

Optimizing Dairy By-Product Utilization: A Comprehensive Overview

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Abstract

The utilization of dairy by-products, such as skim milk, buttermilk, whey and ghee residues, is crucial in maximizing the economic potential of dairy farming while addressing nutritional needs. The 4 F pyramid categorizes their utilization hierarchy, emphasizing human consumption as the primary focus, followed by animal feed, fuel production and fertilizer. Technological advancements offer opportunities for efficient utilization, but challenges persist, particularly in economically leveraging whey and ghee residues. Understanding their nutritional properties and exploring diverse applications, from food processing to industrial and environmental uses, underscores the importance of optimizing dairy by-product utilization for sustainable dairy production and economic growth.

Introduction:

A dairy by-product can be defined as a valuable product generated during the production of a primary dairy item, such as whey, buttermilk, skim milk and ghee residues. The array of dairy by-products is vast, posing a challenge in their effective utilization during dairy processing. Due to their significant and unique nutrient content, it's essential to ensure their proper utilization for the benefit of the broader population. Converting nutritious elements into non-edible substances would be detrimental, especially considering the prevalent malnutrition in many developing nations. Maximizing the economic potential of dairy farming hinges on efficiently harnessing these by-products, making it a crucial aspect of a profitable dairy business. Technological advancements offer promising opportunities for exploring novel avenues for utilizing these dairy by-products effectively.

Skim milk, buttermilk, whey and ghee residue represent some fundamental dairy by-products. Each constituent of milk holds distinctive nutritional value and should be processed

carefully into consumable forms. Nevertheless, dairy facilities, particularly in India, commonly face challenges regarding the economical utilization of by-products, notably whey and ghee residue.

The 4 F Pyramid:

The 4 F pyramid prioritizes the utilization of dairy by-products, placing human consumption at the top due to their high market value. Next is animal feed, enhancing livestock nutrition. Following this is the conversion into biofuels or biogas for alternative energy sources. Finally, they can be processed into organic fertilizers to improve soil fertility and crop yields. This framework guides the most valuable applications of dairy by-products based on market demand and utility.

By-product their principle of utilization and name of food product made

Sr. No		Main Product	By-Product	Processing method	Products Made
1	Cream	Skim milk	Pasteurization	Flavoured milk	
			Sterilization	Sterilized flavoured milk	
			Fermentation	Cultured Buttermilk	
			Fermentation and Concentration	Concentrated sour skim milk	
			Concentration	Plain and Sweetened Condensed skim milk	
			Drying	Dried skim milk or Skim milk powder or Non-Fat Dry Milk (NFDM)	
			Coagulation	Cottage cheese, Quarg, edible casein	
2	Butter	Buttermilk	Fermentation and Concentration	Condensed buttermilk	
			Concentration and drying	Dried buttermilk	
			Coagulation	Soft cheese	

3	Cheese, Casein, Chhana, Paneer	Whey	Fermentation	Whey beverage, Yeast whey
			Concentration	Plain and sweetened condensed whey, whey protein concentrate, whey paste, lactose
			Drying	Dried whey
			Coagulation	Ricotta cheese
4	Ghee	Ghee residue	Processing	Sweetmeat, Toffee, Sweet paste

Skim Milk and Its By-Products:

Skim milk, a by-product derived from cream manufacturing, boasts elevated solids-not-fat content and significant nutritional value. In dairy processing facilities, it predominantly serves two primary functions: either as a component in standardization processes for the production of primary dairy commodities or is desiccated via spray drying for preservation. Its utilization in either of these forms or as a liquid does not classify it as a by-product; rather, it attains this designation when economically unutilized or directed towards derived products such as casein, coprecipitates, or protein hydrolysates.



Casein and Co-Precipitates:

Casein, comprising roughly 80% of milk's protein content, has historically been utilized across diverse industries such as paper, textile, paint, leather, and rubber. In edible forms like casein and caseinates, prominent dairy by-products, they find extensive application in dairy and food products. Commercial casein production involves precipitation from skim milk through acidification to yield acid casein or coagulation with rennet to produce rennet casein. Other commercially available forms include coprecipitate and caseinates. However, the production of soluble casein, notably caseinates, has faced challenges in India due to economic constraints stemming from high drying costs, low bulk density, and elevated expenses associated with packaging, storage, and transportation.



Co-Precipitates:

The commercialization of co-precipitates, despite offering advantages over casein such as increased yield, versatile functional properties, and enhanced nutritional value, has been hindered primarily by poor solubility, particularly pronounced in calcium-rich co-precipitates. This solubility limitation compromises their effectiveness in various applications, leading to concerns regarding product quality, consistency, and consumer acceptance, thereby impeding widespread adoption by industries. Addressing this challenge is pivotal for enhancing the commercial viability of co-precipitates. Strategies including process modifications, formulation enhancements, and the development of innovative additives are imperative for overcoming solubility constraints and facilitating broader utilization of co-precipitates across diverse industrial sectors.

Milk Protein Hydrolysates:

Protein hydrolysis stands as a pivotal advancement within the food industry, offering a wide array of applications in nutritional, dietetic, and formulated foods, particularly beneficial for individuals with protein allergies, gastrointestinal disorders, or requiring easily digestible dietary options. Despite its potential, there exists considerable scope for improving the quality of protein hydrolysates in India. Enhancements could encompass refining hydrolysis processes to achieve targeted protein breakdown, augmenting flavour profiles and palatability, ensuring consistent adherence to quality and safety standards, and exploring novel protein sources for hydrolysis. Furthermore, dedicated research and development endeavours tailored to customize protein hydrolysates to specific nutritional demands and consumer preferences can further enhance their value in addressing dietary challenges and promoting overall health and wellness. By prioritizing investment in research, innovation, and stringent quality control measures, India can harness the substantial potential of protein hydrolysates to meet evolving consumer needs and propel advancements in the food industry.

Utilization of Skim Milk:

- **Food Processing:** Skim milk serves as a key ingredient in various food products such as yogurt, cheese, ice cream and baked goods, providing nutritional value while reducing fat content.
- **Nutritional Supplements:** Skim milk powder is used to fortify beverages, infant formula and nutritional supplements with protein and essential nutrients.

- **Manufacture of Dairy Products:** Skim milk is utilized in the production of dairy products like condensed milk, evaporated milk and buttermilk, contributing to their texture and flavor while reducing fat content.
- **Industrial Applications:** Skim milk finds application in industries such as cosmetics, pharmaceuticals and animal feed, where its protein content is utilized for its emulsifying, binding and nutritional properties.
- **Research and Development:** Skim milk serves as a common medium for bacterial culture growth in laboratory settings and is used in research studies exploring its health benefits and technological applications

Buttermilk:

Buttermilk, a significant by-product of butter manufacturing, is produced in three main types in our country: sweet and sour buttermilk in the organized sector, and lassi at the household level. Rich in phospholipids, buttermilk serves as an effective emulsifier in food systems, making it a valuable functional ingredient for various food products such as chocolate, cheese seasonings, margarine,



bread, ice cream mixes, and yogurt. Buttermilk concentrate, particularly abundant in phospholipids, has been integrated into processed cheese spreads to improve their sensory, rheological, and functional properties, thereby enhancing their utility as functional foods. Sweet buttermilk, condensed through heat and vacuum processes, has been used to increase the yield of pizza cheese by leveraging denatured whey proteins. Moreover, buttermilk has shown promise as an ingredient in buffalo milk-derived chhana, an Indian-style soft cottage cheese analogue. Technological evaluations have explored substituting milk with increasing proportions of sweet buttermilk in cream cheese production, resulting in correlated increases in moisture content and yield. Additionally, adding buttermilk to reduced-fat cheese formulations, up to 40%, has led to sensory enhancements compared to control samples.

Utilization of Buttermilk:

- **Emulsifying Agent:** Buttermilk, with its high phospholipid content, serves as an effective emulsifier in various food systems.

- **Functional Ingredient:** It is utilized as a functional ingredient in a wide range of food products including chocolate, cheese seasonings, margarine, bread, ice cream mixes, and yogurt.
- **Processed Cheese Spreads:** Buttermilk concentrate, rich in phospholipids, is incorporated into processed cheese spreads to enhance their organoleptic, rheological, and functional properties.
- **Pizza Cheese Production:** Sweet buttermilk, when condensed and added to cheese milk, improves the yield of pizza cheese, contributing to denatured whey protein content.
- **Chhana Production:** Buttermilk is used as an ingredient in the production of chhana, an Indian-style soft cottage cheese analogue, providing unique texture and flavour.
- **Cream Cheese Formulation:** It can be substituted for milk in cream cheese production, with increasing proportions leading to higher moisture content and yield.
- **Reduced-Fat Cheese Enhancement:** Addition of buttermilk to reduced-fat cheese formulations improve sensory scores, enhancing overall consumer acceptance and product quality.

Whey:

Whey, a thin, easily perishable, greenish-yellow liquid, stands as the most significant by-product of dairy processing, arising from cheese, casein, chhana, paneer, chakka, and co-precipitate production. Its composition and acidity vary widely, containing approximately half of milk's total solids and boasting rich nutrients like lactose, whey proteins, minerals, and vitamins. Despite its modest quantity, whey proteins possess high nutritional value, with a protein efficiency ratio of 3.6, a biological value of 104, and a net protein utilization of 95, ranking second only to egg protein. Furthermore, its abundant lactose content makes whey an excellent fermentation medium in various products. Through lactose breakdown into glucose and galactose, typically in whole or deproteinized whey, sweetness is enhanced. These lactose-hydrolysed syrups, often condensed, find predominant usage in sweet confectionery items and ice cream. The global whey products market, valued at around \$6.5 billion, is projected for future growth, driven by the industry's increasing focus on nutritional products, especially in dietary, sports, and clinical sectors.



Whey Proteins:

Ultrafiltration stands out as a highly promising technology for whey processing in India. This method involves the separation and purification of whey proteins from liquid whey through an effective membrane filtration process, followed by spray drying. This process yields either whey protein concentrate, containing 65-80% protein in dry matter or whey protein isolate, which boasts an even higher protein content of 90% in dry matter.

Utilization of Whey:

- 1. Food Industry:** Utilized in baked goods, dairy products, confectionery, and beverages to enhance texture, flavour, and nutritional content. Also used in protein bars, shakes, and supplements.
- 2. Animal Feed:** Serves as a nutritious feed ingredient for livestock, providing essential nutrients for growth and health.
- 3. Fermented Products:** Acts as a fermentation medium for yogurt, kefir, and fermented vegetables, contributing to desirable Flavors and textures.
- 4. Biotechnology:** Components like lactose and proteins are utilized in processes such as fermentation, bioactive peptide production, and enzyme manufacturing.
- 5. Cosmetics and Personal Care:** Whey proteins are incorporated into products like moisturizers, shampoos, and anti-aging creams for skin and hair health.
- 6. Pharmaceuticals:** Whey proteins are utilized in nutritional supplements, infant formulas, and medical foods for specific dietary needs and health conditions.
- 7. Environmental Applications:** Used in wastewater treatment and biogas production, serving as a substrate for microbial fermentation and a nutrient source for microbial growth.

Ghee Residues:

Ghee residue, a by-product of the ghee manufacturing industry, is produced in significant quantities in India. During the process of ghee preparation, a blackish-brown residue, primarily composed of the solid non-fat (SNF) portion of cream, is coagulated out when the cream is heated. This residue, obtained as a moist brownish sediment after the molten ghee has been strained out, possesses several noteworthy properties:





1. **Nutritional Properties:** Ghee residue is rich in both protein and fat, in addition to containing a considerable amount of minerals. This makes it a potentially valuable dietary supplement for humans.
2. **Antioxidant Properties:** Ghee residue exhibits rich natural antioxidant properties, attributed to its constituents influenced by various technological parameters. These antioxidant properties arise from both lipid and non-lipid constituents present in the residue.
3. **Flavouring Properties:** Ghee residues serve as a rich and natural source of flavour compounds, including free fatty acids (FFA), carbonyls and lactones. These flavour compounds contribute to the distinctive taste and aroma associated with ghee residue.

Utilization of Ghee Residues:

1. **Animal Feed:** Rich in protein, fat, and minerals, it can serve as a nutritious feed ingredient for livestock, aiding in their growth and health.
2. **Dietary Supplement:** Processed into dietary supplements for human consumption, providing additional protein, fat, and mineral content to diets.
3. **Industrial Applications:** Utilized as natural antioxidants or flavoring agents in food production, enhancing the quality and taste of food products.
4. **Biogas Production:** Used as a substrate for biogas production through anaerobic digestion, generating methane for renewable energy sources.
5. **Composting:** Composted with other organic materials to produce nutrient-rich compost, improving soil health and promoting plant growth in agriculture and horticulture.
6. **Research and Development:** Utilized in studies related to food science, nutrition, and sustainable waste management practices, contributing to advancements in these fields.

Conclusion:

The utilization of by-products in dairy manufacturing is a pressing concern, given their unique composition and nutrient richness. Efforts to properly utilize these by-products are imperative for the welfare of the populace. Recent years have seen increased attention towards industrial utilization of dairy by-products, indicating their growing economic significance. Effectively harnessing these by-products can substantially enhance the profitability of dairy

operations, becoming essential for a thriving dairy business. Advancements in technology offer vast potential for exploring novel avenues of by-product utilization in dairy processing.

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