Whey Beverages: A Review

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Abstract

The use of cheese whey as a base for manufacture of a variety of beverages, both alcoholic and nonalcoholic, is reviewed.

Introduction

Growing concern over pollution and environmental control has renewed the pressure on cheese manufacturers to stop dumping whey into streams and municipal sewage systems. Consequently, the search has begun again for new methods to use whey. In light of growing global food shortages, the most logical use would be to return whey to the human food chain in a palatable form.

Several authors have suggested that whey could be used in the formulation of nutritious soft drinks or high-protein beverages and also might be used as an additive in soups and fruit juices (5, 46, 64, 73, 94).

Using cheese whey as a beverage in human nutrition, especially for therapeutic purposes, can be traced back to the ancient Greeks; Hippocrates, in 460 B.C., prescribed whey for an assortment of human ailments. In the Middle Ages, whey was recommended by many doctors for varied diseases, and, by the mid-19th century, whey cures reached a high point with the establishment of over 400 whey houses in Western Europe (88). As late as the 1940's in spas in Central Europe, dyspepsia, uremia, arthritis, gout, liver diseases, anemia, and even tuberculosis were treated with the ingestion of up to 1500 g of whey per day (72).

Available literature indicates that whey beverages have been studied extensively in Germany and Eastern Europe; of published reviews of the use of whey in various beverages (35, 40, 51, 57, 63, 66, 71), none is comprehensive. We have tried to review all aspects of whey-beverage manufacture which have been developed.

I. *Beverages from whole whey.* The cheapest, most efficient method of preparing a whey-based beverage is to drain the whey from the cheese vat, pasteurize, deodorize if desired, flavor appropriately, and package for later consumption.

In 1898, Graeff (36) patented a simple process whereby whey was heated, deaerated, and charged with carbon dioxide and formaldehyde under pressure.

In 1913, Jolles (45) described the preparation of a "salutary" drink from whey. The whey was decolorized and deodorized with charcoal and sterilized by addition of acid. Salts, medicaments, and/or carbon dioxide could then be added to produce a finished beverage.

The whey flavor, particularly that of acid whey, is most compatible with citrus flavors, particularly orange. Several experimental citrus-flavored beverages have been developed, for which high consumer acceptability was claimed, from cheddar and cottage wheys.

Meyer (67) described beverages and tinctures prepared by mixing whey with vegetable or fruit juices. However, he considered them more as effective medicinal agents than as products for normal consumption.

O-way, a product developed at Michigan State University (23), was visualized as a breakfast meal incorporating either sweet or acid whey and orange juice. One volume of fresh orange juice concentrate was mixed with four volumes of deodorized whey and packaged. The product contained .7 to 1.0% protein; the authors suggested that the beverage could be carbonated and sold as a nutritious soft drink.

Researchers at the University of Arizona (69) combined 25 to 40% whey with grapefruit juice and 7 to 20% of other fruit juices and tested these drinks by sending them into homes as commercially sterile canned products. A peach-grapefruit-whey combination received an average flavor score of 5.9 on a hedonic scale of 1 to 7. A second series of beverages, using vinifera grape juice, whey, and 3% passion fruit juice also had good ac-

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ceptance in preliminary studies. An orange flavored drink (70) containing 33% cottage cheese whey was rated 6.3 by 51 tasters whereas a nonwhey drink rated 4.7. Acceptable drinks containing 80 to 90% whey and flavored with 10% natural strawberry puree or 20% natural peach puree received acceptable scores by panels.

Good consumer acceptance was claimed (27) for another orange flavored acid whey beverage further acidified with citric acid. Although the protein content was less than that of skimmilk, the vitamin C content was much greater, depending on the kind and amount of orange concentrate used. The fat and caloric contents were similar to those of fortified skimmilk.

A drink based on cheddar whey has been formulated at Mississippi State University (59). This product was prepared by mixing whey, sugar, orange concentrate, citric acid, and other ingredients to produce a pH of 3.8 and a total solids content of 16.5% in the finished beverage for which a shelf-life of at least 14 days at 5, 10, or 22 C was claimed. A total of 956 consumers of all ages sampled the beverage; 76.5% of the respondents rated the drinks acceptable (87). Personal interviews with 46 families showed that 90% would purchase the product for $.38 per liter.

A new beverage based on whey, called Freshi, was developed by the Verbandsmolkerei, a dairy co-op in Berne, Switzerland (51, 56, 57). This product contained about 50% purified whey, plus sugar, water, and natural orange flavoring with lemon and grapefruit flavors added for topnotes. The whey mixture was uperized at 90 C and packaged aseptically into .25 liter Tetra Paks[3]. Since the product was highly acid, the low sterilization temperature was possible; shelf life was claimed to be about 6 mo without refrigeration.

Kosikowski (6, 48, 49) has shown that an acceptable beverage could be made by incorporating up to 6% acid whey powder in reconstituted frozen orange juice. The blend contained 2.5 times the protein of orange juice alone. Acid whey powder at 6% imparted a slightly salty taste; when the content was reduced to 4%, tasters rated the flavor of the product excellent. The orange juice concentrate could be thawed to a thick slurry, the proper amount of acid whey powder mixed in, and the mixture recanned and refrozen at −25C. After 1 mo of storage, the reconstituted beverage retained the quality of the freshly reconstituted blend.

B. H. Webb (93) described the development of a combination cold drink or soup beverage made from tomato juice and sweet whey. The product contained 65% tomato juice, 34.6% fresh sweet whey and whey cream, and .4% salt. This mixture had a pH of 4.3 to 4.5 and contained 2.5% butterfat. After homogenization at 175.8 kg/cm^2, the product was canned and sterilized. Separation during storage was only slight.

Whittier and Webb (95) described the preparation of prune juice by extracting dried prunes with clarified whey. Fresh sweet whey was allowed to sour to pH 4.8; the whey was then further acidified to pH 4.5 with citric acid or lemon juice, boiled, and the clarified liquid decanted or filtered. Dried prunes were then extracted with two parts whey by either cooking or leaching the prunes in the whey. The final extract (pH 3.8 to 4.0) was canned and sterilized at 100 C for 30 min. The use of whey in this manner helped reduce hydrogen swells which after 2 to 3 mo often cause corrosion of cans of water-extracted prune juice.

Laessig (55) prepared a nonalcoholic beverage concentrate to be diluted with water. The mixture was composed of freeze-concentrated fermented whey containing 5% lactic acid plus 1.3 times its weight in sucrose. After holding at 100 C to produce invert sugar and reduce microbial contamination, the concentrate was ready for use. Laessig suggested adding fruit juices or flavorings.

A frozen whey concentrate has been developed (89) which, when diluted one to three with gingerale, etc. had possibilities as a party punch base. The product, in which at least half the liquid was fresh sweet whey, was similar to frozen orange juice concentrate and was claimed to have no whey flavor.

A patent issued to S. A. Chambourcy (25) described a carbonated beverage made from decaseinated milk. Fatty emulsifiers and marine algae were added to whey, and the mixture was homogenized. Sugar and fruit juice concentrate were added, and the mixture was carbonated in the final package.

An interesting product, Zincica, was described by Prekopp (74). This byproduct of ewes' milk cheese manufacture was heated until the protein coagulated; the coagulum was

[3] Reference to brand or firm name does not constitute endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned.

then stirred vigorously back into the liquid until thoroughly blended. After the addition of salt, the mixture was consumed either warm or cold.

Besserezhnov (19) has described a simple process for preparing a yoghurt flavored beverage. Freshly pasteurized sweet whey was inoculated with a 10% culture consisting of *Lactobacillus Bulgaricus, L. acidophilus, L. helveticus, L. casei,* and *Streptococcus thermophilus.* After 24 h incubation, the product was cooled and packaged.

For a sparkling beverage, Anatovskii and Yaroshenko (1) first incubated sweet whey for 24 h with *L. acidophilus* or *Streptococcus lactis,* then added yeast and 8 to 10% sugar. The mixture was held in sealed vessels at 8 C for 3 to 4 days, then was ready for use. The authors emphasized the curative properties of the drink.

II. *Nonalcoholic beverages from deproteinized whey.* Beverages manufactured from deproteinized whey have been the subject of considerable research in several countries. The whey may have been fermented either before or after protein removal and the finished beverage may or may not be sparkling. This type of beverage represents a more nutritive version of the carbonated soft drinks and still beverages so familiar to the American consumer.

The most popular method of deproteinization is by heating whey, which is usually acidified, at about 90 C for different times. The coagulated whey proteins are then removed by filtration or centrifugation, and the clear supernatant is processed further to produce the desired effect.

Tannic acid, herbal leaf extracts containing large amounts of tannins, or natural fruit juices containing tannins are also efficient protein precipitants, particularly in conjunction with heat. The latter two means add desirable flavors to the whey base, and several beverages have been developed by similar procedures.

Treatment with proteolytic enzymes helps protein coagulation and increases the soluble nitrogen content of whey, thus adding to the nutritive aspects of the beverages.

A. *Unfermented beverages.* Bernstein (18) patented a process whereby heat-coagulated whey proteins were removed from acidified whey by filtration. The clear filtrate was claimed to keep well after sterilization.

A patent issued to Mauroy (65) described a process in which the whey was condensed to 2/3 of its original volume and neutralized to pH 7 before clarification by heat. The filtrate was used as a soft drink base.

Another patent (26) described a beverage which was claimed to keep 3 to 6 mo. The clarified whey was sweetened with a flavored sucrose solution containing tartaric and citric acids and was then bottled and sterilized.

Detskii (53) was made by adding pasteurized sugar syrup and carrot juice to deproteinized whey. The mixture was then pasteurized and bottled. The beverage should contain not less than 20% total solids (TS), and 15% sugar and the acidity should not be greater than 12.5° Soxlet-Henkel (SH).

Two sparkling beverages were described by Kuz'mina (54). One was a sweetened orange and lemon flavored product; the other contained 25% tomato juice with added salt and citric acid. Both beverages were exceedingly acid and contained .3% carbon dioxide by weight. They were claimed to keep 5 to 7 days at 20 C.

Dordevic' and Kolev (29) described in detail the manufacture of a carbonated fruit flavored clear beverage. They recommended that the whey be deodorized after protein removal and filtered and deaerated after flavoring to reduce oxidation in the finished product. The beverage was then pasteurized and bottled on a regular bottling line equipped with machines for impregnating with carbon dioxide under a pressure of 1 to 2 N/m^2. The beverage was stable for at least 30 days. The final pH was 3.7; the product contained 4.4% lactose, 14.8% total sugar and 188 mg/100 mg calcium. If an opaque beverage was desired, the filtration step after flavoring was eliminated.

Rzewuska-Rutte (81) gave an excellent description of the utilization of whey in the soft-drink industry in Poland. Experiments showed whey deproteinization necessary to produce beverages of good keeping quality. Deproteinization with heat at pH 7 removed 63% of the protein. Mixing with natural fruit juices deproteinized the whey further so that 1 liter of the final product contained 3 to 4 g of soluble protein. The best soft drinks contained 95% whey; musts and concentrates of all types of fruits were used. Taste panel results showed that musts of cherry, strawberry, and black currant, and black currant concentrates were not suited to the whey flavor. Citrus and peppermint flavors were preferred, and beverages from sweet whey were superior to those from acid whey.

Murray (68) has patented a process for deproteinizing whey with citric and tannic acids. Heated whey was acidified with 10 to 15 g/liter of citric acid followed by addition of .7 to 1.0 g/liter tannic acid. After filtering,

the whey may be flavored and bottled. Murray also described the clarification of whey by filtration through fine particles (80% pass 70μ mesh) of diatomaceous earth in a conventional pressure filtering apparatus.

Maeno (62) and Romanskaya and Kalmysh (80) outlined processes whereby whey was incubated with a proteolytic enzyme for several hours. After the precipitate was removed, the filtrate was sterilized with ultrasonic waves in Maeno's process. In Romanskaya and Kalmysh's process the filtered whey was condensed to ¼ or ⅛ the initial volume, flavored, and bottled.

B. *Fermented beverages.* Some of the beverages described in this section are incubated with yeasts and sucrose for various times to develop carbonation. Although in this step traces of alcohol may be produced, these beverages are considered to be nonalcoholic by their developers and we have classified them as such.

Rivella, a sparkling, crystal clear infusion of alpine herbs, first appeared in Switzerland in 1952 (3, 8, 88). Rivella was prepared by fermenting deproteinized whey with lactic acid bacteria, filtering, condensing to a 7:1 concentrate, adding sugar and flavoring, refiltering, diluting and carbonating, after which the product was bottled and pasteurized. The finished beverage contained 9.7% TS, .125% total nitrogen and the pH was about 3.7. Twenty to 30 million liters are sold annually.

A Polish product, whey champagne, has been extensively described (9, 58, 91). In spite of its name, it is nonalcoholic (81). After separation of residual butterfat and heat deproteinization, 7% sucrose was added to the whey filtrate, and it was inoculated with .1% fresh bakers' yeast. It was then incubated at 25 C until acidity reached 35° SH, colored with 1.5% caramel coloring, flavored, bottled, and stored at 8 C. Correctly made, the beverage should have a pleasant taste characteristic of the added flavoring and should be strongly sparkling. Acidity should not exceed 45° SH. Approximately 230,000 liters were produced annually (81).

Whey kwas, another Polish development (58, 91), was made from fresh sweet whey. After separation and deproteinization, the whey was cooled to 42 C and inoculated with 5% thermophilic starter (no composition given). After 2 h incubation, the product was treated with yeast and caramel coloring and filled into bottles or beer kegs. After 40 h at 8 C, the kwas was ready for consumption. It should have a slightly lactic taste, a clear greenish-yellow color and a acidity not over 45° SH.

Blazek and Sulc (20) patented a method for the manufacture of a dietetic whey beverage. The whey was first inoculated with a 2 to 5% culture of lactose fermenting organisms such as *Streptococcus lactis, Str. diacetilactis, Saccharomyces fragilis,* or *Torulopsis sphaerica,* either singly or in combination, and incubated at 15 to 25 C to pH 4.4 to 4.6. After addition of ethanol, the mixture was boiled to coagulate the proteins and filtered. The pH of the filtrate was adjusted to 5, and flavorings such as sultanas or apples and citric acid and vitamins were added. The beverage was then diluted, reclarified, pasteurized, the pH readjusted to 5, carbonated, and bottled. A later patent of Blazek et al. (21) described the addition of 2% cation exchangers in the hydrogen cycle after the initial fermentation to reduce the pH of the whey to 3.8 to 4.0. The whey was then clarified, filtered, decolorized with carbon and used as a beverage base.

During World War II, Schulz (83) developed an acid whey concentrate, called Lactrone, for beverage use. It contained 17% TS, 10% lactic acid, 2% protein and peptone, 2% reducing sugars, and 3% ash. The whey was fermented first with kefir culture; Schulz and Drache (84) recommended kefir fermentation followed by vacuum evaporation as being the best for removing the whey taste. After the alcohol was distilled off, the resulting stable product was concentrated. Vitamin C, when added to this product, was stable and enhanced the flavor of the diluted beverage (83).

Schulz and Drache (84) used this concentrate as the base for a series of fruit-whey beverages. The concentrate was diluted 10 to 20 times, mixed with the desired fruit juice, and deproteinized by the so-called Lactannid process. In this process, whey proteins and solid particles were precipitated by the addition of tannins extracted from foliage leaves and herbs. The process was described in detail by Schulz and Fackelmeier (86). The mixture was held 24 h in the cold to allow the precipitate to settle; the clear supernatant was decanted off and either filtered or centrifuged. The liquid was then sweetened with about 7% sugar or 8 to 12 g saccharine/100 liter, pasteurized either by heat or by a bacterial filter, and bottled. Hamann (39) evaluated diluted lactrone drinks and found the raspberry and citrus flavors to be most satisfactory. He calculated the food value of the diluted beverage to be 24 kcal/liter. Unopened bottled drinks kept for 1 wk without refrigeration.

III. *Alcoholic beverages from whey.* Alcoholic beverages can be manufactured from whey with proper techniques. A good beverage should be transparent, clear, and preferably sparkling. Deproteinization of whey would be especially important in the production of such beverages.

The shortages of raw materials arising from World War II accelerated research aimed toward development of good quality alcoholic beverages derived from whey, and some success was achieved, particularly in the manufacture of whey beers. Whey wines and other low-alcohol beverages have also been produced.

A. *Beverages containing less than 1% alcohol.* Schulz and Fackelmeier (85, 86), using standard brewing techniques, developed a completely new type of aromatic fermented whey beverage which they named Milone. The whey was first fermented with kefir culture to obtain 1% lactic acid and 3.5% lactose. An equal volume of a 3% extract of leaves and herbs was added; the tannins precipitated the whey proteins (Lactannid process). After filtration the aromatic flavored whey was end fermented with lactose-fermenting yeast and sweetened with saccharine. The final beverage contained .8% alcohol. It was bottled under carbon dioxide and was stable for 1 yr.

Kumetat (52), comparing procedures for production of Milone and beer, showed that the protein content of Milone was only about ¼ to ½ that of beer. Forty-eight percent of the total nitrogen content of Milone precipitated with tannins compared to 7% in beer. He attributed the difference to a greater breakdown of protein to soluble components in the brewing processes necessary for beer production.

Roeder (79) patented a process for a beverage base in which the whey was concentrated to 25 to 33% of the original volume, deproteinized, cooked with .1 to .2% hops, and decolorized with carbon. The product at this stage had no whey taste or smell. It was then fermented to .75 to 1.5% alcohol, after which sugar and fruit juice, Vermouth, or other flavorings could be added.

Angelescu and Ionescu (2) deproteinized sweet whey, added 2% sucrose to the filtrate, bottled, sterilized for 20 min at 100 C, cooled, and inoculated it with 2% yoghurt culture and 1% bakers' yeast. After 2 days at 27 C, the alcohol content was .892% and lactic acid, .568%.

Whevit, a sparkling beverage described as a nutritious soft drink was recently developed in India (16). After deproteinization, 50% sugar syrup at the rate of 3.6 l. to 16 l. of whey was added and the mixture was made .2% in citric acid. The mixture was inoculated with .5 to 1.0% *Saccharomyces cerevisiae* and incubated at 22 C for 14 to 16 h. After the addition of citrus flavors, the product was bottled and pasteurized. The finished beverage contained 10 to 11% total sugar, .4 to .6% nitrogenous material, and .5 to .7% alcohol.

B. *Whey beer.* Any discussion of the use of whey in the manufacture of whey beers of various types is limited because so much of the research was in Germany just before and during World War II, and access to the literature is difficult. Fortunately, an excellent review by Hesse (40) is available, and much of the following discussion is taken from that paper.

Whey has many properties which make it suitable for the manufacture of beer-like beverages. Because whey contains material similar to the colloids of beer wort, it has a great capacity for binding carbonic acid. Whey, like beer wort, has a high salt content. Some constituents in whey, after prolonged heating under pressure, develop caramel-like flavors which are similar to the taste and odor of cured malt. Lactose is only slightly sweet so it does not alter the taste of the finished beverage.

Roeder (78) proved that whey has a greater buffer capacity than beer wort, and, therefore, the pH of the whey is crucial to the proper development of acidity in the mash. In the normal mash process, if the acidity of the whey is incorrect, the mash does not develop the acidity necessary to precipitate the protein upon cooking with hops (the break). Tannic acid present in the hops helps precipitate the protein.

Roeder (77) showed that up to 30% of the malt could be replaced by deproteinized whey. The whey was partly deproteinized by cooking at pH 4.5 to 5.5 with the hops and the filtrate was blended with the malt wort. Fermentation with bottom-fermenting beer yeasts followed. Because these cannot ferment lactose, enough malt constituents with fermentable carbohydrates must be used so that the intended contents of carbon-dioxide and alcohol are guaranteed.

Dietrich (28) developed a beer substitute by mixing 5.4% malt wort with 2.5% deproteinized whey. The malt-whey mixture was fermented by *Saccharomyces lactis;* after 5 to 7 days, the product had developed a true beer flavor and character.

Brunner and Vogl (24) also produced

a good quality dark beer from a whey concentrate which was made into a mash with crushed malt, boiled, and fermented. Keeping quality of the whey beer was inferior to that of standard beer.

Two beer-like beverages have been developed in Russia. Bodrost (60) is produced commercially and is a sparkling beverage made from deproteinized whey. The whey was mixed with beet sugar (103 kg/ton), 5 kg raisins, and 5 g kefir starter, plus flavoring and caramel coloring.

Bochyu (99) was made from deproteinized whey which is diluted 2.5 times with water, and sweetened with 7.5% sugar. The mixture was then pasteurized, .2% sultanas and .2% yeast were added and it was fermented for 6 to 8 h. After 1% caramelized sugar and .3% hops extract were added, the mixture was filtered into standard wooden beer kegs and held for 6 to 8 h at 6 to 8 C. The final sparkling product had a lactic-hops flavor and contained 3.8% alcohol.

Hesse (40) mentioned other whey beer possibilities. A whey beer could be produced from deproteinized whey without malt by cooking with hops and fermenting with special lactose-fermenting yeasts.

A whey malt beer could be produced from malt with up to 50% whey addition. Starch and sugar syrup were added, and the mixture was cooked with hops and fermented with top-fermenting beer yeasts. The beer was refermented with sugar before decantation and pasteurization.

Another type of whey beer was produced by substituting other starch carriers, such as potatoes or maize, for the malt. The starch was broken down by diastase during the mash process into the normal hydrolysis products of dextrin and maltose.

Hesse (40) also mentioned a nonalcoholic, beer-like whey beverage in which deproteinized whey was cooked with hops, colored with caramelized lactose and, while not fermented, was impregnated with carbon dioxide and skimmed.

Reiter (75) produced imitation beer from whey using the Moltra process. This process removed lactic acid and lactates from whey before it was fermented. Deproteinized whey was inoculated with a strain of *Geotrichum* which was able to utilize lactic acid and its salts but not lactose. After incubation at 28 C for 5 to 9 h, the mycelium was removed and the supernatant pasteurized. It was then ready for conversion into beverages. The mycelium was claimed to contain 50% protein and was thought to be a valuable byproduct of the process.

C. *Whey wine.* The growth of so called pop wines has been spectacular since 1967 and, in 1971, accounted for 231 million liters, about 25%, of the wine produced in the United States. These products, aimed at the younger consumer, have relatively low alcoholic contents and are mostly fruit flavored. Wines based on whey would seem to fit in with the natural beverage trend and some promising products have been developed.

Baldwin (15) described the preparation of a cordial from whey and brown sugar: 5.7 liters of whey was mixed with 454 g brown sugar. The mixture was then allowed to ferment to produce a pleasant drink.

E. R. Engel (32, 33) has patented a process for producing a sauterne or sherry-like alcoholic beverage from whey. Fresh whey and sucrose in the proportions of 2.5:1 up to 9:1 were fermented with 1.2 to 9.9% bakers' yeast. This mixture was allowed to age for 3.5 mo. For the first few days, it was held at 17.8 C and gradually cooled. After 10 days, a black crust formed on the surface; this was removed and an oily film, which subsequently formed, was also removed. The liquid was then siphoned from the tank and stored in the dark for 10 to 54 days to permit flavor development. After chilling to −23 C for 4 days to fix the flavor, it was aged at 10 C for several days, at which time it was ready for use as a flavoring agent or a beverage. Father Engel, culminating 44 yr of experimentation, is currently producing his milk-wine elixir with an alcoholic content of 11% at Alaska's only bonded winery (14).

Zadra (97) patented a process for making a carbonated alcoholic beverage from whey. After protein removal, the whey was cooled to 35 C and lactase or 1% powdered almonds were added. After 4 h incubation, the liquid was decanted, cooled to 4 to 6 C, treated with beer yeast, fermented, decanted, stored at 0 to 2 C under pressure for 1 to 2 wk, filtered, and bottled. By hydrolyzing the lactose to its monosaccharides, glucose and galactose, no added sucrose was needed for fermentation. Zadra has also developed a noncarbonated coffee flavored alcoholic beverage from whey (98).

More recently, Yoo and Mattick (96) have studied the production of alcohol by *Saccharomyces fragilis* fermentation on both sweet and acid whey. They found that ethyl alcohol production from whey was maximum with a

lactose concentration of 12%. Lactose in acid whey (pH 4.2) fermented more rapidly and produced more alcohol than sweet whey (pH 5.7). They produced an acceptable whey wine containing 10% alcohol when 16% sucrose was added to a 10% acid whey solution.

D. *Alcoholic beverages containing protein.* A kumiss-like beverage was produced from a mixture of milk, whey, and lactose by Jagielski (44). Lactic acid and alcohol fermentation proudced a sparkling product which contained alcohol, lactic acid, and carbon dioxide.

Khrul'kevich (47) also produced a kumiss-type beverage from whey. A mixture of equal volumes of whey and buttermilk was inoculated with 25% of a culture of kumiss yeasts, *Lactobacillus bulgaricus* and *L. acidophilus*. The beverage was claimed to have a refreshing sour-alcoholic taste. Stability and consistency of the beverage were improved by adding gelatin.

Bernstein (17) produced a peptonized beverage from whey. The whey was first fermented with a proteolytic bacterium which did not cause coagulation but produced lactic acid. Then the whey was incubated with a lactase yeast to produce an alcoholic drink.

IV. *Protein beverages.* High-protein beverages using whey offer an attractive possibility, not only from the standpoint of the protein processors, but also because such beverages have a great potential for popular acceptance. These beverages fall into two groups: those that may be considered milk-like or extended milk and those that resemble soft drinks.

A. *Milk-like beverages.* Bodmershof (22), for example, prepared a sparkling beverage from a mixture of 40% sour milk, 50% whey, and 10% fruit juice. This concoction was bottled under 7 N/m^2 of carbon dioxide and was claimed to keep for several months.

Downham (30) patented a process for making products claimed to resemble human milk. Sweet whey was homogenized with some of the following ingredients: cream, butterfat, milk sugar, sugar, skim milk, sodium citrate. The finished beverages were reported to be useful for infant and invalid feeding.

Researchers at Michigan State University (23) have prepared a product called Way-Mil, an imitation milk formulated from whey, selected vegetable oils, vegetable hydrocolloids, and, in some applications, skim milk. The beverage contained 2.4% fat and 1 to 1.5% protein. The fat-protein dispersion was claimed to be physically stable for 3 to 4 wk.

Edmondson et al. (4, 31) have developed a sterile milk-like beverage from sweet whey and cream. This product, condensed to 35% TS and flavored with chocolate, was sterilized by a standard high temperature short time (HTST) procedure, then homogenized and canned aseptically. When reconstituted to 17.5% TS, this product scored 6.5 on a 9 point hedonic scale compared to 6.9 for commercial chocolate milks.

A recent study by Vajdi and Pereira (92) described the use of whey as a milk substitute in the production of strawberry, lemon, and chocolate beverages. The pH of liquid whey was adjusted to 6.7 with .1 N KOH. Strawberry drink was prepared by adding 2.59 kg of 35% fat cream, 2.27 kg of sugar, 2.72 kg of skim milk powder, stabilizers, and flavoring to 39 kg of liquid whey. The mixture was stirred vigorously, heated at 82 C for 2 min, and homogenized at 35.2 and 105.5 kg/cm^2. After homogenization the product was cooled to 10 C and bottled. Lemon drink was prepared in similar fashion after addition of 2.59 kg of 35% fat cream, 2.27 kg of sugar, flavors, and stabilizers to 40.8 kg of whey concentrate. Chocolate drink was prepared after addition of 2.27 kg of sugar, .91 kg of chocolate, 3.63 kg of whey powder, and stabilizer to 38.6 kg of liquid whey. These products had low production costs and good flavor. Shelf life studies showed no change in state or flavor during 1 mo of storage under refrigeration. In addition taste panels found no significant difference between commercial chocolate milk and the chocolate whey drink.

In the past the soybean has offered a cheap nutritious source of protein for increasing the protein content of whey. Soy protein is low in lysine, an amino acid essential for growth, as well as in the sulfur-containing amino acids. Whey proteins, on the other hand, are particularly rich in lysine and also contain significant amounts of methionine and cystine. Therefore, a soy-whey beverage with a protein content equivalent to or greater than that of milk would appear to be a desirable addition to the available food supply.

Tsugo (90) has described a process whereby sweet whey or neutralized acid whey and soybean milk were condensed to produce a product resembling evaporated milk and which could be used in a similar manner.

A soy-whey milk made from soybeans and cottage cheese whey has also been developed at the University of Illinois (10). The beany flavor was destroyed by boiling the whole bean before it was broken for incorporation into the whey. The product had a flavor resembling that of egg nog.

A high-protein beverage powder, from soy and whey, readily reconstitutable in water would be far easier and cheaper to transport and store than a fluid product. This would be particularly useful for shipment to developing countries where protein is in short supply.

Loewstein and Paulraj (61) have shown that a powder made by coprecipitating and drying defatted soy flour and whey protein to a final blend of 3 parts soy to 1 part whey protein is clearly superior to soy protein alone in promoting growth in rats.

Sasaki and Tsugo (82) described the manufacture of synthetic milk powder from whey and soybeans by extraction of the soybeans with hot whey. Their research led Guy and his associates (38) to develop a process for spray drying a soy-whey mixture which yielded a powder containing 67% sweet whey solids and 33% full fat soy flour. A powder containing 55% sweet whey solids, 28% soy flour, and 17% corn oil could also be manufactured by this process. The formulation of this product was flexible and permitted the easy addition of flavorings and carbohydrates to produce a powder readily dispersible in water to yield a beverage containing 2.7% protein. Citrus and cherry-vanilla flavors were highly acceptable to a trained taste panel (4, 37).

A spray dried beverage powder developed in Canada (7) contained skim milk, whey, and whole soybeans. The estimated cost of this product in 1971 was about $.55 per kg, enough to make 4.2 liters.

Kraft (50) patented a process for making a spray dried food ingredient powder which contained 4 parts comminuted sesame seed to 3 parts whey solids. Sesame is high in methionine, the limiting amino acid in milk proteins. The powder manufactured by this process could be readily dry blended with sugar and cocoa to make a nutritious beverage mix which, when reconstituted with water, produced a drink containing 15 to 20% TS.

B. *Beverages resembling soft drinks.* The development of new techniques for fractionating whey, such as ultrafiltration, gel permeation, electrodialysis, polyphosphate precipitation, or combinations of these methods has led to the production of high-protein concentrates and dehydrated high-protein isolates from sweet and acid whey which their manufacturers claim to be suitable for formulation of protein beverages (34) or protein-fortified soft drinks (11).

In 1971, an orange-flavored carbonated beverage, resembling the conventional soft drinks which dominate the American market was test marketed in Brazil (13). This product, Tai, contained 1.5% whey protein and was manufactured from a high-protein concentrate prepared by reverse osmosis.

Holsinger and her associates (12, 41, 42, 43, 76) fortified existing soft drinks with whey-protein isolates manufactured by ultrafiltration followed by gel permeation, vacuum evaporation, and spray or vacuum shelf drying. They demonstrated that carbonated beverages could be fortified with up to 1% whey protein without detectable change in flavor or appearance, provided the whey proteins were isolated in undenatured form. These spray-dried isolates could also be used to fortify the popular "ade" beverage powders. Full-scale commercialization is dependent upon the cost of concentrating whey proteins in an undenatured form.

Conclusions

For many years whey has provided the base for a wide variety of palatable beverages. Information on the processing advantages and marketing problems associated with the manufacture of most of these products is scanty.

Perhaps the greatest commercial success of any whey beverage has been enjoyed by Rivella which is sold in most of Western Europe. It is currently being test marketed at two locations in the United States, being promoted as something of a therapeutic tonic for athletes as well as a refreshing table beverage. A number of whey beverages such as Prego, which is sold in the Lucerne, Switzerland, area, are produced for local consumption and are not documented in the literature.

The real problem associated with the production and marketing of whey based beverages has been an economic one. To date, it has generally proven impossible in the United States to manufacture a whey beverage which can be sold at a price competitive with those of snack beverages or, in the case of a high protein whey beverage, fresh or dehydrated milk.

However, stringent pollution regulations have forced renewed interest in reclaiming the discarded nutrients of whey. Consequently, whey beverages, mostly an interesting laboratory curiosity to date, may prove to be economically viable after all.

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