrated inhibitory effects against various pathogens, suggesting its potential as a natural preservative or antimicrobial agent (Lin et al., 2018, Wang et al., 2023). The immunomodulatory factors in yak milk have shown promise in regulating immune responses and supporting immune function (Kulyar et al., 2021). Additionally, yak milk contains antioxidants that help combat oxidative stress and reduce the risk of chronic diseases (Wang et al., 2023).

Yak milk is also regarded as hypoallergenic compared to cow's milk due to its different protein composition, making it a potential alternative for individuals with cow milk allergies or lactose intolerance (Wang et al., 2023). Yak milk has been

found to possess potential anticancer properties, with cytotoxic effects against cancer cells and promising bioactive peptides. It also has antibacterial properties, with peptides derived from yak milk showing inhibitory effects against various bacteria (Kulyar et al., 2021). Yak milk's bioactive peptides with angiotensin-converting enzyme (ACE) inhibitory activity may help lower blood pressure, potentially offering a natural alternative to hypertension management. Additionally, yak milk has been investigated for its potential anti-fatigue effects, improving exercise performance, reducing fatigue, and enhancing endurance capacity. Furthermore, yak milk has been associated with improved bowel movement and constipation relief due to its high fat content and bioactive compounds (Kalwar et al., 2023).

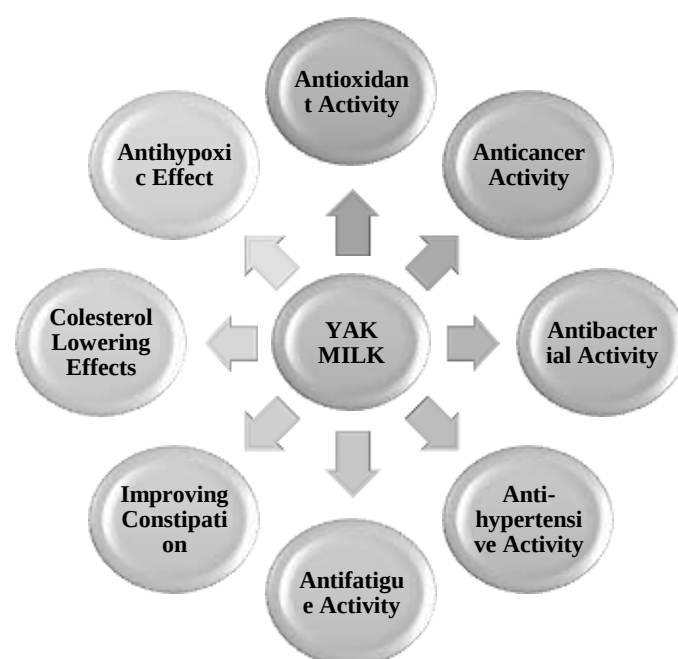


Figure 1: Potential health benefits of yak milk

While further research is needed to fully explore the potential of yak milk in the health industry, its unique composition and bioactive components make it an intriguing ingredient for functional foods, nutraceuticals, antimicrobial agents, sports nutrition, and pharmaceutical

applications. Incorporating yak milk and its derivatives into health-focused products can provide a natural and valuable resource for promoting wellness, supporting immune function, and addressing specific health needs.

Conclusion

In conclusion, the exploration of yak milk's potential has revealed its remarkable composition, nutritional properties, and diverse applications in the food and health industries. Yak milk stands out with its unique nutritional profile, including higher levels of proteins, fats, vitamins, and minerals compared to cow's milk. Moreover, yak milk contains bioactive compounds that offer antimicrobial, immunomodulatory, and antioxidant effects, which hold promise for therapeutic applications

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Role of Hydrocolloids in Dairy Food Applications

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Hydrocolloids may be defined as the non-digestible, long complex chain of polymers (polysaccharides and protein), originated from the Greek word by combining “hydro+kolla” which means “water+ glue”. These are hydrophilic in nature and among the most commonly used ingredients in the food industry because it can readily dispersed, are partial or fully soluble in cold as well as in hot water (Phillips and Williams, 2020). Due to their hydrophilic nature it is able to form colloidal solution in an aqueous phase. It provide thickening or viscosity building effect after dissolving or dispersing in water. Hydrocolloids used as functional ingredients in food formulation to increase consistency, gelling effect of food and also to control the microstructure, texture, flavor, and shelf life of food. It can also able to reduce or inhibits the formation of sugar or ice crystals in ice cream. Also, hydrocolloids provide some nutritional benefits hence it is also called as healthy food additives and protect us from various diseases such as CVD, colon cancer and diabetes mellitus (Liu et al., 2014).

Various functions of hydrocolloids making it to be in market demand. Increasing the consumers demand for convenience food and low calorie food, contributing indirectly to increase the demand of hydrocolloids as fat replacer, stabilizer, thickening agent and binding agent as well. The global hydrocolloids market size accounted for USD 9.07 billion in 2019. The market projected to grow from

USD 9.37 billion in 2020 to 13.37 billion in 2027 at CARG of 5.13% during the 2020-2027 period. India food hydrocolloids market is projected to grow at a CAGR of 7.2% during the forecast period.

Classification of hydrocolloids

A wide list of hydrocolloids is given in the Table 1 and 2. Each of the hydrocolloids are listed here having their own functions and applications.



Traditionally, it is classified as polysaccharides and grouped according to their source. It can be also be classified based on their chemical structure.

Table 1. Classification based on their source/ origin

Source of hydrocolloids	Examples
Plant	Pectin, inulin, gum Arabic, gum ghatti, gum tragacanth, gum karaya, cassia seed gum, basil seed gum, mesquite seed gum, fenugreek gum, chicle gum, oat gum, rye gum, konjac, psyllium, guar gum, locust bean gum, flaxseed gum, wattle gum, starches
Animal	Chitin, chitosan, gelatin

Seaweed	Agar, carrageenan, alginic acid, alginate, furcellaran, ulvan, fucoidan, red alga xylan
Microbial	Xanthan, gellan gum, tara gum, dextran, pullulan, welan gum, curdlan, levan
Synthetic	Methyl cellulose, methyl ethyl cellulose, carboxy methyl cellulose, hydroxyethyl cellulose, hydroxyl propyl cellulose, hydroxypropyl methyl cellulose, microcrystalline cellulose

Table 2. Classification based on their chemical structure

Class	Examples
Glucan	Starch, oat gum, barley gum, curdlan, welan gum, pullulan, dextran
Fructan	Inulin, levan
Xylan	Red alga xylan
Rhamnan	Ulvan
Galactomannan	Guar gum, locust bean gum, tara gum, cassia seed gum, basil seed gum, mesquite seed gum, fenugreek gum
Glucomannan	Konjac, alginate
Arabinoxylan	Psyllium, flaxseed gum (containing another galacturonan fraction), rye gum, wheat gum
Galactan	Agar, carrageenan, fucoidan, furcellaran
Arabinogalactan	Gum Arabic
Galacturonan	Pectin
Glycano-rhamnogalacturonan	Gum karaya, gum tragacanth (containing another arabinogalactan fraction)
Glycano-glucuronomannoglycan	Gum ghatti
Glucosamine polymer	Chitin, chitosan
Protein	Gelatin

Role of hydrocolloids in Dairy Products

Hydrocolloids are widely used in dairy and food industries due to its vast application. These are having high molecular weight and play various roles in food matrices such as thickeners, gelling agents, emulsifiers, foam stabilizers, fat replacers, coating agents, adhesives, clarifying, clouding, flocculating, clarifying and encapsulating agents. Hydrocolloids can able to improve the shelf life of dairy products by increasing the water holding capacity as well as reducing the whey syneresis, suspending dispersed particles or by inhibiting flocculation of protein micelles. Sahan et al. (2008) reported that addition of β -glucan in non-fat yogurt led to reduce whey syneresis. Studies reported that addition of hydrocolloids in dairy products will reduces the amount of whey separation from free fat, low-fat and full fat dairy products such as yoghurt (Emine and Ihsan, 2017), cheese (Rubel, 2019) and ice-cream (Sharma et al., 2009).

Thickening property

Hydrocolloids widely used to improve the thickening property of which is due to increase in viscosity of the products. Increase in viscosity after addition of hydrocolloids is due to intermolecular entanglement, which leads to resists the flow. Improving the thickening properties will leads to improve the sensory properties of the products. The thickening behavior of hydrocolloids generally depends on the type of hydrocolloid used, its concentration, pH of the food system and temperature.

Gelation

In addition to thickening, many hydrocolloids possess gelling effect. Gels may be defined as the mechanical rigid network between the liquids and solid state involving the cross linkage of

polymer molecules that forms 3D-network in an aqueous solution, trapping water within it and finally increases the viscosity. Hydrocolloids gels are also called physical gel because linkage of gels composed of hydrogen bond, hydrophobic association and cation mediated cross links. Hydrocolloids such as gelatin, gellan, carrageenan, pectin, agar, hydroxylpropyl methylcellulose and methyl cellulose is widely used as gelling agent. The above gelling agents were widely used in dairy dessert, milk shakes and milk-based desserts.

Fat replacer

As fat is the major contributor to calorie, hence reduced fat or free-fat foods products are gaining interest in the markets. Dairy products such as cheese, ice-cream, yoghurt, etc. are widely used to produce low-fat products. Fats and oils generally replaced with 'structured water' to give healthy, reduced-calorie foods with excellent eating quality. Removing fat from food will impair the sensory and textural properties of foods. Addition of hydrocolloid will bind the water and give better mouthfeel and textural properties similar the fat-rich foods. Inulin is the most common hydrocolloids added into reduced fat dairy and meat products.

Reduces whey syneresis

Shrinkage of gel is known as whey syneresis. It is very common defect in gels mainly in cheese and yoghurt occurs during storage. Addition of hydrocolloid leads to reduce the whey syneresis from gels. Many author reported that addition of Hydrocolloids in dairy products will reduces the amount of whey separation from dairy products such as yoghurt, cheese and ice cream. Adding hydrocolloids in cheese and yoghurt leads to increases the viscosity and decreases the syneresis. Many authors reported that gelatin and inulin have

quite prominent effect in reduction of whey syneresis.

Edible films and coatings

A thin coating that can be eaten, coated on food, or used as a barrier between food and its surroundings is referred to as an edible film. Hydrocolloids are now widely used to produce edible films on food surfaces and between food components. Such films aid as inhibitors of moisture, gas, aroma and lipid migration. Many gums and derivatives have been used for coating proposes which include carrageenan, alginate, cellulose and its derivatives, pectin, starch and its derivatives, and others. Because of their hydrophilic nature, the coatings they produce have limited moisture barrier properties. However, if they are used in a gel form, they can reduce moisture loss during short term storage where the gel acts as sacrificing agent rather than a barrier to moisture transmission. In addition, in some cases an inverse relationship exhibited between water vapor and oxygen permeability, such films acts as barrier to oxidation of lipid and other susceptible food ingredient.

Stability

Often, the function of the hydrocolloid is to stabilize the emulsion, to prevent separation and, in the case of frozen foods, to control ice crystal formation. Though, new technology and new ingredients have been developed specifically to report the problem of ice crystals in frozen foods, but hydrocolloids will continue to play a vital role. Virtually every ice cream product is stabilized with carrageenan, locust bean gum and/or guar gum.

Conclusion

Hydrocolloids are the non-digestible polymers possess vast function such as thickeners, gelling agents, emulsifiers, stabilizers, fat replacers,

clarifying agents, flocculating agents, clouding agents and whipping agents which make it the most common ingredient to be used in the dairy industry. Hydrocolloids are now widely used in due to increase in demand on low-fat or free-fat dairy products. Hydrocolloids not only improve the textural property of the dairy products but also improve the shelf life of the products by reducing the whey syneresis and increasing the water holding capacity. In addition to the above properties hydrocolloids can also improve the nutritional value, and also improve the emulsifying characteristics of dairy products.

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Application of Pulsed Light Technology in Dairy Industry

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Pulsed Light Technology (PLT), known as high-intensity pulsed light (HIPL), is a novel non-thermal technique used in food processing. It utilizes short, intense pulses of broad-spectrum light to deactivate and decontaminate microbes. Pulsed light technology offers several advantages such as minimal impact on product quality, fast processing times, versatility in applications, and reduced reliance on chemicals. It has gained significant attention due to its ability to effectively eliminate microorganisms, improve food safety, and extend product shelf life. With its versatility spanning various industries, including dairy, it plays a crucial role in surface disinfection and ensuring food safety.

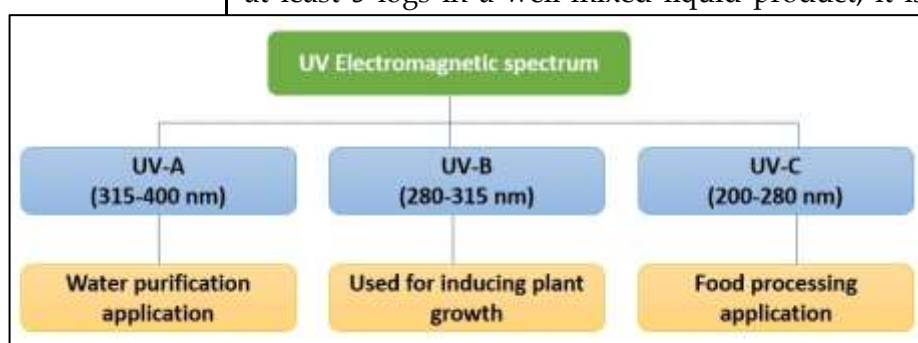
Sources of PLT

PLT incorporates various types of electromagnetic radiation, including UV rays ($\lambda = 200\text{--}400\text{ nm}$), visible light ($380\text{--}700\text{ nm}$) and infrared (IR) rays ($\lambda = 700\text{--}1100\text{ nm}$). UV rays are further classified into UV-A, UV-B and UV-C (Mandal *et al.*, 2020). The pulses generated by pulsed light technology have a short duration, typically ranging from $1\text{ }\mu\text{s}$ to 0.1 s . These pulses are characterized by their high intensity, and in the context of decontamination, UV-C light with a peak wavelength of 253.7 nm has been found to be the most effective.

The dose of Pulsed Light (PL) treatment is measured by its 'fluence,' which represents the total radiant energy of PL exposure on the surface of the

food. The intensity of PL is typically measured in J/cm^2 , and the energy of PL is determined using actinometry techniques. Commercial PL units designed for food processing are available in both batch and continuous treatment modes, offering effective microbial elimination capabilities.

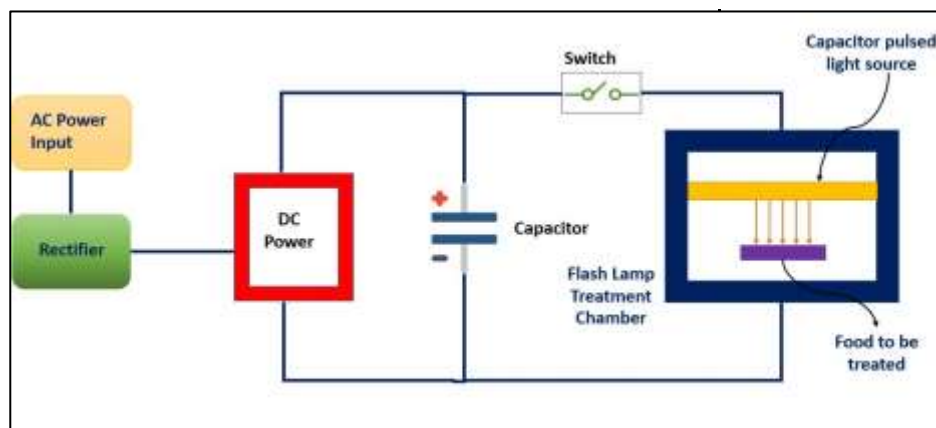
The effectiveness of UV treatment in the dairy industry depends on several critical process factors, which include the UV light absorption capacity of the dairy product, the geometric design of the UV reactor, the characteristics of the light (intensity, wavelength, power, and duration), the physical arrangement of the UV sources, and the flow profile of the milk or dairy products being treated. These elements collectively play a significant role in determining the success of the UV treatment process. As per FDA, to achieve a microbial load reduction of at least 5 logs in a well-mixed liquid product, it is



recommended to apply a minimum treatment dose of $400\text{ J}/\text{m}^2$ of UV radiation (Datta *et al.*, 2015).

Equipment

The low-power, low-voltage AC continuous current from the line source is transformed into low-power, high-voltage DC continuous electric current through a converter or rectifier. This converted



current is then stored using capacitors. Electric pulse forming network (switches) further convert the stored energy into high-power, high-voltage pulsed DC electric current. This pulsed current is directed to a pulsed light source, typically inert-gas flashlamps. The resulting high-power pulsed light is then utilized for the intended application.

By subjecting xenon gas within the flash lamp to a high voltage electrical pulse, the gas is ionized, leading to the formation of plasma and the generation of a substantial current. As this high current pulse passes through the ionized xenon gas, the electrons within the gas are energized, transitioning to higher energy levels. The emission of pulsed light occurs when these excited electrons release their energy by transitioning from higher to lower energy levels, resulting in the production of photons.

Mechanism of action

The germicidal efficacy of UV light primarily stems from its ability to modify microbial DNA through the formation of cyclobutyl pyrimidine dimers, which cross-link the pyrimidine bases. The degree of cross-linking is directly proportional to the dose of UV light administered. These dimers impede DNA transcription and replication, compromising essential cellular functions and ultimately leading to

the death of microbial cells. Three mechanisms by which microbial inactivation occurs are:

- Photo-chemical effect: By formation of pyrimidine or thiamine dimers
- Photo-thermal effect: Heat generation by the IR rays effectively eliminates pathogenic

organisms on the surface

- Photo-physical effect: High energy pulses are capable of destructing the cell membranes of microorganisms

Advantages

- Non thermal process
- Operation at ambient temperature
- Less detrimental effects on colour, flavour
- Suitable for batch and continuous process
- No chemical residue after treatment
- Vitamin D enrichment in milk by UV
- Low maintenance cost
- Low installation and operational cost
- Minimum usage of energy
- Reduced use of chemicals
- Time efficiency: Process is extremely fast and treatment time ranges from fraction of seconds to a few seconds
- Can be easily incorporated into the existing setup

Applications in Dairy Industry

Commercial applications of PLT includes disinfection of water, sanitization and sterilization of equipments, enhancement of shelf life and microbial load reduction in food industry, photodynamic

therapy for cancer treatment, waste water treatment and control of industrial emissions.

Package and surface disinfection

As this technology possess lower penetration power, it is commonly used for the surface disinfection of products as well as package. In the dairy industry, UV technology is highly recommended for microbial disinfection of solid packaging surfaces, as it effectively extends the shelf life of dairy products. This application encompasses the reduction of microbial counts on various packaging materials used in the dairy industry, such as tubs, bottles, cans, lids, covers, and foils for yogurt, milk, butter, cheese, and other dairy products. By subjecting these solid surfaces to continuous UV radiation at appropriate doses and durations before filling them with dairy products, the growth of food spoilage microorganisms is significantly reduced. As a result, the product's shelf life is prolonged, and the risk of contamination is minimized.

Problems with PLT treatment

- Sensory defects arise in whole milk and skim milk when proteins undergo oxidation as a result of exposure to UV light
- Decrease in the amount of vitamin present in milk in the order of C>E>A>B2
- Not ideal for milk packed in translucent packaging
- Efficiency of the treatment reduces in cloudy and opaque liquids
- UV exposure can lead to burns, skin cancer, damage to human eyes

The stage of photo-reactivation serves as a damage control mechanism in injured microorganisms by utilizing repair enzymes, known

as photolyases. This process enhances the survival capacity of microorganisms, but also reduces the shelf life of UV-treated products. Photo-reactivation mainly occurs when the treated food is exposed to light and so it is utmost important to control the light exposure by the treated product in order to maintain the quality and safety of foods (Mandal *et al.*, 2020).

Conclusion

Pulsed light technology serves as a valuable asset to the dairy industry, offering a potent tool to strengthen food safety measures, extend the shelf life of products, and uphold stringent quality standards. By efficiently decontaminating surfaces and mitigating the risk of microbial contamination, this technology plays a crucial role in safeguarding dairy products and ensuring their freshness and integrity. Consumer acceptance of Pulsed Light (PL) technology in the food industry is rapidly increasing due to multiple factors. Firstly, PL treatments are non-invasive, preserving the natural state of the food and aligning with the demand for minimally processed options. Secondly, PL technology offers versatility in various applications like surface disinfection, shelf-life extension, and reduction of spoilage microorganisms, leading to improved product appearance and consumer confidence. Additionally, PL treatments are comfortable for consumers as they involve no heat or chemicals. With well-established safety credentials, regulatory approvals, and growing accessibility, PL technology is becoming more feasible for food manufacturers to implement and offer PL-treated food products to consumers.

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Table 1: Application of Pulsed Light Technology in Dairy Products

Food Products	Pulse energy/ Dose	Treatment time (µs)	Log ₁₀ Reductions	Reference
Milk	25.1 J/cm ²	114s	>2.0 of <i>Serratia marcescens</i>	(Smith et al., 2002)
Packaged cheese	53.4 J/cm ²	40s	2.98 of <i>Listeria monocytogenes</i> and 1.25 of <i>P. roqueforti</i>	(Can et al., 2014)
Concentrated milk (45% TS)	8.4 J/cm ²	-	<1 for <i>E. coli</i> ATCC 25922	(Miller et al., 2012)
Infant milk powder	-	9500	3 for <i>L. monocytogenes</i>	(Choi et al., 2010)
Raw whole milk	-	-	4 for <i>E. coli</i> W1485	(Choudhary et al., 2011)
Skimmed milk	700 J/m ²	-	3.3 for <i>E. coli</i> 25922	(Milly et al., 2007)

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Spectrum of Antibiotic Resistant Aerobic Bacterial Spore from Raw Milk

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Milk is a very nourishing medium that can help a variety of microorganisms grow. For a range of reasons, aerobic spore-forming bacteria are significant in the dairy sector. It is practically hard to avoid these spore formers' presence in raw food and products due to their ubiquity (Aouadhi *et al.* 2014).

Raw milk frequently contains aerobic *Bacillus* spore-forming bacteria. Their spores endure pasteurisation, germinate, develop, and then reproduce. They are to blame for the deterioration of UHT products, pasteurised milk, and milk products (McGuiggan *et al.*, 2002). Milk samples must be handled carefully during collection to avoid any unintentional contamination and to limit the growth of microorganisms during transit and storage of the milk (Pervin *et al.* 2016).

In stable environments, *Bacillus* spp. spores frequently indicate a secondary contamination of milk during the milking process. Other than the most common mesophilic species, such as *Bacillus licheniformis*, *Bacillus subtilis*, and *Bacillus pumilus*, the dominant psychrotrophic isolates are those of the *Bacillus cereus* strains (Yacoub *et al.* 2017).

Make sure that raw milk contamination is kept to a minimum to prevent aerobic spore-forming bacteria from contaminating milk and dairy products (Scheldeman *et al.* 2005). Bacterial spores in dairy products with liquid bases rarely pose a health risk, but they might degrade products if pasteurisation or storage procedures are insufficient, resulting in product degradation and revenue losses.

For dairy powders, thermophilic spore-forming bacilli can survive in the final product (Burgess *et al.* 2010).

Antibiotics are used not just to treat bacterial illnesses in humans but also to protect flocks or herds from infection. In animal husbandry, they are also employed as growth-promoting substances. The US Food and Drug Administration (FDA) first permitted the use of antibiotics to boost "feed efficiency," or the ability to grow animals quicker, in the early 1950s. This practise led to a shorter period to harvest animals with better economic benefits for farmers and lower costs for consumers (Shea, 2003). Antibiotic resistance is mostly caused by the reckless use of antibiotics in human, animal, and environmental medicine. (Canica *et al.* 2019).

Antibiotic susceptibility testing (AST) is frequently used in clinical settings to identify the antibiotic resistance patterns of bacterial isolates, to direct antibiotic treatment choices, and to forecast the success of therapeutic interventions. The most used techniques for AST testing include the disc diffusion method, the E-strip test, and genotypic techniques like PCR and DNA hybridization. (Syal *et al.* 2017).

Heat-resistant spore-forming microorganisms that carry antibiotic resistance genes cause non-sterility issues in UHT milk products. If they survive, they pass those genes to other bacteria through a process called horizontal gene transfer. There is a distant possibility that the presence of antibiotic-resistant microbes and their genes in heat-

treated milk for human consumption will harm people (Te Giffel *et al.* 2002).

Material & Methods

Sample collection

20 raw milk samples were collected from different sources like individual cow milk, Bulk tank milk, pooled milk from different areas of Bengaluru, Chikkaballapur, Doddaballapur, Kolar and were kept in ice box and transferred to microbiological lab for analysis.

Enumeration of aerobic spore forming bacteria

11ml of well mixed raw milk samples were transferred to 99ml sterile saline diluent and mix the sample thoroughly and heated to 80°C /10min and cool immediately to <10°C using ice cold water. From this make serial dilutions. Dilutions of 1:100 and 1:1000 were prepared. Transfer 1ml of each dilution to sterile petri plates. Transfer 10-15ml of sterile molten 2% Nutrient agar to petriplates and mix the contents slowly. Allow the medium to solidify and incubates the plates in inverted position at 37°C 24-48h. Select the plates having colonies between 30-300. Count the number of colonies present in each dilution, take the average and express the results as cfu/ml (Harrigan, 1998).

Isolation and maintenance of aerobic spore-forming bacterial isolates

Select the countable plate having colonies with erose, curled, flat, irregular morphology. Inoculate loopful of colony into nutrient broth. The isolates were transferred to nutrient agar slants and subcultured once in a month and maintained in refrigerator at 5°C.

Characterization of aerobic bacterial spore isolates

A total of 50 isolates were subjected to preliminary test to confirm the genus and further specific biochemical tests conducted helped to place

them in species. Preliminary tests include Gram staining, Motility test, Catalase test, Oxidase test and specific tests includes Oxidative- Fermentative test, Starch hydrolysis, Casein hydrolysis, Voges-proskaur reaction, Nitrate reduction, Egg yolk reaction, Growth at 50°C (Harrigan, 1998).

Antibiotic susceptibility test for aerobic bacterial spore isolates

Characterized isolates of aerobic bacterial spore were subjected to antibiotic susceptibility test using E- strip method against different groups of antibiotics like β -lactam, Aminoglycoside, Quinolones, Flouroquinolones, Tetracyclines Nitrobenzene. The isolates were grown at 37 °C for 24 h in nutrient broth, 0.2 ml (10^5 cells/ml) of each isolate transferred to sterile labelled assay plate and then pour 10-15 ml of sterile molten Muller Hinton Agar (MHA) into the respective plates. Allow to solidify and swab the isolate in nutrient broth on the solidified agar using sterile cotton swab. Antibiotic strips (HI Media, Mumbai) were placed on the agar plates using applicator. Group of antibiotics like β -lactam- Ampicillin (0.016-256 μ g/ml), Ceftriaxone (0.016-256 μ g/ml), Cefotaxime (0.016-256 μ g/ml), Aminoglycosides- Streptomycin (0.016-256 μ g/ml), Gentamycin (0.016-256 μ g/ml), Quinolones- Ciprofloxacin (0.016-256 μ g/ml), Fluoroquinolones- Enrofloxacin (0.02-32 μ g/ml), Tetracycline (0.016-256 μ g/ml), Nitrobenzene- Chloramphenicol (0.016-256 μ g/ml) were used. Plates were incubated at 37 °C/24 h. Read the MIC (Minimum Inhibitory Concentration) (CLSI, 2018) value where the edge of the inhibition ellipse intersects the side of strip. Further, the isolates were determined as resistant or susceptible based on the MIC (μ g/ml) (Madhusudan, 2016).

Statistical analysis

The data was analyzed using R software [R. version 4.1.2] for statistical computing. Data on the respective variables were collected for three replications for each of these treatments. ANOVA tables were prepared to analyse the data and where the F value is significant, the critical difference was calculated ($P=0.05$) and used to identify where significant differences existed and was indicated in the table use superscripts.

The formula for the critical difference (CD) is

$$CD = \frac{\sqrt{2} \times MSS(E)}{R} t_{\alpha} @0.05$$

Where, MSS (E) = Mean Sum of squares of the error

R = number of replications

t_{α} = table t value of the α level of significance

Results

Enumeration of total aerobic bacterial spore from individual cow milk (ICM), bulk tank storage milk (BMST), pooled milk (PM) of different regions

The results showed that the average count of total aerobic bacterial spore in individual cow milk was ranged between 1.0 log cfu/ml to 2.0 log cfu/ml and average count of total aerobic bacterial spore in bulk tank storage milk was ranged between 1.0 log cfu/ml to 2.146 log cfu/ml and similarly the average count of total aerobic bacterial spore in pooled raw milk was ranged between 1.0 log cfu/ml to 2.0 log cfu/ml. The average count of aerobic bacterial count for raw milk samples of different sources were shown in Table 1.

Characterization of aerobic bacterial spore isolates obtained from raw milk samples

Total of 50 isolates were subjected to preliminary tests, results showed that among 50

isolates 40 isolates were aerobic spore forming bacteria. 80% of isolates were Gram positive, rod shape, motile, catalase positive, aerobic in nature. Preliminary identified bacterial isolates were grouped under the Genus *Bacillus*

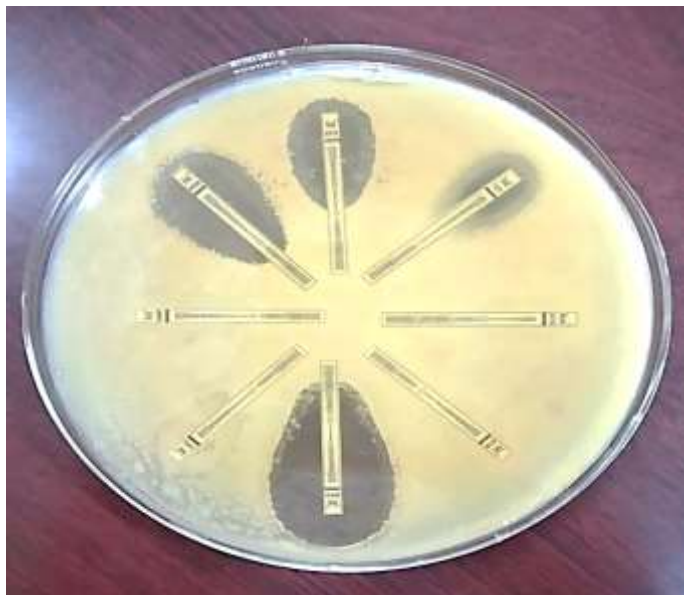
Preliminary identified isolates of Genus *Bacillus* were subjected to specific biochemical tests like OF test, Starch hydrolysis, Casein hydrolysis, Voges-proskaur reaction, Nitrate reduction, Egg yolk reaction, Growth at 50°C (Harrigan, 1998). Among 40 isolates of 15 isolates were identified as *Bacillus licheniformis*, 10 isolates as *Bacillus subtilis*, 10 isolates as *Bacillus cereus* and 5 isolates as *Bacillus tropicus*. All identified isolates had the ability to produce catalase enzyme, nitrate reductase, growth at 50°C and hydrolyze starch and casein. *Bacillus licheniformis* and *Bacillus subtilis* showed oxidase negative. Except *Bacillus subtilis* (O+F-) all the isolates showed positive to the Oxidative and fermentative test.

Out of 40 isolates 37.5% were *Bacillus licheniformis*, 25% were *Bacillus subtilis*, 25% were *Bacillus cereus* and 12.5% were *Bacillus tropicus*.

Antibiotic susceptibility properties of isolated *Bacillus* species from raw milk

The identified isolates of *Bacillus licheniformis*, *Bacillus subtilis*, *Bacillus cereus*, *Bacillus tropicus* were subjected to antibiotic susceptibility test using E-strip method. The results showed that *Bacillus licheniformis* and *Bacillus subtilis* showed resistant to β -lactam (ampicillin, Ceftriaxone, Cefatoxime) and tetracycline antibiotics, *Bacillus cereus* showed resistant to β -lactam (Ceftriaxone) whereas *Bacillus tropicus* showed resistant to nitrobenzene (chloramphenicol). The MIC of each *Bacillus* isolate was shown in Table 2 and intersection of elliptical inhibitory zone was shown in figure 1.

Figure 1: Representing antibiotic susceptibility characteristics of *Bacillus* species against various group of antibiotics. The intersection of the elliptical zone at the sides of antibiotic strip indicates MIC of a *Bacillus* species.



Discussion

Spore-formers are ubiquitous and can be isolated from a wide variety of environments, including soil, sediments, dust, and natural waters. In the present study from the 20 raw milk samples aerobic spore formers were isolated and characterized. The total aerobic bacterial count from different milk samples of ICM, BMST and PM showed the range between 1 to 2.146 log cfu/ml. The total of 40 isolates were characterized as *Bacillus licheniformis*, *Bacillus subtilis*, *Bacillus cereus* and *Bacillus tropicus*. In contrast to the present study, Khater and Abdella (2017), collected 10 raw milk samples from Cairo market and examined for aerobic bacterial spore count. Aerobic spore forming bacterial count was ranged between 3.505 to 4.431 log cfu/ml. Out 20 isolated aerobic spore formers from raw milk samples 18(90%) were *Bacillus anthracis* and 2(10%) were *Bacillus mycoides*.

Antibiotic susceptibility test of aerobic bacterial spore isolates of raw milk such as *Bacillus licheniformis*, *Bacillus subtilis*, *Bacillus cereus* and *Bacillus tropicus* was performed using E strip methods using MHA agar. MIC of inhibition zone is notes and determined the isolates as susceptible and resistant to antibiotics of different groups by comparing with standards of CLSI. The results showed that *Bacillus licheniformis* and *Bacillus subtilis* were resistant to β -lactam (ampicillin (AMP), Ceftriaxone (CTR), Cefatoxime (CTX)) and tetracycline (TET) antibiotics, *Bacillus cereus* showed resistant to β -lactam (Ceftriaxone (CTR)) whereas *Bacillus tropicus* showed resistant to nitrobenzene (chloramphenicol (CHL)). Similarly, to the above study Jaber et al. 2021 performed antibiotic susceptibility test for aerobic bacterial spore isolates named as *Bacillus thuringiensis*, *Bacillus subtilis*, *Bacillus cereus*, *Bacillus licheniformis* using disc assay method. The results showed that all the isolates were resistance to cadazolid (CDZ) and chloramphenicol (C) and medium sensitivity for tetracycline (TE), erythromycin (E) and vancomycin (VA), its show highest sensitivity to ciprofloxacin (CIP) and cephalixin (CN).

Conclusion

The aerobic bacterial spore isolates were characterized and subjected for antibiotic susceptibility test. *Bacillus* species namely *Bacillus licheniformis*, *Bacillus subtilis*, *Bacillus cereus*, *Bacillus tropicus* were identified. Antibiotic susceptibility property of the *Bacillus* species showed variation in their minimum inhibitory concentration (MIC) and showed resistance to different group of antibiotics like β -lactam, aminoglycosides, quinolones, fluoroquinolones, tetracyclines and nitrobenzene. Use of antibiotics in veterinary medicine should be moderate and careful. If the remaining spores have a

resistant trait and are contaminated by bacteria after heating, these germs could cause health issues if milk and milk products are consumed.

Acknowledgement

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Table 1. Enumeration of total aerobic bacterial spore from raw milk obtained from from different resources

No. of samples	Source		Count log cfu/ml	Codes of isolates	Identified organism
1	Individual cow milk (ICM)	ICM, Kanchenahalli, Chikkaballapur	1.0 ^d	A1, A2, A3, A4, A5	<i>Bacillus licheniformis</i> (15)
2		ICM, Nallimaradhalli, Chikkaballapur	0 ^e	Nil	
3		ICM, Kondenahalli, Chikkaballapur	1.845 ^{ab}	A6, A7, A8, A9	
4		ICM, Medihalli, Kolar	1.903 ^{ab}	A10, A11, A12, A13	
5		ICM, Tarigenahalli, Kolar	2.0 ^{ab}	A14, A15, A16, A17	
6		ICM, Naganahalla, Kolar	1.602 ^{bc}	A18, A19, A20, A21	
7		ICM, Yelahanka	0 ^e	Nil	
8		ICM, KVAFSU dairy farm	0 ^e	Nil	
9	Bulk milk storage tank (BMST)	BMST1, BAMUL	2.146 ^a	A22, A23, A24, A25	<i>Bacillus subtilis</i> (10)
10		BMST2, BAMUL	1.94 ^{ab}	A26, A27, A28, A29	
11		BMST3, BAMUL	1.30 ^{cd}	A30, A31	
12		BMST4, BAMUL	1.0 ^d	A32	
13		BMST5, BAMUL	2.0 ^{ab}	A33, A34, A35, A36	
14	Pooled milk (PM)	PM, SEDP	1.0 ^d	A37, A38, A39	<i>Bacillus cereus</i> (10)
15		PM, KVAFSU Dairy farm	0 ^e	Nil	
16		PM, Yelahanka	1.903 ^{ab}	A40, A41, A42,	
17		PM, Devanahalli	2.0 ^{ab}	A43, A45, A46	
18		PM, MPCS, Doddaballpur	0 ^e	Nil	
19		PM, MPCS, Chikkaballapur	1.8 ^{abc}	A47, A48	
20		PM, MPCS, Kolar	2.0 ^{ab}	A49, A50	
CD (P=.05)			0.28	50 isolates	40 isolates

Note:

- The results were average of three trials.
- Same superscript show non-significance while different indicate statistically significant difference (P=.05)

Table 2: Antibiotic susceptibility properties of isolated *Bacillus* species from raw milk

Antibiotic class	Antibiotics Strips (µg/ml)	MIC (µg/ml) of <i>Bacillus</i> species			
		<i>B. licheniformis</i>	<i>B. subtilis</i>	<i>B. cereus</i>	<i>B. tropicus</i>
B-lactam	Ampicillin (AMP)	0.0 ^e R	0.0 ^e R	0.19 ^{de} S	3.0 ^b S
	Ceftriaxone (CTR)	0.0 ^e R	0.0 ^e R	0.0 ^e R	2.0 ^c S
	Cefatoxime (CTX)	0.0 ^e R	1.5 ^d S	1.0 ^c S	1.0 ^d S
Aminoglycosides	Streptomycin (STR)	2.0 ^c S	48.0 ^b S	4.0 ^a S	2.0 ^c S
	Gentamycin (GEN)	0.25 ^{de} S	0.94 ^e S	0.38 ^{de} S	0.25 ^e S
Quinolones	Ciprofloxacin (CPH)	0.50 ^d S	0.64 ^e S	0.047 ^{de} S	0.094 ^e S
Fluoroquinolones	Enrofloxacin (EFX)	0.19 ^{de} S	0.47 ^{ef} S	0.032 ^{de} S	0.032 ^e S
Tetracyclines	Tetracycline (TET)	64.0 ^a R	64.0 ^a R	0.50 ^d S	0.50 ^d S
Nitrobenzene	Chloramphenicol (CHL)	8.0 ^b S	3.0 ^c S	1.5 ^b S	24.0 ^a R
CD (P=.05)		0	0	0.298	0.344

Note:

- The results were average of three trials.
- Same superscript show non-significance while different indicate statistically significant difference (P= .05)
- R=Resistant, S=Sensitive

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Emerging Concepts in the Probiotic Field

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In 1907, Elie Metchnikoff initiated the concept of probiotics for the benefit of human health. He attributed the long-life expectancy of old Bulgarians to the products containing live lactic acid bacteria. Since that period, the Science of Probiotics by Elie Metchnikoff has been linked to the beneficial bacteria with health benefits got evolved to new terms. The probiotic that normalizes the gut microbiota is a novel method for boosting health because of the depth of information by gut microbiology studies which signifies the balance of gut microbiota in health, and the research of dysbiosis as a cause of several illness problems. When administered, probiotics have positive effects not only on the gastrointestinal (GI) tracts but also a variety of human ecosystems like vaginal and skin tracts.

Growing research in this area opens up fresh opportunities like Next Generation Probiotics, live therapeutic items, and the potential use of non-viable bacteria, bacterial substrates, and bacterial end products for safe administration. The new approaches in probiotics had boosted the development of novel functional impacting directly the consumers and the public. The market for functional foods has been expanding more quickly in the probiotics sector. Now, in addition to the living probiotic microorganisms, the beneficial benefits had also been demonstrated by the inactivated probiotic cells, digested cells, metabolic products, and other chemicals that are produced from the lysis of the

bacteria. They can be described using the phrases 'parabiotics' or 'ghost probiotics'. As a result, the definitions and terminologies were modified to reflect a new generation probiotic concept. These definitions are explained below with examples (Table 1).

Probiotics: Probiotics are live microorganisms which when administered in adequate amounts confer a health benefit on the host (FAO/WHO, 2002). They are defined and will not include undefined microorganisms and any fecal microbiota transplants.

Prebiotics: According to the International Scientific Association of Probiotics and Prebiotics (ISAPP), dietary prebiotics are "selectively fermented ingredient that results in specific changes in the composition and/or activity of the gastrointestinal microbiota, thus conferring benefit(s) upon host health

Synbiotic: The combination of prebiotic and probiotic in a product benefits the health of its users by boosting the survival and adherence of healthy bacteria in GI tracts and by selectively promoting the growth of a number of these bacteria.

Parabiotics/Inactivated probiotics: The inactivated probiotics or crude cell extracts without live microorganisms in the product when orally administered in adequate amounts will benefit the host.

Postbiotics: They are inactivated bacteria and their metabolic products from microorganisms that have biologically active in the host.

Probioceuticals: Probiotic derived factors

Biogenic: Products made by or of life forms including secretions and metabolites

Pharmabiotics: The bacterial cells originated from human or their products with a proven role in health or disease pharmacologically.

Psychobiotics: The probiotics and prebiotics that can improve human mental health by balancing the gut microbiota.

Immunobiotics: Immunobiotics are the collection of bacteria that promotes and activates the mucosal immune system

Cobiotics: These are a combination of probiotic bacteria, prebiotic compounds and different digestive enzymes like lipase, amylase and protease.

Live biotherapeutic Product (LBP): It is a biological product that uses live organisms to treat, prevent, or cure a disease or condition that affects people; it is not a vaccine.

Next-Generation Probiotic (NGP): Live microorganisms identified based on comparative microbiota analyses that, when administered in adequate amounts, confer a health benefit on the host.

The definition of probiotic has evolved from its origin till now after careful analysis by several experts. The most accepted definition is the one given by the panel of ISAPP, 2014 (International Association of Probiotics and Prebiotics) as “live microorganisms that, when administered in adequate amounts, confer a health benefit on the host” and proposed only a slight grammatical modification of the definition already proposed by

the FAO/WHO in 2001. The definition differentiates commercial starters and commensal microorganisms from probiotics. The ingestion of live microorganisms is also highlighted in the definition. The old terms were broad spectrum and there was the requirement of subdivisions that led to the introduction of new terms. Many scientists have created subgroups and new terminology in response to the term's vast scope, taking into account any potential illnesses or systems that might be addressed. For example, psychobiotics are products targeting patients having difficulty with psychiatric issues and immunobiotics target the mucosal immune level thereby improving the health of the host.

Traditionally, the probiotics are bacteria isolated from healthy human GI tracts and GI tracts of animals, fermented, non-fermented food, breast milk, soil respectively. They are Generally Regarded as Safe (GRAS) as per Food and Drug Administration (FDA) and Qualified Presumption of Safety (QPS) at the species level by European Food Safety Authority (EFSA). The most widely used genera include *Lactobacillus* and *Bifidobacterium* but there are some from the genera *Bacillus*, *Escherichia coli* and yeast *Saccharomyces*. They all are having a long history of safe use and are proven safe to use as food supplements or food for human consumption. The next generation probiotics that have been recently isolated are powerful tools that can even modify the starters and commensal microorganisms. They are isolated from diverse genera that related to both healthy and unhealthy individuals. The new term introduced by FDA called LBPs are biological products with live organisms and are used to prevent or treat disease conditions in human beings which is not similar to a vaccine that can be attenuated or genetically modified pathogen. This is added as a

replacement for NGP but not systematically corrected as NGP because they cannot modify the other commensal microorganisms.

Type	Examples
Probiotics	<i>Lactobacillus helveticus</i> <i>Bifidobacterium longum</i>
Prebiotics	Galactooligosacharrides, fructooligosacharrides, inulin
Synbiotics	Fructo oligosacharride+ <i>Bifidobacterium longum</i>
Parabiotics	Inactivated probiotics
Postbiotics	Antimicrobial peptides, Vitamin B
Probiocuticals	Immunobiotic, Coldman syrup liquid by Sundyota Numandis Probiocuticals Pvt. Ltd.
Pharmabiotics	Acetylcholine, Catecholamines, Serotonin and γ -aminobutyric acid
Psychobiotics	<i>Lactobacillus helveticus</i> <i>Bifidobacterium longum</i>
Immunobiotics	<i>Lactobacillus plantarum</i> , <i>Lactobacillus rhamnosus</i> GG
Cobiotics	<i>Lactobacillus bacidophilus</i> and ginger extract
LBP	AOBiome, Azitra, DermBiont, Naked Biome

Probiotics and prebiotics, as well as many other related therapies, have grown in popularity as a result of the plethora of research into microbiome-

targeted therapeutics and nutrition. The probiotic field had become a broad science, and scientists, particularly microbiologists, had seen its development. Thus, it offers a fantastic chance to enhance probiotics' capacity to achieve a variety of specific targets in the upcoming era and significant in regulatory, academic, and transitional context. New probiotics and prebiotics will appear both inside and outside of the boundaries of the current classifications, challenging both scientific and legal limits. The greatest strategy to combat issues is to disseminate as much reliable scientific data and creation of multidisciplinary field and consortium.

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Exploring Innovative Techniques to Predict and Extend the Shelf-Life of *Dahi*

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Millions of people around the nation regularly eat *dahi*, which is a popular dairy product. It is a common ingredient in many recipes due to its creamy consistency, tangy flavour, and various health advantages. *Dahi* does have a shelf life, though, just like any perishable food item. It is essential to assure its freshness and quality that you are aware of the elements that affect its shelf life and that you are using correct estimating techniques. Predicting shelf life involves developing methods or techniques to determine the quality and remaining shelf life of *dahi*. This can be achieved through various means such as sensory evaluation, microbial analysis, chemical analysis, and advanced analytical techniques.

By accurately predicting the freshness of *dahi*, producers can ensure that consumers are provided with high-quality products and minimize wastage. Prolonging the freshness of *dahi* refers to employing innovative approaches to extend its shelf life. This can involve the use of different preservation methods, including physical techniques (e.g., refrigeration, modified atmosphere packaging) and chemical methods (e.g., food additives, antimicrobial agents). Additionally, advancements in packaging materials and technologies can help maintain the quality and freshness of *dahi* for a longer duration. The shelf life of *dahi* has recently been extended by the application of mathematical models and the creation of bionanocomposites, with promising results.

Factors Affecting the Shelf Life of *Dahi*

Microbial contamination

Dahi can become contaminated by microorganisms such as bacteria, yeast, and mould, which causes spoiling. The fermentation process used to make *dahi* is carried out by lactic acid bacteria, which are essential in controlling the growth of dangerous bacteria. *Dahi*'s shelf life can be shortened by incorrect handling, unsanitary circumstances, or storage at high temperatures, which can promote the growth of spoiling microorganisms.

pH level

The microbiological stability and shelf life of *dahi* are influenced by its acidity, which is dictated by its pH level. Most bacteria cannot grow at *dahi*'s low pH, which normally ranges from 4.0 to 4.6. It's essential to maintain the proper pH levels during production and storage to stop the growth of spoiling microorganisms.

Temperature

Dahi's shelf life is significantly influenced by temperature. Microbial growth is accelerated by high temperatures and slowed by cold temperatures. *Dahi* benefits from storage at frigid temperatures (4°C) since it keeps its quality and shelf life longer. However, exposure to temperature variations or storage at a higher temperature than is advised might cause food to spoil.

Oxygen exposure

The shelf life of *dahi* can be harmed by oxygen exposure. It can trigger oxidative reactions that result in off flavours and a reduction in product quality as

well as encourage the growth of aerobic spoilage bacteria. *Dahi* needs to be protected from these negative effects by using proper packaging that reduces oxygen permeability.

Ingredients and additives

The methodology and quality of ingredients used in *dahi* manufacture have a big impact on the duration it will preserve. The product's overall freshness and durability are influenced by premium milk, starter cultures, and stabilisers. Additionally, by preventing the growth of bacteria that cause deterioration, preservatives and antimicrobial compounds can increase the shelf life of *dahi*.

Estimation Methods for Predicting the Shelf Life of *Dahi*

Sensory Evaluation

The sensory evaluation of *dahi* comprises trained panellists rating its sensory qualities, including flavour, texture, aroma, and appearance. Experts can estimate a product's shelf life and predict the period when it stops meeting up to consumer expectations by tracking changes in sensory properties over time.

Chemical and Microbiological Analysis

Chemical analysis is used to track particular substances or changes in *dahi*'s composition over time. This technique offers information on the product's stability and freshness while assisting in the identification of chemical reactions that take place over time. Quantifying the bacteria load in *dahi* samples is part of the microbiological analysis process. Experts can determine the shelf life of a product based on the microbial count and the storage circumstances by monitoring the growth of microorganisms, particularly spoilage bacteria.

Accelerated shelf-life (ASL) testing

In order to imitate the consequences of prolonged storage over a shorter period of time, accelerated shelf-life testing involves testing *dahi* samples to accelerated storage conditions, such as increased temperatures. Experts can calculate the product's shelf life under normal storage settings by observing changes in quality features, as shown in Table 1 (Leahy *et al.*, 2014).

Table 1. Stability study conditions, temperature, and storage intervals

Stability study conditions	Storage intervals (days)	Storage temperature (°C)
Shelf storage conditions	90, 180, 270 and 360	20-25
Accelerated shelf life conditions ¹	30	40-54
Accelerated shelf life conditions ²	14	54±2

Mathematical Models for Shelf-life Prediction

Arrhenius equation

The correlation between temperature and the rate of chemical reactions is described by the Arrhenius equation. The Arrhenius equation can be used to calculate the rate of chemical or microbiological reactions that impact product quality in the context of predicting the shelf-life of *dahi* (Eq. 1). Experts can extrapolate the shelf life under varied storage situations by applying the equation to various temperature environments.

$$k = k_0 \exp\left(-\frac{E_a}{RT}\right) \quad (1)$$

where,

- K_0 = Constant
- E_a = Activation Energy
- R = Gas constant
- T = Absolute temperature

Arrhenius method was used by Zhi *et al.* (2018) to predict the shelf life of *dahi* samples. Based on the

results, sample 1 and sample 2 had a shelf-life prediction of 15.5 and 18.5 days, respectively, at 5°C. It was interpreted from the study that Arrhenius model is an effective method in predicting the shelf-life and to improve the quality parameters of *dahi*. Due to popularity of Arrhenius model, it is been used as an alternate of ASL test.

Zero-order kinetics

In zero-order kinetics, the response rate is assumed to be constant over time. This model can be used to calculate the degradation of particular *dahi* ingredients, like vitamins or flavours, and to forecast the time when their concentrations will decline below safe levels (Eq. 2).

$$[A] = [A]_0 - kt \quad (2)$$

where,

N_0	=	Initial log number of cells
N	=	Log number of cells
k	=	Rate of reaction
t	=	Time

Weibull distribution

In reliability engineering, the Weibull distribution is frequently used to simulate how quickly things degrade. By taking into account the likelihood of product failure owing to microbial spoilage, changes in sensory characteristics, or chemical degradation, it can also be used to estimate the shelf life of *dahi*.

This model considers variables including temperature, pH, and storage conditions as well as the likelihood of failure or spoiling over time (Eq. 3). It offers a more thorough understanding of the ageing and degradation processes that *dahi* goes through.

$$\text{Log}(N) = \text{Log}(N_0) - \left(\frac{t}{\text{delta}} \right)^p \quad (3)$$

where,

N	=	Log number of cells
N_0	=	Initial log number of cells
T	=	Time
delta	=	Time for the first decimal reduction
p	=	Shape, $p=1$, log-linear $p>1$, concave downward curve $p<1$, concave upward curve

Another common model used for shelf-life prediction of *dahi* is the modified Gompertz model. This model takes into consideration the microbial growth of *dahi* during storage, as well as the decline in pH and sensorial qualities. It can provide an estimate of the time it takes for the *dahi* to reach a certain level of spoilage based on these factors.

Techniques for Extending the Shelf Life of Dahi

Packaging plays a crucial role in preserving the freshness of *dahi*. Innovations in packaging materials and technologies, such as oxygen and moisture barrier films, active and intelligent packaging systems, and modified atmosphere packaging, can help create a protective environment and inhibit the growth of spoilage microorganisms. Active packaging is an innovative technique used to extend the shelf life of *dahi* by incorporating functional elements into the packaging material, which actively interact with the *dahi* to improve its quality and freshness throughout its storage period.

Additionally, the compatibility of the functional components with the *dahi*, sensory consequences, and regulatory compliance must all be carefully taken into account when designing active packaging for *dahi*. The active packaging components and additives utilised must be secure,

efficient, and permitted for interaction with food, as defined by manufacturers.

Bionanocomposites-based packaging

Definition and properties

Nanoscale fillers, such as nanoparticles or nanofibers, are combined with a biopolymer matrix to create bionanocomposites (Fig. 2). High mechanical strength, barrier qualities, and antibacterial activity are just a few of these materials' special qualities (Basavegowda and Baek, 2021).

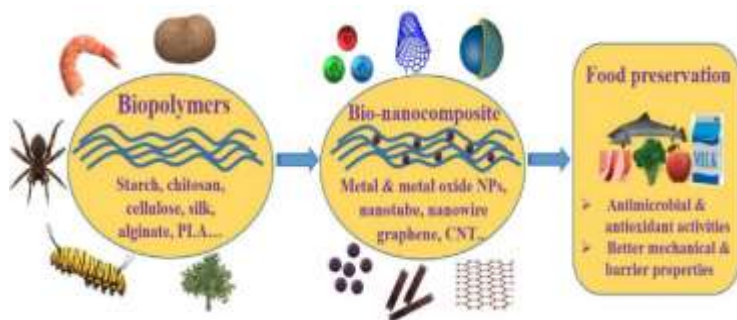


Fig. 2: Bionanocomposites for food preservation

Dahi packaging made with bionanocomposites can provide better defence against microbiological contamination, moisture loss, and oxygen permeation.

Methods of Incorporation in *dahi* packaging

Researchers have looked into a number of ways to include bionanocomposites into the materials used to package *dahi*. These consist of electrospinning, solvent casting, and melt mixing. Each technique seeks to achieve the necessary characteristics and usefulness by maximising the dispersion of nanofillers inside the polymer matrix.

Benefits of using Bionanocomposites

Dahi packaging made from bionanocomposites has several benefits. The product's shelf life is first extended by improving the barrier qualities, and preventing oxygen entry and moisture loss. The growth of spoilage bacteria is efficiently inhibited by the antimicrobial characteristics of

bionanocomposites, lowering the risk of contamination. They offer mechanical reinforcement, enhancing the robustness and integrity of the packaging.

Comparison Between Traditional and Novel Packaging Techniques

Each packaging technique contains its own pros and cons, although the choice of packaging depends on the storage conditions and specific application. The Table 2 contains benefits of using bionanocomposite-based packaging, polypropylene (PP) cup packaging and polyethylene (PE) pouch packaging for *dahi*.

Table 2. Comparison between traditional and novel packaging techniques

Bionanocomposite-based packaging	PP cup packaging	PE pouch packaging
Antimicrobial Properties	Convenient and lightweight	Compact and lightweight
Enhanced Barrier Properties	Cost-effective	Flexible and versatile
Enhanced Shelf Appeal	Durability and recyclability	Convenience and portability
Sustainability and customizability	Good for marketing opportunities	Product visibility and efficient space utilization

Conclusion and Future Scope

To preserve *dahi*'s quality and freshness, it is essential to comprehend methods to extend its shelf life. The shelf life of *dahi* is greatly influenced by elements such as microbial contamination, pH levels, temperature, oxygen exposure, and additives. The correct prediction of shelf life is made possible by estimation techniques such as sensory evaluation, microbiological analysis, chemical analysis, and accelerated shelf-life testing. The Arrhenius

equation, zero-order kinetics, and the Weibull distribution are a few examples of mathematical models that can be used to estimate shelf life based on temperature, chemical processes, and the likelihood that a product would fail.

Moreover, the use of bionanocomposites in dahi packaging offers a variety of benefits, including as enhanced barrier capabilities, antibacterial activity, and mechanical reinforcement. The shelf life of dahi could be further improved through ongoing research in bionanocomposites, assuring consumers receive fresh and high-quality goods. The field of dahi packaging continues to evolve, driven by technological advancements and consumer demands. Future trends in dahi packaging include smart packaging with integrated sensors for real-time monitoring, sustainable packaging innovations, and further optimization of barrier properties. By staying informed about emerging trends, manufacturers can stay ahead of the competition and meet evolving consumer needs.

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Nanofluid Based Heat Exchangers in Dairy and Food Industry

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Nanofluid is a term used to describe a type of fluid that contains nanoparticles dispersed in a base fluid. These nanoparticles can be metallic or non-metallic and are usually on the order of 1 to 100 nanometers in size. The nanoparticles used in nanofluids are typically made of metals, oxides, carbides, or carbon nanotubes. Common base fluids include water, ethylene glycol and oil. When the nanoparticles are introduced into the base fluid, they form a colloidal suspension, where the nanoparticles are uniformly distributed throughout the fluid. It is obvious from a survey of thermal properties that all thermal fluid used today as heat transfer fluids exhibit extremely poor thermal conductivity (with the exception of liquid metal, which cannot be used at most of the pertinent useful temperature ranges). Nanofluids exhibit unique properties that can differ significantly from those of the base fluid alone. One of the most notable properties is the enhanced thermal conductivity of nanofluids compared to the base fluid. The presence of nanoparticles increases the ability of the fluid to conduct heat, making nanofluids attractive for various heating and cooling applications (Ahmed, 2019).

Nanofluids have been extensively studied in recent years due to their potential for improving heat transfer efficiency in various engineering and industrial applications. Some of the areas where nanofluids have shown promise include electronics cooling, automobile engine cooling, solar thermal systems, and heat exchangers. However, it's important to consider challenges associated with

nanofluids, such as the potential for nanoparticle agglomeration, stability issues, and the cost of producing and maintaining nanofluids. Researchers continue to explore ways to optimize nanofluid formulations and address these challenges to make them more practical and commercially viable for a wide range of applications.

Method of Production of Nanofluid

The production of nanofluids involves dispersing nanoparticles into a base fluid to form a stable colloidal suspension. There are several methods for producing nanofluids, and the choice of method depends on the type of nanoparticles, the base fluid, and the desired characteristics of the nanofluid. Here are some common methods used for nanofluid production:

Two-Step Method

a. Synthesis of Nanoparticles: The first step involves synthesizing the nanoparticles. This can be done through various techniques, such as chemical reduction, sol-gel, thermal decomposition, or physical vapor deposition.

b. Dispersing Nanoparticles in Base Fluid: In the second step, the synthesized nanoparticles are mixed into the base fluid using mechanical agitation, ultrasonication, or other dispersion methods. The goal is to achieve a uniform distribution of nanoparticles throughout the fluid.

One-Step Method

This method involves simultaneously synthesizing nanoparticles and dispersing them in

the base fluid. For example, in a co-precipitation method, the nanoparticles are formed in situ during the mixing of precursor materials and the base fluid.

Surfactant-Assisted Method

Surfactants or surface-active agents can be used to stabilize the nanoparticles in the base fluid and prevent agglomeration. Surfactants act as dispersants, helping to maintain a stable nanofluid by reducing the attractive forces between nanoparticles.

High-Energy Ball Milling

In this method, mechanical energy is applied to the nanoparticles and base fluid mixture using high-energy ball mills. The impact and shear forces during milling break down the nanoparticles and disperse them in the fluid.

Micro fluidization

Micro fluidization involves forcing the mixture of nanoparticles and base fluid through microchannels or small orifices under high pressure. This process helps to reduce nanoparticle agglomeration and achieve better dispersion.

Electro-hydrodynamic (EHD) Method

In the EHD method, an electric field is applied to the mixture of nanoparticles and base fluid. The electric field induces flow patterns that promote dispersion and mixing of the nanoparticles.

It is essential to carefully control the process parameters during nanofluid production, such as nanoparticle concentration, mixing time, temperature, and shear rate, to obtain a stable and well-dispersed nanofluid. Additionally, surface modifications of nanoparticles and the use of additives can further improve the stability and performance of nanofluids in specific applications.

Nanofluid-based heat exchangers

Nanofluid-based heat exchangers are heat exchange devices that utilize nanofluids as the working fluid to enhance the efficiency of heat transfer between two fluids at different temperatures. These heat exchangers leverage the improved thermal properties of nanofluids, which are engineered colloidal suspensions containing nanoparticles dispersed in a base fluid (such as water, oil, or ethylene glycol). Nanofluid-based heat exchangers have gained attention in various industries, including the dairy and food industry, due to their potential to improve heat transfer efficiency.

Here's how nanofluid-based heat exchangers work and their advantages:

Enhanced Heat Transfer: Nanofluids have significantly higher thermal conductivity than conventional fluids, which allows for enhanced heat transfer rates in heat exchangers.

Reduced Fouling: Nanofluids can help reduce fouling on the heat exchanger surfaces.

Increased Heat Capacity: The specific heat capacity of nanofluids is often higher than that of the base fluid, which can further enhance the heat absorption or release capabilities of the heat exchanger.

Enhanced Thermal Stability: Nanofluids can exhibit improved thermal stability and resistance to thermal degradation, making them suitable for high-temperature heat exchange applications.

Flexibility in Design: Nanofluid-based heat exchangers can be designed with compact sizes, making them ideal for applications where space is limited or weight reduction is crucial.

Despite these advantages, there are some challenges to consider when using nanofluid-based heat exchangers:

Nanoparticle Agglomeration: Nanoparticles have a tendency to agglomerate in the fluid, which can reduce the effectiveness of the nanofluid and lead to flow blockages in the heat exchanger.

Cost and Availability: Some nanoparticles used in nanofluids can be expensive, which may increase the overall cost of the heat exchanger.

Stability Issues: Nanofluids can experience stability problems over time, leading to particle settling and changes in the fluid's properties.

Application of Nanofluid based Heat Exchanger

The enhancement of heat transfer in heat exchanger of dairy and food industries includes various unit operations (heating, cooling, frying, freezing, concentration, evaporation, drying) which results in better product safety and quality, reduction in processing time, and overall costs with improved energy efficiency. However, compact design of HT/storage/exchange equipment reduces workspace requirements and operating cost, facilitate automation, assist safe handling, and minimize heat losses. Nanofluid could be used indirect heat exchangers for pasteurization, commercial sterilization, blanching and UHT (ultra-high treatments) processing of milk, fruit juices, and other liquid foods. It can be also used in refrigeration, cold storage, and air conditioning. Nano refrigerants showed better performance (COP) and energy efficiency in domestic as well as large scale refrigeration systems. Hence, primary as well as secondary nano refrigerants can be used in dairy and food industry for cold rooms/cold transport systems. NFs have great potential to be an efficient PCM for thermal (heating cooling) energy storage and can be used in ice-bank-tanks (generally maintained in milk and food processing plant to

store cooling energy) and solar panels (for readily absorbing and releasing stored energy)

Taghizadeh et al. (2016) used titanium dioxide nanoparticles (TiO₂) in hot water stream (@ 0.25%, 0.35% and 0.8%) in milk PHE to enhance heat transfer capability of as the working media. It was found that nanofluid at all concentrations showed higher heat transfer rate and pressure drop than that of the distilled water. Pantzali et al. (2009) studied the efficacy of nanofluids as a coolant in PHEs and reported a significant increase in the measured pressure drop and consequently in the necessary pumping power when the nanofluid is applied instead of pure fluid. Ravi et al. (2022) developed nanofluid based milking pail for colling of milk. The fresh raw milk was passively chilled from 37 to below 10 °C within 1 h and the chilled milk was maintained below this safe limit using the NePCM capsuled inside the jackets of a cylindrical milk chilling module.

Conclusion

Despite these potential advantages, it's important to note that the commercial implementation of nanofluid-based heat exchangers in the dairy and food industry is still limited. Challenges such as nanoparticle stability, cost-effectiveness, and potential health and safety concerns associated with nanoparticles need to be addressed. Extensive research and development efforts are ongoing to optimize nanofluid formulations and manufacturing processes for practical applications.

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Blockchain Revolution: Unlocking Transparency and Trust in the Dairy Industry

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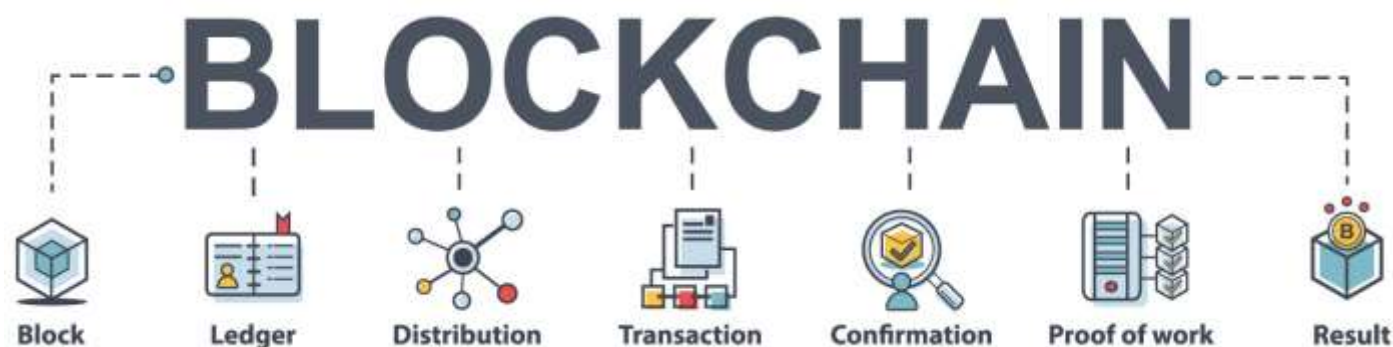
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Blockchain technology is a decentralized and distributed ledger system that enables the secure recording, storage, and verification of transactions across multiple computers or nodes. Unlike traditional centralized systems where a single authority maintains control, blockchain operates through a network of participants who collectively

manipulation, and enhances the efficiency of processes.

The dairy industry plays a vital role in the global food supply chain, providing essential products such as milk, cheese, butter, and yogurt. It is a significant sector that contributes to the economy, generates employment, and supports the



validate and maintain the integrity of the data. The core concept behind blockchain is the creation of a chain of blocks, where each block contains a list of transactions. These blocks are linked together using cryptographic techniques, forming an immutable and transparent chain of information. One of the key features of blockchain is its ability to achieve consensus among participants without the need for a trusted intermediary, making it highly secure and resistant to tampering or fraud.

Blockchain technology offers several benefits that make it attractive for various industries. First and foremost, it provides transparency and trust in transactions by ensuring that all participants have access to the same information. This eliminates the need for intermediaries, reduces the risk of errors or

livelihoods of millions of farmers and dairy processors worldwide. However, the dairy industry faces several challenges that can hinder its growth and sustainability. One of the major challenges is the need for improved transparency and traceability in the supply chain. Consumers are increasingly concerned about the source and quality of the products they consume, demanding more information about the origin, production practices, and safety standards of dairy products.

Another challenge is the complexity of the dairy supply chain, which involves multiple stakeholders such as farmers, processors, distributors, and retailers. Coordinating and managing the flow of milk and dairy products from farm to table can be a daunting task, leading to inefficiencies, delays, and potential quality issues.

Furthermore, the dairy industry is subject to stringent regulations and standards related to food safety, quality control, animal welfare, and environmental sustainability. Compliance with these regulations can be challenging, requiring extensive documentation, audits, and record-keeping. Non-compliance can result in penalties, loss of market access, and damage to the industry's reputation. Addressing these challenges and embracing innovative solutions is crucial for the dairy industry to thrive in a rapidly evolving market. Blockchain technology holds significant potential to overcome these challenges by providing transparency, traceability, and trust throughout the dairy supply chain.

Application of Block Chain Technology in Dairy Industry

Improved traceability and provenance of dairy products: Blockchain technology can create an immutable and transparent record of each step in the dairy supply chain. From the farm to the processing facility, distribution, and retail, every transaction and movement of products can be recorded on the blockchain. This enables stakeholders and consumers to easily trace the journey of dairy products, ensuring transparency and accountability. For example, consumers can verify the source of milk used in a specific product, the farming practices employed, and the transportation methods used, promoting trust and providing a clearer understanding of the product's provenance.

Prevention of fraud and counterfeit products: The dairy industry is susceptible to fraudulent activities such as mislabeling, adulteration, and the sale of counterfeit products. Blockchain technology can combat these issues by creating a tamper-proof

system that securely records every transaction and product movement. With blockchain, each dairy product can be assigned a unique identifier, such as a digital token, that verifies its authenticity and prevents unauthorized alterations. This ensures that consumers receive genuine, high-quality dairy products and eliminates the risk of purchasing counterfeit or adulterated items.

Enhanced food safety and quality control: Food safety is a critical concern in the dairy industry, with potential risks such as contamination, spoilage, and improper handling. Blockchain can help improve food safety by enabling real-time monitoring and recording of temperature, humidity, and other relevant variables throughout the supply chain. Smart sensors and IoT devices can integrate with the blockchain to provide continuous data on storage conditions, allowing stakeholders to identify and address any deviations promptly. By ensuring optimal conditions during transportation, storage, and distribution, blockchain technology enhances quality control measures and reduces the likelihood of compromised dairy products reaching consumers.

Monitoring and recording of temperature, humidity, and other variables: Blockchain technology can integrate with Internet of Things (IoT) devices and sensors to continuously monitor and record crucial variables such as temperature, humidity, and storage conditions throughout the dairy supply chain. This real-time data can be securely stored on the blockchain, providing an immutable record of environmental conditions. In case of any deviations from the required parameters, alerts can be triggered, enabling prompt corrective actions to maintain the quality and safety of dairy products. By ensuring optimal storage and transportation conditions, blockchain technology

helps prevent spoilage, minimize wastage, and maintain the freshness of dairy products.

Ensuring compliance with regulations and standards: The dairy industry is subject to a wide range of regulations and standards related to food safety, quality control, animal welfare, and environmental sustainability. Compliance with these regulations is essential for maintaining consumer trust and market access. Blockchain technology can streamline compliance processes by securely storing and verifying relevant documentation, certifications, and audits on the blockchain. This allows regulators, auditors, and stakeholders to access and verify compliance records easily, reducing administrative burdens and ensuring adherence to regulatory requirements. Blockchain's transparent and tamper-proof nature also helps demonstrate a commitment to compliance, thereby enhancing the industry's reputation.

Streamlined auditing processes: Auditing plays a vital role in ensuring transparency and accountability in the dairy industry. Traditional auditing processes can be time-consuming, resource-intensive, and prone to errors. By leveraging blockchain technology, auditing processes can be streamlined and made more efficient. With all transactions and data recorded on the blockchain, auditors can access a single, reliable source of information. This eliminates the need for reconciling multiple records and conducting manual checks, reducing the time and effort required for audits. Auditors can easily trace the flow of dairy products, verify compliance with regulations, and identify any irregularities or discrepancies, enhancing the accuracy and effectiveness of auditing procedures.

Enhanced animal health monitoring and data management: Blockchain technology can facilitate the collection and management of data related to

animal health and welfare. By integrating IoT devices, such as wearable sensors or smart collars, with blockchain, real-time data on factors like animal behavior, activity levels, and health indicators can be recorded securely. This data can provide valuable insights into the well-being of dairy animals, enabling early detection of health issues, timely intervention, and preventive measures. Transparent access to this information can also improve communication and collaboration among stakeholders, including farmers, veterinarians, and regulators, leading to better animal care and welfare practices.

Consumer Engagement and Trust: Blockchain technology plays a pivotal role in enhancing consumer engagement and fostering trust within the dairy industry. By leveraging blockchain-enabled platforms and applications, consumers gain direct access to comprehensive product information, including the origin, production practices, and certifications of dairy products. This transparency enables consumers to make more informed choices and align their purchasing decisions with their values, such as supporting animal welfare or



sustainable practices. Ultimately, blockchain technology empowers consumers, fosters transparency, and cultivates trust, contributing to a more engaged and loyal consumer base within the dairy industry.

Challenges

Implementing blockchain technology in the dairy industry presents challenges and considerations. These include potential barriers to adoption, resistance to change, and the need to educate stakeholders about the benefits. Data privacy and security concerns must be addressed through robust measures such as encryption and permissioned access. The cost of infrastructure and ongoing maintenance is another important consideration for organizations. Overcoming these challenges requires collaboration, industry-wide standards, robust security measures, and regulatory frameworks to facilitate the successful implementation of blockchain technology in the dairy industry.

Future Outlook and Conclusions

The future outlook for blockchain technology in the dairy industry is promising. As the technology continues to mature and gain wider adoption, it is expected to revolutionize the industry by addressing key challenges and providing numerous benefits. Blockchain's ability to enhance transparency, traceability, and trust in the dairy supply chain will improve consumer confidence and drive market growth. Additionally, blockchain's potential to streamline processes, reduce costs, and enable new business models will unlock opportunities for increased efficiency and innovation. With continued

collaboration, investment, and regulatory support, blockchain technology has the potential to reshape the dairy industry, creating a more sustainable, secure, and consumer-centric ecosystem.

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Dairy and Food based Instant Dry Mixes: Manufacturing Techniques and Application

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The preservation of food products in its dry form is an old age technique; the low moisture content in the dry product not only lowers the shipping cost and storage space requirement, but also produces a shelf-stable valuable product that can be stored at ambient temperature for extended periods (Kumar *et al.*, 2015). One of the major constraints which restrict the large-scale organized production and marketing of traditional Indian foods are the limited shelf life of the product under both ambient and refrigerated storage (Amadou *et al.*, 2011). Therefore, all stakeholders in this segment have realized the need to develop instant dry mixes of these products. In addition to the substantial value-addition and product diversification achieved by this line of product development, instant dry mixes are also designed to provide convenience to the consumers during its preparation, reduce wastage from spoilage, save consumers time, and reduce financial costs using economics of scale (Saxena, 2018). The manufacturing instant dry mixes requires a delicate balance of technological expertise, food science knowledge, and stringent quality control to deliver consistent and safe products to consumers. The specific manufacturing techniques used can vary based on the type of instant dry mix being produced.

Methods of Production for Instant Dry Mixes

The convenience instant dry mixes available in the market are manufactured by various

techniques such as, dry blending, spray drying, osmotic dehydration, tray drying (with or without vacuum), roller drying, extrusion cooking, and dry-crystallization process (Kulkarni and Reddy, 2007). Several instant mixes of indigenous food products have been described by various authors; some of the products can be directly reconstituted in a suitable medium such as milk or water before their consumption, while some mixes require minimum preparation steps before its ready for consumption.

Dry Blending Process

Dry blending is the one of most widely reported technique for manufacturing of instant dry mixes which involves mixing dry ingredient in standardized/ predetermined proportion to produce a well-mixed dry product. The addition of a small amount of liquid to the mix in the dry blending process has also been reported (Wu *et al.*, 2000). The dry blending process has been reported in a big vat with baffled arrangement for effective mixing of each and every ingredient. The equipment's commercially employed for dry blending purpose are solid blender designs such as ribbon blender, tumbler mixer, etc. The process technology for several dry blended mixes have been reported, including popped weaning food, *kheer* ready mix, *Palada payasam* dry mix, *gulabjamun* mix, instant corn based dairy dessert mix, instant dry peas curry mix, instant mix of *idli* and *dosai poha* mix, *upma* mix, *Rabri* mix, *uttapa* mix and *Gasagasa payasam*.

Dry Blending with Spray Coating Process

A modified method of dry blending, where in the dry blended solid ingredients were coated with a relatively small amount of liquid with techno-functional attributes as a sweetening, colouring, flavouring and seasoning agent has been reported for ready-eat-cereal and dry sugar cocoa-mix. The process is accomplished using specially designed spray gun/ nozzles installed on the top of the mechanical blender. In recent times, rice and millets based instant mixes, roasted nuts, and pharmaceutical drugs have also been manufactured using the spray coating technique.

Extrusion Cooking Process

Extrusion cooking is the HTST process of simultaneous cooking and shaping/ forming of a moistened blend or dough (composed of starch, protein, fat and other ingredients) by a combined mechanism of heating, pressure and mechanical shear (Sahay and Singh, 1996). The extrusion process results in several physico-chemical changes in the food including gelatinization of starch components, glass transition of lactose/ sucrose, denaturation of protein, degradation of anti-nutritional factors, and destruction of microorganism, which impart characteristic textural and flavour attributes, while concurrently improving the overall digestibility and acceptability of product.

Several attempts to manufacture dry mixes using the extrusion cooking technique have been reported in the literature, e.g., RTE snacks, extruded snacks, instant rice porridge, precooked rice granules (extrudate) in instant *kheer* mix, instant vegetable soup mixes, and sorghum cowpea instant porridge.

Spray Drying Process

The spray drying process is a dilute bed drying process based on the principle of atomizing

the feed slurry or liquid, (preferably preheated and concentrated), to form a fine spray of very minute droplets, directed in a drying chamber where they mix intimately with a current of hot air. The large surface area of these mist-like particles results in an almost instantaneous moisture transfer from the particles which is thus dried to a fine powder. Spray drying process has been employed for the preparation of many dry mixes, such as, instant milk-rice powder, *vermicelli* pre-mix, mango milk powder, *basundi* mix powder, *kulfi* mix and *basudi* mix.

Fluidized Bed Drying Process

The fluidized bed drying process is an expanding bed drying process that has been employed in the preparation of instant dry mix, for the production of instant grains from preconditioned soaked grain. The grains are suspended in the hot drying medium (air) stream flowing at a high velocity sufficient to cause the grains to remain in a fluidized state in the dryer. The application of this technique in the process technology of dry mixes includes the preparation of instant rice grain (Jha *et al.*, 2000), instant wheat grains (Shalini, 2005), instant dalia mix (Khan *et al.*, 2014).

Tray Drying Process

Tray drying technique has been reported for the drying of large varieties of solid, semisolid and liquid food products during the preparation of instant dry mixes. Quick-cooking rice in instant *kheer* mix, precooked instant jasmine rice, ready-to-cook instant *kheer* mix have been formulated using a vacuum and/ or atmospheric tray drying process.

Dry-crystallization Process

Dry-crystallization is basically a concentration process recently reported for the preparation of instant dry mixes of dairy desserts such as *payasam*. This process involves the

concentration of solid food ingredient along with milk and sugar till supersaturation stage, and cooling is carried out thereafter, so that the sugar crystallizes over the surface of solid food ingredient. Dry-crystallization has been reported for the preparation of *Palada payasam* dry mix (Unnikrishnan *et al.*, 2003), *Gasagasa payasam* dry mix (Nath *et al.*, 2004) and *Avalakki payasam* dry mix (Nath *et al.*, 2008)

Conclusion

The production of instant dry mixes involves several key steps to create a stable, easy-to-use, and convenient product. The method use for the production of instant mixes affects the overall quality and shelf life of final product. Overall, the production of instant food mixes requires a delicate balance between traditional culinary expertise and modern food processing techniques. It is through this harmonious integration that manufacturers can consistently produce high-quality, safe, and enjoyable instant food mixes that meet the demands of busy consumers seeking convenient and delicious meal solutions. The technology advances in production technique need to be exploited by the scientists and manufacturers for filling the basket of more instant mixes of traditional Indian dairy and food products to meet national and overseas demand of consumers.

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The Milk Value Chain in India: Nourishing a Nation

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The milk value chain plays a significant role in India, as the country is the world's largest producer and consumer of milk. India holds the distinction of being the world's largest milk producer, with an estimated production of over 190 million metric tons in 2021. The country surpassed the European Union and the United States to secure this position. Milk is an integral part of the Indian diet, and per capita milk consumption has been steadily increasing. As of 2021, the average annual per capita milk consumption in India was approximately 394 kilograms, highlighting the significant role milk plays in nourishing the population. With a vast network of dairy farmers, cooperatives, processors, and retailers, the milk value chain in India not only contributes to the economy but also provides livelihood opportunities to millions of people. This article explores the various stages of the milk value chain in India, highlighting its importance, challenges, and future prospects.

Dairy Farming

The milk value chain begins with dairy farming, where millions of farmers across the country rear cattle and buffaloes to meet the ever-growing demand for milk. Traditional methods coexist with modern dairy practices, and farmers play a pivotal role in ensuring the availability of milk. However, challenges such as lack of access to quality feed, healthcare services, and breeding facilities persist. Efforts are being made to promote scientific dairy farming practices, provide training

and financial support to farmers, and enhance milk productivity.

Milk Collection Infrastructure

After milk is procured from individual farmers, it goes through the collection phase. India boasts an extensive milk collection infrastructure. Over 1.6 lakh village-level milk collection centers, known as Dairy Cooperative Societies (DCS), serve as the primary interface between farmers and the milk value chain. These centers ensure the collection, testing, and storage of milk before it is transported for processing.

Cooperative Movement

The cooperative movement in the milk industry has been instrumental in shaping the milk value chain in India. Cooperative societies, such as The Amul cooperative model, pioneered by the Gujarat Cooperative Milk Marketing Federation (GCMMF), has been a notable success. Amul, an acronym for Anand Milk Union Limited, has empowered millions of dairy farmers by providing them with fair prices, technical support, and access to markets. These societies collect milk from farmers, maintain quality standards, and provide fair prices, ensuring a steady income for the farmers. The cooperative model has been successful in reducing the influence of middlemen, promoting farmer welfare, and fostering a sense of community among dairy farmers.

Milk Processing

Once collected, milk is transported to processing plants, where it undergoes various stages

of processing, including pasteurization, homogenization, and packaging. India has a robust infrastructure of milk processing plants, both in the organized and unorganized sectors. India possesses a robust milk processing industry. The organized sector comprises modern processing plants, while the unorganized sector consists of smaller units. As of 2021, the country had an estimated milk processing capacity of over 55% of its total milk production, with major players like Amul, Mother Dairy, and Nestle contributing to the organized sector.

Dairy product Development

The milk value chain in India extends beyond liquid milk. The industry offers a wide range of dairy products, including butter, ghee (clarified butter), cheese, yogurt, paneer (cottage cheese), ice cream, and condensed milk. The sector provides employment opportunities and contributes to value addition in the milk value chain.

Distribution and Retail

The processed milk and dairy products are distributed through a vast network of wholesalers, distributors, and retailers. This ensures that milk reaches consumers across the country, even in remote areas. Cooperative societies often operate their own retail outlets, ensuring a direct link between the farmers and consumers. Additionally, modern retail chains and online platforms have emerged as important channels for milk and dairy product distribution, offering convenience and a wide range of choices to consumers.

Importance

Livelihood and Income Generation: The milk value chain is a significant source of livelihood for millions of rural households in India. It provides employment opportunities for small-scale dairy farmers, milk

collection agents, transporters, dairy processors, and distributors. The income generated from the milk value chain helps alleviate poverty and supports rural development.

Food Security and Nutrition: Milk is a vital source of nutrition, particularly for children and pregnant women. The milk value chain ensures the availability of safe and nutritious milk across the country. It helps meet the protein and micronutrient requirements of the population, contributing to improved food security and nutrition outcomes.

Rural Development: Dairy farming, a critical component of the milk value chain, encourages rural development. By engaging in dairy activities, farmers have a diversified income source, reducing their dependency on a single crop. It promotes entrepreneurship, enhances agricultural productivity, and contributes to rural infrastructure development.

Employment Generation: The milk value chain creates employment opportunities along its various stages, providing income and economic stability to individuals. From animal rearing and fodder cultivation to milk processing and distribution, it generates jobs at different skill levels, supporting both rural and urban economies.

Women Empowerment: Dairy farming and milk processing offer significant opportunities for women empowerment in rural areas. Women actively participate in milk production, collection, and processing activities, gaining economic independence, and enhancing their socio-economic status. Many dairy cooperatives in India are women-led, providing them with leadership roles and decision-making powers.

Market Linkages and Integration: The milk value chain facilitates market linkages between rural

producers and urban consumers. Dairy cooperatives, private milk processing companies, and retail chains establish robust supply chains, ensuring milk reaches consumers efficiently. This integration helps in price stabilization, reduces middlemen exploitation, and enhances market access for dairy farmers.

Export Potential: India is one of the largest milk-producing countries globally. The milk value chain, with its focus on quality and hygiene standards, opens doors for export opportunities. Indian dairy products, such as milk powder, ghee, butter, and cheese, are exported to various countries, contributing to foreign exchange earnings and boosting the national economy.

Environmental Sustainability: The milk value chain promotes sustainable agricultural practices. Dairy farmers adopt efficient animal management techniques, sustainable fodder production, and waste management systems. These efforts contribute to environmental conservation, such as reducing greenhouse gas emissions and conserving natural resources.

Challenges

The milk value chain in India faces several challenges that impact its efficiency and growth. However, there are also promising future prospects that can contribute to its development. Here are some challenges and future prospects for the milk value chain in India:

Small-scale and Fragmented Operations: The milk value chain in India is characterized by numerous small-scale producers, fragmented supply chains, and lack of economies of scale. This fragmentation leads to inefficiencies in milk collection, processing, and distribution, hindering cost-effectiveness and quality control.

Inadequate Cold Chain Infrastructure: Maintaining milk quality and freshness requires a robust cold chain infrastructure. However, many parts of India lack adequate refrigeration and storage facilities, especially in rural areas. This leads to post-harvest losses, compromising the overall value chain efficiency.

Quality and Safety Concerns: Ensuring milk quality and safety throughout the value chain is a significant challenge. Issues such as adulteration, contamination, and lack of hygiene practices pose risks to consumer health and erode consumer trust. Maintaining consistent quality standards across the value chain remains a priority.

Limited Access to Credit and Technology: Small-scale dairy farmers often face challenges in accessing credit facilities and modern farming technologies. Lack of financial resources and outdated farming practices hinder productivity improvement, limiting the potential for growth and profitability along the value chain.

Price Fluctuations and Market Risks: The milk value chain is susceptible to price fluctuations influenced by factors such as seasonal variations in milk production, demand-supply imbalances, and market dynamics. Uncertain prices and market risks impact the income and stability of farmers and other stakeholders involved.

Future Prospects

Technological Advancements: Adoption of innovative technologies, such as IoT-based milk collection systems, milk quality testing devices, and automation in processing and packaging, can enhance the efficiency, traceability, and safety of the milk value chain. Technology-driven solutions can streamline operations and improve productivity.

Value Addition and Diversification: The milk value chain has significant potential for value addition and diversification. Producing value-added dairy products like flavored milk, yogurt, cheese, and dairy-based desserts can open new market opportunities, increase revenue streams, and improve profitability.

Strengthening Cooperative Models: Dairy cooperatives have played a crucial role in the success of the milk value chain in India. Strengthening cooperative models by providing training, capacity building, and financial support can empower farmers, improve bargaining power, and enable collective decision-making for the benefit of all stakeholders.

Government Support and Policy Reforms: Continued government support through policies, investments, and infrastructure development is essential for the growth of the milk value chain. Initiatives promoting access to credit, cold chain infrastructure, and market linkages can help address existing challenges and create an enabling environment for the sector.

International Collaboration and Exports: Exploring international collaborations and expanding dairy product exports can boost the growth of the milk value chain. Building strategic partnerships, improving quality standards, and tapping into global markets can enhance the economic viability of

the sector and contribute to foreign exchange earnings.

Overall, addressing the challenges faced by the milk value chain in India requires collaborative efforts from stakeholders, technological advancements, policy reforms, and investment in infrastructure. With the implementation of appropriate strategies and the realization of future prospects, the milk value chain can further strengthen its position, contribute to rural development, and meet the growing demand for safe and nutritious dairy products in India.

Conclusion

The milk value chain in India is a complex and dynamic system that contributes significantly to the country's economy and sustains the livelihoods of millions of farmers. While challenges such as low productivity, limited access to resources, and price fluctuations persist, efforts are being made by government agencies, cooperatives, and private players to address these issues. The increasing demand for milk and dairy products, driven by population growth and changing consumption patterns, presents immense opportunities for the growth and development of the milk value chain in India. By promoting sustainable dairy farming practices, improving infrastructure, and ensuring fair prices to farmers, India can continue to nurture its milk value chain, benefiting both the industry stakeholders and the health of its citizens.

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