By-products of dairy industry and their utilization

Introduction

During the manufacture of different dairy products, the inevitable problem of utilization of by-products is encountered. Because of their unique and important nutrients available in the by-products, they have to be utilized in a proper manner considering the welfare of the general masses.

Conversion of edible nutrients into non edible substances will not augur well given the rampant malnutrition staring at the face of the impoverished developing countries.

The profitability of the dairying can be greatly improved by economically utilizing the dairy by-products and it can be considered as a prerequisite to profitable dairy business.

With the advancement in technology, the scope is wide open for creating newer channels of utilization of the by-products arising from dairy processing.

A dairy by-product may be defined as a product of commercial value produced during the manufacture of a main product. The newly acquired economic importance of a by-product will make it a main product in the future. Important by-products available from the dairy industry and their utilization are given in the Table 1.

Table 1. Important by-products available from the dairy industry and their utilization

S. 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, Channa, 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, buttermilk, whey and ghee residue are the various basic dairy by-products. Each and every component of milk must be judiciously processed into edible form for the obvious reason of its unique nutritional value. However, dairy plants, particularly in India, are

usually confronted with the problem of by-products utilization, especially that of whey and ghee residue in an economical manner. In the past 25 years, whey has transformed from a waste by-product to a valued functional co-product. Whey technologies have grown exponentially during the past 25 years with the perfection of membranes and ion-exchange as well as an increased understanding of whey itself.

The western dairy industry especially American and European and also of Australia and New Zealand have been the harbingers in the utilization of by-products. They have developed technologies for the utilization of by-products, developed large automated plants and also developed users for by-products in dairy and food industry.

The production of other derived by-products like casein, caseinates, co-precipitates, protein hydrolysates, whey protein concentrates, lactose, whey beverages, low lactose powder and many others have prominence in advanced dairy countries and Indian dairy industry is trying to make advancement in this direction. It is only after economic liberalization and delicensing of the dairy industry in 1993 that dairy by-products, which were mostly neglected by the dairy plants earlier started receiving due attention. A number of by-products based dairies with large automatic and continuous manufacturing plants have been set up and quite a few more are in line. India is still to emerge as a global player in the international scenario. A low per capita availability of milk, higher proportion of buffalo milk, poor quality of raw milk, lack of organized manufacture of products, lack of adequate technology, high cost of new technologies, lack of in-house R & D, lack of proper infrastructure, lack of equipment and plants indigenously etc. are the host of problems associated with the production and utilization of by-products in India.

1. Skim milk and its by-products

Skim milk is a by-product obtained during the manufacture of cream. It is rich in solids-not-fat content and has high nutritional value. In dairy plants, it is mostly utilized either in standardization for the manufacture of main dairy products or preserved by removing moisture in spray dried form. The skim milk when utilized in either of these two forms or consumed as liquid is not considered a by-product. It is regarded as a by-product only when it is either not economically utilized or utilized for derived by-products like casein and related products, co-precipitates, protein hydrolysates etc.

Casein and caseinates

Casein has a long history of technical use in industries producing paper, textile, paint, leather, rubber etc. Edible casein and caseinates are also long established dairy by-products finding use in many dairy and food products. The world production of caseins/caseinates is hard to define due to lack of a significant data. However estimation could be about 3.5 lakh tonnes. The large producers are New Zealand (1.4 lakh tonnes), Netherlands (80,000 tonnes), and Germany (24,000 tonnes). The world market of casein/caseinates used in the food industry fluctuates between 2 to 2.5 lakh tonnes. The biggest importer of casein is United States of

America, where food casein demand can be estimated at 20,000 tonnes per year and caseinates demand at 27,000 tonnes per year. About 20% of this demand is for nutraceutical applications. A lot of casein is utilized for the manufacture of imitation cheese. The second biggest importer is Japan.

Production of edible casein is an economically feasible proposition, only when the whey thereby produced is efficiently and economically utilized. This has been one of the main reasons why edible casein was not produced seriously in India before 1995. Most of the requirement of this by-product, even for industrial uses, was met through import. During the last 12 years, there has been an entry of a few large automatic and continuous manufacturing plants in India for the manufacture of edible casein, lactose and whey protein concentrates. Presently, most of the casein produced is being exported, but eventually with the assured Indian market, the product would be diverted for internal consumption also.

The production of soluble form of casein, i.e., caseinates has not picked up in India. The economic constraints for the production of spray dried caseinates are their high drying cost, low bulk density and high packaging, storage and transportation costs.

Co-precipitates

The manufacture of co-precipitates has several advantages like increased yield and flexible functional properties and higher nutritional value over that of casein. However, even though its production was standardised in sixties and seventies,it has never been commercially exploited to any great extent. A poor solubility, especially of the higher calcium coprecipitates, is a particular limitation in its functionality.

Milk protein hydrolysates

Today protein hydrolysis has assumed a new dimension in the food industry. Protein hydrolysates find extensive use in nutritional, dietetic and formulated foods, where a predigested form of protein is needed. Protein hydrolysates are boon to the people who are suffering from protein allergy or stomach disorders and to those who require easily digestible foods. In India, there lies a great scope for making improvement in the quality of the protein hydrolysates being prepared.

2. Butter milk

Buttermilk is the by-product obtained during the manufacture of butter. Sweet cream buttermilk resembles skim milk in gross chemical composition and is usually admixed with bulk of skim milk for further spray drying or even product manufacture in dairy plants. Desi buttermilk, on the other hand, has long been an important domestic beverage in India. It has high nutritive and therapeutic value. It also finds its way in the preparation of a host of items such as kadhi, dhokla and idli. Also a number of federations and private plants sell salted and spiced buttermilk in 200 ml pouches. Surat-based Sumul does business out of selling buttermilk (chhach) in and around the city. "Sumul chhach" in 500ml packs reaches practically very nook

and corner of Surat, covering over 850 retail outlets. In the summer, sales average around 45,000 litres a day.

3. Whey and its by-products

Whey is a dilute, highly perishable greenish yellow fluid and the largest by-product of the dairy world produced during the manufacture of cheese, casein, *chhana*, *paneer*, *chakka* and co-precipitates Its composition and acidity varies widely (Table 2). It contains about half of the total solids of milk, and is a source of precious nutrients like lactose, whey proteins, minerals and vitamins. Whey proteins, though present in small quantity, have high protein efficiency ratio (3.6), biological value (104) and net protein utilisation (95) and are next only to egg protein in terms of nutritive value. Further, being a rich source of lactose, whey is a good fermentation media for a number of fermented products. In many applications, lactose in whole or deproteinised whey is hydrolysed to glucose and galactose, thereby increasing its sweetness. Such lactose hydrolysed syrups, generally after condensing, are mostly utilised in sweet confectionery products and in ice cream. The market for whey products is estimated at about $ 6.5 billion in sales globally. Future growth is expected to be led by the industry's increasing focus on nutritional products, particularly in the dietary, sports and clinical segments of the market.

Table 2. Composition of different whey systems

Constituents	*Cheddar cheese*	*Acid casein*	*Rennet casein*	*Chhana and paneer*	*Co-precipitates*
Total solids (%)	7.0	7.0	6.8	6.5	6.2
Fat (%)	0.3	0.1	0.1	0.5	0.1
Protein (%)	0.9	1.0	1.0	0.4	0.3
Lactose (%)	4.9	5.1	5.1	5.0	5.1
Ash (%)	0.6	0.7	0.5	0.5	0.6
T.A. (%)	0.2	0.4	0.2	0.4	0.3

The continuing annual growth in the production and consumption of the cheese and coagulated milk products represents the generation of extremely large additional quantities of whey because of the huge base. The current world production of whey is estimated at about 165 million tonnes. Cheese whey accounts for nearly 95% of total whey. In India, the major source of whey is from the production of chhana and paneer. In the absence of systematic surveys/statistics, the predicted value for whey production is estimated at 5 million tonnes per annum. In view of the low solids content of whey, there has been a gross lack of interest in its utilisation compared to other fluid by-products of dairy industry.

Utilization of whey has been of a great concern in the dairy industries engaged in manufacturing of cheese and coagulated milk products. The techno-economic problems associated with the utilisation of whey have been receiving considerable attention and remarkable advancements have been made. For more than 25 years, a virtual explosion of papers and reports has appeared about whey and its by-products, by and for scientists in industry and

academia. Whey proteins, together with lactose, have provided an excellent area for research. Today, modern industrial processing techniques such as ultrafiltration (UF), reverse osmosis (RO), new drying methods, hydrolysis, electrodialysis, ion-exchange, fermentation and protein fractionation, among others, have converted whey into a major source of ingredients with differing functional and nutritional properties, that could be used in various branches of food and dairy industry. The global market for whey derivatives is growing at an average of around 10% annually. The predominant driving force behind the development of whey utilisation has been stringent regulations imposed by the environmental pollution agencies all over the world. Other aspect relates to economic return from whey, which contains almost half the solids of original milk. Food manufacturers are increasingly viewing whey products as an ideal means of achieving added value.

Despite significant gains in the amount of whey being processed, a large amount of current whey production still is disposed of as raw whey. Much of this represents production of small plants, where the cost of purchasing, processing as well as the subsequent transportation and handling clearly exceeds the value of any whey product that might be produced. In small plants, the choice remains some form of disposal, be it municipal treatment, spreading raw whey on local farm lands for its nutrient value or feeding to local livestock. Further, acid whey, because of high mineral content and low pH pose considerable difficulties in utilization and, therefore, mostly remain unutilized.

Condensing and drying

By far the single largest use of whey solids on global basis is in the form of whole dry whey and it continues to grow. This is whole whey that has been condensed and spray dried as such or after blending with certain other liquid ingredients. These powdered whey products are marketed as commodity ingredients for a variety of food and animal applications. The feed industry may be the largest consumer of dried whey and whey products.

Considerable advancements have been made in condensing and drying equipments for energy conservation and for the production of better quality product. A significant trend in the last two decades has been the increasing interest in reverse osmosis for removing water from whey. Small plants concentrate whey by RO for shipment to the larger plants. Medium sized plants concentrate whey by evaporation for large drying plants. Large plants concentrate their own whey plus outside sources whey to high solids for lactose crystallization and drying.

Demineralization

At the other end of the spectrum, a small percentage of utilized whey (less than 5%) is demineralized by ion exchange or electrodialysis prior to spray drying to produce dry demineralized whey for specialized uses. These include whey protein based infant formulas and other medical and nutritional products that require lactose, special nutritional quality of whey proteins and low mineral content.

Whey drinks

A variety of beverages consisting of plain, carbonated, alcoholic and fruit flavoured have been successfully developed and marketed all over the world, because they hold great potential for utilizing whey solids. In India also, a number of refreshing and low cost whey drink 'Whevit' or 'Acidowhey' is in the market. These drinks are prepared from *paneer*/*chhana* whey which is acidic and has low protein content (0.4%).

Whevit, an orange, pineapple, lime or mango flavoured alcoholic drink from whey, was developed at National Dairy Research Institute, Karnal. For its manufacture, fresh whey is efficiently separated in cream separator, deproteinised by steaming for half an hour and cooled to room temperature. To the deproteinised and clarified whey, 22- 23% of 50% sugar solution is added followed by 2-2.1% of 10% citric acid, colour and flavour. It is then fermented by incubation at 22 °C for 14-16 hr with a 1% culture of *Saccharomyces cerevisae*. The product is bottled, pasteurised (75 °C /30 min), cooled and stored at low temperature (5-10 °C). For the manufacture of Acidowhey that is a non-alcoholic whey drink, deproteinised whey is fermented with *a* culture of *Lactobacillus acidophilus and Lactobacillus bulgaricus* (1:1).

Lactose production

The production of lactose from whey continues to be one of the most important form of whey utilisation. The global market for lactose based goods is valued at over $3 billion. The market for lactose ingredients is likely to be strengthened as the dairy industry focuses more on healthy and nutritional products. The renewed research interest in application of lactose is expected to drive interest in lactulose, lactitol and galactooligosaccharides. A significant quantity of food and pharmaceutical grade lactose is produced by conventional process. During the process, a protein-mineral precipitate is segregated, which is dried and sold as a byproduct for animal feed. It has limited application as a food ingredient because of the high mineral content and the less functional (insoluble) property of the denatured whey proteins.

Ultrafiltration processing

By 1981, UF had become the most widely used process for recovery of soluble whey protein concentrates (WPC). By this process, a highly functional WPC is produced as the primary end product for a wide variety of applications as a substitute for non-fat dry milk and other protein ingredients. The largest potential use of WPC is as a replacement for non-fat dry milk (NFDM) in the food industry. WPC with 35% protein is perceived to be a universal substitute for NFDM because of the similarity in gross composition and its dairy character. WPC can also be seen competing with casein, egg albumin and soya proteins within the existing markets.

However, WPC constitutes a very small proportion (10%) of protein utilisation in food industry. More product formulation work, especially in the food industry, is needed to move WPC into the general market place. Whey proteins are also being used for reactive extrusion to supplement polyethylene - a common non-biodegradable plastic.

UF permeate stream

Although UF of whey has been in commercial use since 1972, the industry has been slow to adopt it. This is because the process generates a UF permeate as a by-product rich in lactose and minerals that creates a waste disposal problem, equal in magnitude to the disposal of whole raw whey. Of concern too is the fact that a great deal of milk permeate is now coming on stream (the by-product from UF processing), adding to the problem. The fuel crisis of the seventies and perhaps the possibility of another looming on the horizon in the 1990's provided stimulants to look at an array of fermentation possibilities of using whey or milk permeates to produce alcohols, methane, organic acids, microbial biomass protein and other useful products. To some extent, lactose and alcohol is produced from the UF permeate but the identification of the most cost effective means for its utilization is still awaited by most dairy companies world wide. In India, all the lactose, the total production capacity being about 15,000 tonnes per annum, is produced from UF permeate.

Alcohol

The lactose in whey can be converted by fermentation by a variety of organisms to products ranging from lactic acid to flavouring materials.

Milk mineral products

Milk mineral products rich in natural calcium and phosphate are valuable nutritional supplements in today's osteoporosis-sensitive world. These products are prepared by precipitation of calcium phosphate in whey UF permeate under suitable conditions of concentration, pH, time and temperature. The crystals that first precipitate quickly undergo solid state transitions depending on the conditions to which they are subjected. It is necessary to grow calcium phosphate particles to sufficient size to recover them in a good yield by centrifugation and filtration. Milk mineral is used as a natural calcium supplement in a growing range of food products including milks, yoghurts, canned milk powders and confectionary and health foods.

4. Ghee residue

Ghee residue is a by-product of ghee industry and is produced in large quantity in India. This nutritious by-product has been studied for its physico-chemical characteristics and for its utilization in a number of food products like chocolate burfi, samosa filling, chapatis etc. However, most dairy plants in India have not been utilizing ghee residue profitably except for fat extraction. Most of the ghee residue goes to waste. A sincere R & D work and a strong willingness on the part of manufacturer is required to develop food uses of ghee residue and put it in the market place.