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Milk By-Products Utilization

Syed Mansha Rafiq and Syed Insha Rafiq

Abstract

The dairy industry processes raw milk into an array of products including butter, cheese, cream, yogurt, ghee, condensed milk, dried milk, ice cream, etc. and produces various by-products including buttermilk, whey, ghee, and skim milk. These dairy by-products have high nutritive value and have found applications in many food industries as well as nonfood applications. Buttermilk which is a by-product of butter-making is used both in liquid form (fermented to produce a beverage *chaas*) and dried to be used as an ingredient. Whey, a by-product of cheese and paneer manufacture with high nutritive value, has been utilized in the preparation of products like sports drinks and beverages. Whey is also used in the preparation of certain types of cheese like ricotta. Skim milk which is a by-product of cream manufacture has been used to produce flavored milks and certain type of cheeses like cottage and quark cheese. Ghee residue from ghee manufacture has been used in the preparation of sweets, cookies, and chocolates. Casein and casein derivatives are mainly used in bakery and confectionary. In addition to these food applications, whey proteins (WP) and caseins have found applications as packaging films.

Keywords: buttermilk, whey, ghee residue, skim milk, caseins

1. Introduction

A number of by-products like whey, buttermilk, skim milk, and ghee residue (GR) and derived by-products like caseins, caseinates, lactose, whey proteins (WP), etc. are produced by the dairy industry. Attempts have been made globally to utilize these by-products because of their high nutritive value. Dairy plants in India are still confronted with the problem of by-product utilization because of lack of adequate technology and high cost of new technologies. However the Indian dairy industry is making advancement in this direction. Whey is the major by-product of the dairy industry. It is a useful resource of nutrients containing about 50% of the solids of milk [1]. Whey production is steadily growing, and its high organic content is an important environmental and health issue. Therefore, suitable management of this by-product is required. Like milk, whey may have different origins (e.g., goat, sheep, and buffalo), but the most relevant in terms of production volume and economical value is that obtained from cow milk processing. Skim milk is a by-product obtained from cream manufacture. It is rich in SNF content and has high nutritional value and has been utilized in the manufacture of a number of dairy products or in powder form. Buttermilk, a by-product of butter manufacture, has been used as such or in dried form. Ghee residue from ghee manufacture has also found applications in many food products.

2. Whey utilization

Whey, a by-product of cheese manufacturing, contains approximately 7% dry matter of which 13% is proteins. It generally represents a volume fraction of 90% in milk and is being classified into sweet and acid whey. The sweet whey originates from cheese manufacturing or from industrial casein production where the casein is coagulated by rennet, at pH of 6.0–6.5, while the acid whey (pH < 5.0), resulting from processes in which casein is coagulated by fermentation or addition of organic or mineral acids, as in the processing of fresh, acid-coagulated cheeses (e.g., cottage cheese or quark) or strained yogurt (e.g., Greek-style yogurt). The main components for both types of wheys are given in **Table 1**. Water constitutes approximately 93% of the whey, while the total solid fraction contains lactose (70–72%), minerals (12–15%), and whey proteins (8–10%). The main difference between both wheys is the mineral content, the acidity, and the composition of the whey protein fraction. Acid whey has higher calcium content as, at this low pH, the colloidal calcium contained in the casein micelles in normal milk solubilized and partitioned into the whey [2]. Composition of whey protein fraction is different as sweet whey contains glycomacropeptide, a fragment of the κ -casein molecule produced by rennet clotting, constituting 20% of the whey protein fraction of sweet, rennet-based wheys [2]. Acid whey has a large potential to be used as the main component of beverages because of its nutritional composition. The utilization of liquid acid whey offers an interesting approach as there is no need for using complex technology other than pasteurization.

Up until very recently, whey resulting from the curd during manufacture of cheese was regarded as a polluting effluent from the dairy industry. Nowadays, the potential of a vast range of whey proteins and their peptides with great potential health benefits is well known. Recently, whey gained interest as a food ingredient, coming into use as a technological agent particularly through whey proteins, achieving a unique blend between nutritional and functional properties with applications both in food and health. Whey components are being separated by isolation and fractionation on selective porous membranes. Extensive investigations focused on the exploitation of techno functional, biological, and nutritional properties of the whey [3]. By far, membrane technology enabled the breakthrough of whey processing into several derivatives favoring their incorporation as ingredients into different foods. These whey proteins are separated and purified from the liquid whey in an efficient membrane filtration process and subsequent spray drying to obtain either whey protein concentrate (WPC) (65–80% protein in dry matter) or whey protein isolate (WPI) (90% protein in dry matter). Ultrafiltration (UF) techniques have been used for cheese milk to retain whey proteins to increase the yield of the

Component	Sweet whey (g/L)	Acid whey (g/L)
Total solids	63.0–70.0	63.0–70.0
Lactose	46.0–52.0	44.0–46.0
Protein	6.0–10.0	6.0–8.0
Calcium	0.4–0.6	1.2–1.6
Phosphate	1.0–3.0	2.0–4.5
Lactate	2	6.4
Chloride	1.1	1.1

Source: [2].

Table 1.
Typical composition of sweet and acid whey.

end product. Moreover, whey proteins have been added into cheese to boost its nutritional profile. Different pre-treatments of cheese milk have been developed to incorporate native or denatured WP in the cheese matrix. These options opened new avenues for progress in cheese-making.

Although these whey proteins are used as additives in the agro-food industry, such as the athletic drinks, still, 40% of whey remains unprocessed, which makes it an interesting resource in view of its excellent oxygen barrier properties [4, 5]. Whey protein films have excellent oxygen, aroma, and oil barrier properties. They have excellent mechanical properties that provide durability when used as coatings on food products, films separating layers of heterogeneous foods, or films formed into pouches for food ingredients. These films do not significantly compromise the desirable primary barrier and mechanical properties as packaging films and hence add value for ultimate commercial applications [6, 7]. Whey-based formulations are processed for packaging applications and edible coatings through extrusion as well as compression molding. Incorporation of plasticizing agents is necessary to overcome the intrinsic brittleness. Whey protein isolate films are fully transparent. Whey coatings with a barrier layer and an active layer have been developed. The barrier layer contains whey protein isolates supplemented with plasticizers, and the active layer contains antimicrobials or antioxidants to extend the shelf life of the packaged food. Whey-based films may improve the sensory attributes of the coated goods while providing some health benefits to the consumers. These proteins have been used as a coating on paper as well as on plastics, polypropylene (PP), polyvinylchloride (PVC), and low-density polyethylene (LDPE), which demonstrated excellent visual properties, such as excellent gloss and high transparency, as well as good mechanical properties.

3. Technologies to include whey proteins in cheese

The incorporation of whey proteins into the cheese matrix has been made possible with a number of new technologies. Whey protein addition enhances the nutritional and functional properties as well as the economic effectiveness of cheese production. Addition of whey proteins increases the yield but may result in a slightly poor flavor and texture [8]. Whey protein concentrate and whey protein powder addition has been reported in a variety of cheeses that include cream cheese, cheese spreads, Cheddar cheese, Gouda cheese, processed cheese, Domiati cheese, etc. Addition of WPC was found to increase the yields in all cheeses with softer texture in camembert and Iranian white cheese. The influence of whey protein incorporation in processed cheese on its functional and sensory properties has been extensively studied. It has been found that whey proteins can be used to replace caseins up to 2% in processed cheese [9]. Whey protein concentrates are used as fat replacers in processed cheese, and they reduce the hardness of the cheese [10]. Addition of whey proteins/carboxymethyl cellulose complex recovered from whey, corresponding to 25–75% of cheese milk weight in Domiati cheese, increased cheese yield, reduced loss of weight during pickling, and enhanced the body of cheese. Flavor intensity was not affected by the addition of whey proteins [11]. Replacement of rennet casein in part with WPC in mozzarella cheese analogue resulted in greater firmness and meltability, lower cohesiveness and fat leakage, and moderate chewiness [12].

4. Membrane separation processes

Membrane separation techniques have been largely explored by dairy industries for their effective and economic implementation. These techniques work on

the basis of size and shape of molecules as well as on charge and affinity for the membrane. Among these techniques UF was the first to be exploited for cheese enrichment with WP [1, 13]. Whey proteins, which remain entrapped in the curd matrix, contribute to the enhanced yield of cheese. Rennet-curd cheeses, such as mozzarella, cottage, and Cheddar, can be manufactured by this technique [14]. The implementation of spray drying has reduced the thermal degradation of whey components, as well as the cost associated with its concentration. Membrane filtration technique employs semipermeable surfaces (membranes) with specific pore sizes, where the permeate flows through, while the retentate is blocked based on size/molecular weight. Throughout the combination of successive filtrations steps, it is possible to produce protein fractions with different compositions and degrees of purity. This technology leads to a selective concentration of proteins, which after drying is called whey protein concentrate containing about 35–80% of protein. Further purification, often conjugating other techniques as ion-exchange chromatography, allows the achievement of higher degrees of purity with residual or no lactose content and higher desalination, resulting in whey protein isolate containing at least 90% of protein. With the application of more advanced techniques, such as chromatography, partial hydrolyses, and selective precipitation combined with centrifugation and dialysis, it is yet possible to obtain pure whey protein fractions. WPI and WPC can be widely used for food applications because of higher protein and amino acid contents; low calorie, fat, and sodium contents; absence of pathogens and toxic compounds; biocompatibility and generally recognized as safe status; ready availability; and inexpensive products.

5. Ghee residue utilization

Ghee is an important constituent of Indian meal prepared using different methods. It is clarified milk fat with incomparable organoleptic properties, which make it an important ingredient in a wide variety of food applications [15]. About 30–35% of the milk produced in India (112 million tons in 2009–2010) is converted into ghee [16]. A blackish brown residue mainly the SNF part of cream was coagulated out during ghee preparation as a by-product when cream is heated is known as ghee residue. It is obtained as moist brownish sediment after molten ghee has been strained out [17]. The amount of ghee residue was found to depend upon the method of preparation of ghee. This was due to the variation of nonfatty serum constituents of the different raw materials used for the preparation of ghee. Ghee yield was higher from creamery butter method in comparison to direct cream method, whereas ghee residue content was higher in direct cream method in comparison to creamery butter method. The average yield of ghee residue was maximum (12%) in direct creamery (DC) method followed by almost the same yield in creamery butter (CB) and desi butter (DB) methods, that is, 3.7%. Ripening of cream prior to clarification reduces the yield of ghee residue [18, 19]. It is one of the largest by-products of the dairy industry and consists mainly of milk proteins and small quantity of lactose and minerals. The ghee residue has been used in food industries for making sweets, bakery products, and as a flavor enhancer [20]. An appreciable amount of GR is produced in the country which is a nutritionally rich source of proteins and nitrogenous compounds. Ghee residue has been utilized for preparing burfi by mixing it with skim milk powder (SMP), khoa, chocolate, and sugar [21]. It can be utilized for preparing coconut burfi, candies, toffees, pinni, etc. after mixing with other ingredients. The nutritious by-product should be utilized as a food supplement in a variety of foods, food spreads, soups, etc. [22]. The utilization of this by-product in the preparation of some type of candies, toffees, edible pastes, etc. was suggested

about two decades ago but was not adopted commercially by the industry due to lack of awareness about its nutritive value. In general, the residue contains appreciable amounts of nutrients of milk. Ghee residue has been used in the preparation of candy, chocolate, burfi-type sweet, and bakery products.

The phospholipids of milk occur in a complex form with proteins in the fat globule membrane. When butter is heated to 120°C and above, the phospholipids are liberated from the phospholipid-protein complex and transferred to the oil phase. When the ghee-making process is kept much below 120°C, phospholipids, which remain in a complex form with proteins, will not enter ghee and, therefore, will be retained by GR. GR is a rich source of phospholipids from which phospholipids can be recovered and added to ghee. Pruthi et al. [23] described a heat-processing method for the extraction and fortification of ghee with GR phospholipids. The fortification of ghee with phospholipids at 0.1% level showed that the oxidative stability of ghee can be increased by increasing its phospholipid content either through heat treatment of GR with ghee or by the addition of solvent-extracted phospholipids from GR.

6. Buttermilk utilization

Buttermilk is a by-product of butter-making. It contains components derived both from fragments of milk fat globule membrane (MFGM), mainly consisting of proteins and neutral as well as polar lipids and all water-soluble components of cream [24]. Fortification with buttermilk is done to increase the yield provided cheese quality is unchanged. Buttermilk has high phospholipid content that has a significant function as emulsifiers in food systems and makes this dairy ingredient interesting for use as a functional ingredient [25] in an array of food products like chocolate, cheese seasonings, margarine, bread, ice cream mixes, or yogurt [26–28]. The buttermilk concentrate (BMC) rich in phospholipids has been utilized in processed cheese spread to improve its organoleptic, rheological, and functional properties [29]. The use of BMC in processed cheese spreads makes this dairy product useful as a functional food. This perspective could also bring economical income by enhancing the product yield or using low-value by-products from the dairy industry, such as buttermilk. Sweet buttermilk, condensed by heat and vacuum, supplemented at levels of 4 or 6% in regard to cheese milk improved the yield of pizza cheese with the contribution of denatured WP [30]. Kumari et al. [31] verified the effect of buttermilk as an ingredient in buffalo milk-derived chhana, an Indian-style soft cottage cheese analogue. Substitution of milk with variable proportions of sweet buttermilk (from 0 to 50%) was technologically tested in cream cheese [32]. The authors revealed that the progressive increase of buttermilk percentage was followed by increase in moisture and yield. Buttermilk has been added to reduced-fat cheese up to 40% and was found to improve the sensory scores in comparison to the control [33].

7. Skim milk

Skim milk powder for cheese-making requires adequate reconstitution and recombination techniques compared to whole milk powders, and at places where modern equipment and processing facilities for the reconstitution and recombination are not available, the use of whole milk powders could be advantageous. Addition of skim milk powder has been reported in Karish cheese, Domiati cheese, and processed cheese. Skim milk along with milk protein and stabilizers were used

to produce high-quality and acceptable Karish cheese with increased yield. Domiati cheese production was attempted earlier by an Egypt-based company, but the cheese obtained was inferior to that made from fresh milk. The recombined Domiati cheese had a firm texture and developed weak flavor even after the normal maturation period. Later attempts were made to improve the quality of recombined Domiati cheese, and direct addition of skim milk powder to buffalo or cow milk up to 35% total solids and coagulating the concentrated milk covered with brine resulted in acceptable taste and flavor after a month of storage. The FDA recommends the use of nonfat dry milk in processed cheese foods and processed cheese spreads. However, processed cheese made using cheese base produced from reconstituted skim milk powder results in markedly firmer cheese than the control. Skim milk powder has been reported for fortification of nontraditional white soft cheese in Egypt.

8. Conclusions

Utilization of whey proteins in cheese through either the adoption of techniques favoring WP retention in the cheese network or the direct addition of dairy-based ingredients or their combination is a challenging area in dairy sector. Some techniques have been implemented and emerged in industrial processes. In addition, ultrafiltration process can be used to restrain and recover whey proteins from drained whey that can later be added to the cheese milk. Utilizing whey protein into cheese preparation puts whey to good use. Whey protein-based edible films are a viable alternative packaging process for food and improvement of shelf life. Ghee residue is a good source of proteins, and about 100,000 tonnes of proteins can be recovered annually from GR only, and this can help in combating severe problem of protein-energy malnutrition. Potential uses of either crude or purified caseins include the production of plastics, adhesives, gels, composites, and films.

Author details

Syed Mansha Rafiq^{1*} and Syed Insha Rafiq²

1 National Institute of Food Technology Entrepreneurship and Management,
Sonipat, Haryana, India

2 National Dairy Research Institute, Karnal, Haryana, India

*Address all correspondence to: mansharafiq@gmail.com

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