DIRECT-ACID-SET COTTAGE CHEESE WHEY AS A BASE FOR A SHELF-STABLE ATHLETIC-TYPE DRINK

by

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INTRODUCTION

Whey disposal is a problem for most cheese processing plants. Municipal sewage plants impose high surcharges when they accept it, because of its high BOD (biochemical oxygen demand). The equipment needed for processing it for animal or human consumption is costly and not readily available to small cheese producers.

The cost of disposing of or processing the whey could be eliminated by using the whey in beverage formulations. This research centered on formulating a beverage using direct-acid-set (DAS) cottage cheese whey as the major ingredient that would be similar in composition and flavor to electrolyte-carbohydrate containing athletic-type drinks. The cost of making such a drink should be comparable to that of products currently on the market. The equipment needed, such as batch pasteurization tanks and desludging clarifier, already exists in cottage cheese processing plants.

The objectives of this research were to:

1. develop a process for formulating an athletic-type drink from whey,
2. test the process for making a shelf-stable product,
3. compare its organoleptic properties to an existing commercial product, and determine the consumer acceptance of the drink,
4. compare its composition to that of an existing product,
5. analyse the beverage for sugar and test it for flavor stability and shelf life.

Acid whey for this research was donated by Beatrice Foods Company (Meadow Gold), Topeka, Kansas, or Steffen Dairy Foods Company, Wichita, Kansas. Prior to its use, the pH of the whey was adjusted to 5.2 with potassium hydroxide. It was heated to 90°C and held at that temperature for 10 min to coagulate proteins. The majority of the proteins were removed by centrifugation or filtration. Sufficient calcium hydroxide was added to obtain a pH of 5.6 to 5.7. More potassium hydroxide was added to reach the optimum pH of 6.5 for enzymatic hydrolysis of lactose. A sufficient amount of ß-galactosidase was added to hydrolyse more than 80% of the lactose to glucose and

galactose. Two parts of the processed whey were added to one part water; this reduced the salty character, and citric acid was added to lower the pH to 3.7±0.05. The desired sweetness was obtained by adding sucrose and glucose. Orange flavoring (Norda Natural and Artificial Emulsion # EP-10,806; and Blanke Baer Orange Extract) was added to give the drink a desirable flavor. The product was heated to 88°C, bottled, capped and held 5 min at that temperature to control microorganisms.

REVIEW OF THE LITERATURE

I. Whey Utilization and Disposal

Utilization of cheese whey is still a challange in the United States. Cheese production has been increasing steadily to the point where, in 1981, the Whey Products Institute estimated that the total whey production in the United States reached a record high of 42 billion pounds, including 3.9 billion pounds of acid whey and 38.1 billion pounds of sweet whey. Of the total whey produced, only 54.6% was further processed. This whey was processed into concentrated whey; dry whey for human and animal consumption; modified dry whey products such as reduced lactose whey, reduced minerals whey, and whey protein concentrate; whey solids in wet blends; and whey solids utilized for lactose (Anonymous, 1982b).

Due to water pollution legislation in the 1960's cheese manufacturing plants have had to find means of disposing of whey without causing pollution to natural water systems. Disposing of it through a sewage system is costly, and a waste of the nutrients present in whey. Cottage cheese whey contains 73% of the nutrients of the skim milk used for making the cheese. If the whey is disposed of through the municipal systems, it is costly to the dairy plant, and a waste of the available nutrients (Kosikowski, 1978). Many municipal sewage systems are not equipped to remove the oxygen-consuming pollutants that are in whey, and refuse to accept dairy wastes (Gillies, 1974). The biochemical oxygen demand (BOD) of whey is 32,000 ppm or higher. This is caused by protein and lactose in the whey (Harper et al., 1971; Kosikowski, 1978). Sewage treatment plants often insist that cheese-plant discharges have a BOD of 200 ppm or less to avoid payment of a surcharge. Equipment used to treat the wastes (decrease the BOD), or to condense or dry the whey, is very expensive (Kosikowski, 1978). Eighty-five percent of the unprocessed whey comes from plants with the approximate daily production of 9,000 kg (19800 pounds) of whey or less. Milk processing plants that produce cottage cheese are normally among the small

whey producers. In these plants it may not be economically feasible to purchase the equipment to further process whey, so they are more inclined to dump the whey in municipal sewers, and pay the surcharge (Jelen and LeMaguer, 1976).

Demott (1976) stated that drying acid whey is a problem because of the low pH of 4.6. It does not withstand heating and other processes; it lumps together, and clogs the dryer. Kosikowski (1978) stated that the more acidic the whey, the higher is the drying temperature required. Furthermore, the high acidity is corrosive to the equipment used for drying (Kosikowski, 1978). During drying of acid whey, oversized lactose crystals are formed, and adhere to the interior of the dryer making cleanup difficult (Gillies, 1974). Currently, research is being conducted to utilize whey for producing wine, gasohol, and beverages (Delaney, 1981; Kosikowski, 1979).

II. Composition of Whey

The Federal Food and Drug Administration defines wheys as follows: "the liquid substance obtained by separating the coagulum from milk, cream or skim milk in cheese making. Whey obtained from procedures in which a significant amount of lactose is converted to lactic acid, or from the curd formation by direct acidification of the milk, is known as acid whey. Whey obtained from procedures in which there is insignificant conversion of lactose to lactic acid is known as sweet whey" (Anonymous, 1981b).

The compositions of sweet, acid, and direct-acid-set (DAS) wheys are found in Table 1. Lactose is slightly less in acid whey than in sweet whey. This can be attributed to more lactose fermentation during cottage cheese manufacturing. The total protein of acid whey is less than sweet whey, whereas the nonprotein nitrogen level is a little greater. There is generally more ash in acid whey than in sweet whey, and less fat. This is due to the fact that most acid whey comes from cheese made from skim milk (Glass and Hedrick, 1977). The fat and water contents of dried whey

Table 1. Composition of sweet, acid, and direct-acid-set (DAS) fluid wheys.

	Sweet[a]	Acid[a]	DAS[b]
Fat	0.3%	0.08%	0.24%
Protein	0.9%	0.9%	0.70%
Lactose	4.9%	4.4%	c
Ash	0.6%	0.8%	0.88%
Total solids	6.3%	6.1%	7.25%

[a] From Harper (1972)

[b] From Blackburn (1980)

[c] Not available

are similar to non-fat dry milk (NFDM), but the protein content is about 1/3 of that in NFDM. The types of protein differ also. Casein is the major protein in NFDM, whereas lactalbumin and lactoglobulin are the chief proteins in whey. The ash content is similar to that of NFDM, but the mineral composition between the two differs considerably (Gillies, 1974).

A. Lactose

Lactose is the major component of whey solids, comprising of about 70% of the total solids. It is the characteristic sugar found in milk, other than trace amounts of glucose and galactose, and the only sugar present in milk of most animals. It is a disaccharide that yields D-glucose and D-galactose upon hydrolysis. The systematic nomenclature is 4-0-ß-D-galactopyranosyl-D-glucopyranose. It occurs in both the alpha and beta forms. Lactose is normally found in dairy products in either of two crystalline forms--alpha-lactose monohydrate and anhydrous beta-lactose, or amorphous mixture of alpha- and beta-lactose. The solubility of lactose at 25°C is 24.8 g/ 100g water (Nickerson, 1974). The relative sweetness of lactose is low compared to other sugars (See Table 2). Hydrolyzing the lactose to glucose and galactose results in sweeter products. As the temperature increases the difference in the relative sweetness between these sugars decreases. The difference in sweetness is greater at lower temperatures (Tsuzkike and Yamazaki, 1953).

B. Proteins

Casein is the major milk protein. It coagulates during cheese making and forms the cheese curd. The non-casein proteins (whey proteins) remain in the whey during cheese making. These constitute 14 to 24% of the total milk protein. The major whey protein in milk is ß-lactoglobulin (57.2% of the total whey protein). It has an isoelectric point of 5.3. Alpha-lactalbumin constitutes 20.9% of the total whey protein. It has an isoelectric point of 4.2 to 4.5. Other proteins present in the whey

Table 2. Relative sweetness of some sugars compared to sucrose.

Sugar	Relative sweetness[a]
Sucrose	100
Lactose	39
Glucose	69
Galactose	63
Fructose	114

[a] Cited from Aurand and Woods (1973)

are immunoglobulins which comprise 15.1% of the total whey protein; euglobulins, about 6.6%; pseudoglobulins, about 5.3%. There is 21.1% of the total whey protein that is identified as the proteose-peptone fraction (Gordon and Kalan, 1974). Table 3 shows the percentages of the four major protein fractions in the protein portion of whey.

C. Minerals

The mineral content of acid whey is usually higher than that of sweet whey (See Tables 1 and 4). The amounts of calcium, phosphorous, zinc, and copper are greater in acid whey than in sweet whey. The potassium and sodium contents are similar between the two types of whey. Factors that can influence the mineral content in whey are: type of cheese, geographic area, stage of lactation, source of milk (breed or animal), care during storage, and processing and specific operations (Glass and Hedrick, 1977).

D. Vitamins

Whey is a good source of vitamin B_{12}, riboflavin, pantothenic acid, biotin, and choline (See Table 5). Glass and Hedrick (1977) reported that for acid and sweet wheys there was no significant difference for thiamin, vitamins B_6 and B_{12}, tocopherol, pantothenic acid, folacin, and choline. However, acid whey generally has less riboflavin, biotin, niacin, vitamins A and C than sweet whey. There was considerable variation among the samples analyzed. They speculated that the difference could be due to the cheese processing treatment and the drying procedure. Bacterial growth prior to drying can cause variations in levels of some vitamins. The content of unstable vitamins can decrease during storage, particularly vitamins A, B_6, and biotin (Glass and Hedrick, 1977).

Table 3. Major protein fractions in whey[a].

Protein	% of whey protein
Beta-lactoglobulin	50.0
Alpha-lactalbumin	18.4
Immunogolbulins	13.2
Bovine serum albumin	5.3

[a] Calculated from the data of Gordon and Kalan (1974)

Table 4. Mineral composition of sweet and acid fluid wheys[a].

Mineral	Sweet	Acid
	mg/100ml	
Calcium	61.46	168.28
Phosphorus	76.72	111.16
Sodium	90.09	76.09
Potassium	129.85	134.05
Magnesium	12.46	15.66
Zinc	0.147	0.567
Iron	0.063	0.091

[a] Calculated from the data on dry whey (Glass and Hedrick, 1977)

Table 5. Vitamins in sweet and acid fluid wheys.

Vitamin (units/ 100g)	Sweet	Acid
Vitamin A (IU)	9.52	7.49
Vitamin C (mg)	0.10	0.02
Vitamin B_6 (mg)	0.04	0.04
Vitamin B_{12} (µg)	0.17	0.175
Tocopherol (mg)	0.004	0.005
Thiamin (mg)	0.035	0.034
Riboflavin (mg)	0.15	0.13
Pantothenic Acid (mg)	0.8	0.8
Biotin (µg)	3.01	2.45
Niacin (mg)	0.09	0.08
Folacin (mg)	0.001	0.002
Choline (mg)	7.28	7.07

[a] Calculated from the data on dry whey (Glass and Hedrick, 1977)

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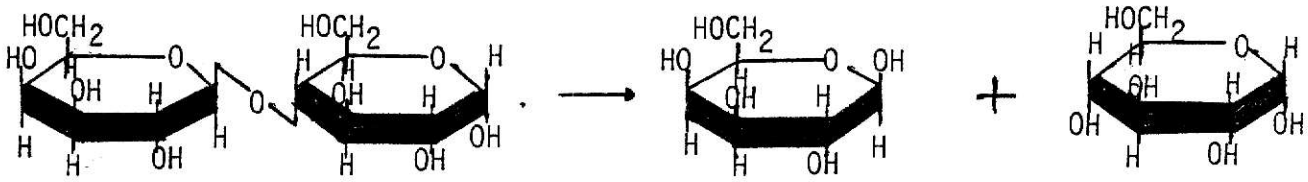
III. Hydrolysis of Lactose

A. Beta-Galactosidase

By enzymatic hydrolysis, the lactose molecule is split into glucose and galactose as shown below.



LACTOSE β-D-GALACTOSE α-D-GLUCOSE

Beta-galactosidase is the trivial name for the enzyme that catalyzes hydrolysis of lactose. The name "lactase" that traditionally has been used by authors because of its convenience is, however, an obsolete term (Richmond et al., 1981). Beta-galactosidase is widely distributed in nature, and can be found in plants (especially almonds, peaches, apricots, and apples), animal organs (such as the intestines), yeast, bacteria, and fungi. The yeasts in which ß-galactosidase is commonly found are Kluyveromyces lactis, K. fragilis, and Candida pseudotropicalis. It also is found in certain bacteria such as Escherichia coli, Bacillus megaterium, Streptococcus lactis, S. thermophilus, Lactobacillus bulgaricus, and L. helveticus, as well as in fungi such as certain species of Aspergillus and Mucor (Shukla, 1975). Beta-galactosidase from different sources varies considerably in many of its extrinsic properties, such as optimum temperature and pH, although the specificity of the enzyme remains essentially the same (Richmond et al., 1981).

The commercial ß-galactosidase (Maxilact L 2000 from G.B. Fermentation Industries) is a purified liquid ß-galactosidase preparation from the dairy yeast

Kluyveromyces (Saccharomyces) lactis. Its optimal pH range is 6.4 to 6.7 at 30°C, and the optimal temperature is 35 to 40°C. However, it is active at temperatures down to 4°C, and pH of 6.3 to 6.8 (Anonymous, 1979).

Bouvy (1975) recommended that the lactose be as dilute as possible before hydrolysis. Galactose is a competitive inhibitor of the ß-galactosidase, and the transgalactosidase activity is more pronounced when lactose is more concentrated (Bouvy, 1975). The enzyme is more active in the presence of potassium than sodium. Potassium hydroxide is recommended over sodium hydroxide for adjusting the pH of the whey. Low concentrations of manganese are essential in maintaining the active structure of the enzyme. Magnesium and cobalt can partly replace manganese in this function. Heavy metals, such as lead, strongly inhibit the enzyme activity (Bouvy, 1975).

B. Formation of Oligosaccharides

During hydrolysis of the glycosidic linkage of lactose, some monosaccharide units may be transferred to active acceptors such as monosaccharides, polysaccharides, or alcohols (Wierzbicki and Kosikowski, 1973). These molecules become the acceptor of the ß-D-galactose moiety instead of water. This transfer reaction is called transgalactosidation. Because a small amount of galactose is transferred to other sugar molecules during hydrolysis, slightly more free glucose than galactose is present after the reaction (Bouvy, 1975).

Burvall et al. (1979) suggested that trisaccharides could be formed by a galactose molecule linking to a lactose molecule. Tetrasaccharides and longer polysaccharides could be formed by a similar mechanism. The authors also suggested that disaccharides other than lactose could be formed; however, they could not be detected by separation techniques used in their study.

The number of types of oligosaccharides formed during lactose hydrolysis with Aspergillus niger galactosidase varied from three to eleven (Pazur et al., 1958).

Wierzbicki and Kosikowski (1973) reported that five different oligosaccharides resulted from the activity of ß-galactosidase of Aspergillus niger. These appeared at low concentrations of 1 to 2% of the total lactose present before hydrolysis. At the lactose concentration of more than 4%, the oligosaccharides appeared in larger amounts (Wierzbicki and Kosikowski, 1973). Burvall et al. (1979) measured oligosaccharide formation in a 5% lactose in a buffer (0.05M potassium phosphate buffer at pH 6.8) solution which was inoculated with Saccharomyces lactis ß-galactosidase (Maxilact). They found that the maximum oligosaccharide formation was about 5% of the total sugar concentration.

Burvall et al. (1979) found that the medium where the hydrolysis takes place, whether it be milk, whey or a buffer solution, affects the oligosaccharide formation. The pH of the medium also can determine the degree of oligosaccharide formation. Smaller amounts of oligosaccharides were produced from lactose in milk than in a buffer solution that contained lactose (Burvall et al., 1979). They suggested that these oligosaccharides can cause intestinal discomfort in the form of flatulence.

C. Depression of Freezing Point

Hydrolysis of lactose is accompanied by a corresponding decrease in the freezing point of the solution. Complete hydrolysis of 50g/ kg of lactose in solution shows a reduction of the freezing point of 0.273°C. This physical property can be used to measure the amount of hydrolysis that occurs. The method is simple, and the reproducibility and accuracy are good (Nijpels et al., 1980).

Acidification of the solution can result in a further decrease of the freezing point, and so the pH must remain constant during hydrolysis (Nijpels et al., 1980). The freezing point is depressed approximately 0.0066°C by the addition of 0.1g ß-galactosidase/ 100ml substrate. During lactose hydrolysis oligosaccharide formation is likely to cause the freezing point depression to be less than it would be if there

were only simple breakdown of lactose into glucose and galactose (Baer et al., 1980).

D. Lactose Intolerance

The enzyme ß-D-galactosidase is deficient in many non-caucasian adults. The insufficienty of ß-galactosidase production in the digestive tract is known as lactose intolerance. It causes abdominal cramps, gaseous distention, and in some cases diarrhea when a large amount of lactose is consumed (Nickerson, 1974). Almost all Japanese and African blacks are lactose intolerant. Sixty-four percent of U.S. blacks and 6% of U.S. whites lack the enzyme (Anonymous, 1979).

IV. Removal of Proteins

A number of procedures have been employed to clarify whey for subsequent uses. Some of these methods are as follows:

1. A chelated protein complex may be precipitated out of the whey by added ferric salts (Block and Bolling, 1955).

2. Polymeric phosphates are used to precipitate the protein (Gordon, 1945).

3. Anionic polyelectrolyte 1-carbo-methoxy-2-carboxy-3-acetoxybutylene copolymer at 50 ppm (based on liquid whey) added to hot whey at a pH of 4.0 to 5.2, and agitated for 2 min, precipitates the protein (Rogers and Palmer, 1966).

4. Gel filtration (Steiner, 1968) has been used in a commercial plant in Sweden to clarify whey.

5. Ultrafiltration (Kosikowski, 1978) separates whey components under pressure across a thin, semi-permeable membrane film. Much of the water, lactose, soluble salts, lactic acid, and nonprotein nitrogen are transferred to the film's outer surface, leaving behind on the inner side, protein and insoluble salts in suspension.

Another method of protein removal from sweet whey by heat was published by Burkey and Walter (1947). The procedure is as follows:

1. Place the whey in the vat in which it is to be heated, determine the pH, and adjust to 6.3 to 6.5. The proteins are most stable to heat at this pH.

2. Heat the whey to at least 94°C (200°F), or as near to boiling as possible, and stir constantly while it is being heated.

3. As soon as the whey is heated, add the acid, or a calcium chloride solution, to the hot whey with constant stirring until precipitation is complete. At this point discontinue stirring, and allow the precipitated protein to stand for a few min to permit it to accumulate.

4. The precipitated protein may be recovered from the whey with a Swiss-cheese dipping cloth, or by draining off the whey, depending on the size and kind of vat and disposition that is to be made of the recovered protein.

The amount of precipitating agent added should be sufficient to produce visibly complete precipitation. It is necessary to add enough acid to lower the pH of the hot whey to between 4.8 and 5.3 for complete precipitation. Calcium chloride solution is then added to adjust the pH to between 5.5 and 5.8. When an insufficient amount of precipitating agent is added, the precipitation will be incomplete. The addition of an excessive amount of precipitating agent is likely to prevent proper flocculation and the protein, instead of collecting into a mass of curd, will remain in small particles that are difficult to recover.

Aside from the precipitating agents, the primary factor in the removal of proteins from cheese whey is heat. The heating process is the most expensive part of the procedure. The whey must be heated to a temperature of at least 90.5°C (195°F) to provide complete protein precipitation. The protein curd may be removed from the hot whey either by means of dipping cloth or by draining the whey off through a vat drain fitted with a fine mesh whey strainer. Approximately 3.5 pounds of whey protein

curd can be obtained from 100 pounds of cheese whey (Burkey and Walter, 1947). Recovery of the protein can be made through a desludging clarifyer. The separation can be commenced immediately without allowing the mass to stand unagitated (Van der Merwe and Downes, 1981).

V. Direct-Acid-Set Cottage Cheese Whey

Acid whey is the principal byproduct of cottage cheese manufacturing. There are two types of cottage cheese i.e. cultured and direct-acid-set (DAS) cottage cheese. Cultured cottage cheese is produced commercially by the addition of selected strains of lactic acid-producing bacteria into pasteurized skim milk. After a period of time the bacteria produce enough acid to reduce the pH and form a soft coagulum. It is cut and cooked to produce curds and acid whey. This cultured method is time consuming, and occasionally subject to failure due to slow growth of starter organisms. The starter culture is propagated in special tanks to guard against bacteriophage and contamination that cause failure of the process. Microbial contamination can cause off flavors (Kosikowski, 1978).

An alternate method is the DAS method. The patented process developed by Corbin (1971) utilizes an acid mixture, coagulator, and acidogen for direct acidification. A mixture of citric acid, lactic acid, and phosphoric acid (Vitex 750) are added to 5°C milk to obtain a pH of 4.9 to 5.0. The milk is then heated to 32°C followed by the addition of D-glucono-delta-lactone (GDL or Vitex 850) and rennet (Vitex cottage cheese coagulator). After an hour the curd is cut, and additional Vitex 750 is then added to obtain a pH of 4.4 to 4.5. The curd is then cooked, drained, and washed as in the conventional method (Corbin, 1971).

The cooking and cutting times for cottage cheese made by the DAS method are 40 and 33% shorter, respectively, than with the short set culture method (White and Ray, 1977). Sharma et al. (1977) reported a 6% yield increase in DAS cottage cheese

over the cultured method. Extended shelf life, improved consistency, and a 1.0 to 1.5% yield increase were reported by Gerson (1970). Since DAS cottage cheese whey is not cultured, it does not have that "whey taint" that is in cultured cottage cheese whey. The DAS whey flavor blends into drinks or beverages better than cultured cottage cheese whey (Demott, 1975).

VI. Beverages Formulated with Whey

A familiar whey beverage in Europe is Rivella (Anonymous, 1960). It was originally developed in Switzerland, and it has been marketed in Holland, Germany, and Australia. It is fermented, clarified whey that is sweetened, flavored, and carbonated.

A Polish scientist developed a soft drink utilizing deproteinized whey (Rzewuska-Rutte, 1967). Deproteinization of whey was carried out at 90°C and pH 7.0, and 63% of the protein was precipitated. Citrus and mint flavors resulted in more acceptable flavored soft drinks than did apples, cherries, strawberries, blackberries, and raspberries. He found that the best soft drinks were prepared with 95% whey.

Kosikowski (1968) incorporated up to 6% whey powder into reconstituted frozen orange juice. It contained 2.5 times more protein than plain orange juice, and was reported to be an acceptable product. He reported that the addition of 6% added whey powder imparted a salty flavor. At 4% added whey powder, however, a taste panel rated the flavor as excellent.

O-whey is a breakfast meal formulated from either neutralized acid whey or sweet whey and orange juice (Brunner et al., 1969). Orange juice is added to deodorized whey at a ratio of one volume concentrate to four volumes whey. The whey was deodorized by vacuum treatment and it can be packaged as a liquid, condensed, or dried product.