FOAM SPRAY-DRIED COTTAGE CHEESE WHEY AS A SOURCE OF SOLIDS IN SHERBETS

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ABSTRACT

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Dry whey solids obtained by foam spray drying fresh concentrated cottage cheese whey or whey which had been cultured with *Lactobacillus bulgaricus* or *Streptococcus thermophilis* were used to replace 25, 50, 75, and 94.5 per cent of the serum solids in orange, lemon and raspberry sherbet. Substitution of plain cottage cheese whey powder at all levels uniformly gave a fine quality sherbet with no flavor criticism. If all of the serum solids were replaced by cultured cottage cheese whey the sherbets were judged as "slight fermented". Sherbets made with whey solids added prior to pasteurization were judged good and possessed smooth body and texture. Addition of whey solids to the sherbet mix after pasteurization produced a slightly smoother sherbet. The amount of citric acid required to lower the pH of orange, lemon and raspberry sherbet to 3.7 was reduced approximately 32, 50 and 26 per cent respectively in sherbet with 94.5 per cent replacement of serum solids by dry acid whey. The bacteriological quality of whey powders and sherbets containing whey was excellent.

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INTRODUCTION

Increasing annual production of cottage cheese has resulted in economic and public health problems associated with whey disposal.

Due to the low pH of cottage cheese whey and the distinct odors and flavors produced by lactic fermentations, the uses for cottage cheese whey are much more limited than is the case for sweet cheese whey. Fluid cottage cheese whey has been used in the manufacture of sherbets. However, the inconvenience of handling liquid whey in many plants and the great difficulty encountered in conventional spray drying of cottage cheese whey has restricted the utilization of whey in sherbets. The relative ease with which cottage cheese whey can be foam spray-dried suggested that such whey powders might be readily substituted for serum solids in the manufacture of sherbet.

The purpose of this research was to determine whether foam spray-dried cottage cheese whey could be used as a source of serum solids in fruit flavored sherbet. If replacement of acidic whey solids for serum solids was feasible from the standpoint of ease of incorporation and quality of the frozen sherbet, then manufacturers could realize economic return from such usage and also make use of a presently wasted food ingredient.

REVIEW OF LITERATURE

In 1962 the United States Department of Agriculture (48) reported that 589 million pounds of cottage cheese curd were produced from approximately 3,680 million pounds of skimmilk equivalent. From the production of this cheese curd more than three billion pounds of whey were left for use or disposal. If the average total solids of this fluid whey was 6.62 per cent as indicated by Webb and Hufnagel (52), 204 million pounds of whey solids could be manufactured from this whey.

From the data of Stine and Sargent (40) on composition of spray dried cottage cheese whey, one can calculate that 204 million pounds of whey solids would yield 24 million pounds of very high quality protein, possibly 2 million pounds of fat, 130 million pounds of lactose and 17 million pounds of lactic acid. Utilization of these presently wasted nutrients in foodstuffs is a matter of worthy consideration in view of our world population explosion.

Increasing annual production of cottage cheese has also resulted in economic and public health problems associated with whey disposal. Many means of disposal and utilization of sweet whey have been developed; however, the uses and disposal of acid whey from cottage cheese are more limited because of low pH, odor and flavor.

Whey Disposal

The discharge of any industrial waste usually creates a disposal problem. Dairy wastes are particularly troublesome in this respect. The large amount of organic matter in whey makes costly the disposal in sewage systems. Dumping whey into streams is unlawful in some states and may soon be in others because of the high biological oxidation demand of such wastes and consequent pollution of the stream. In a review of methods of treatment and disposal of dairy wastes Southgate (39) suggests that biological filtration or the activated sludge process are the best means of waste disposal. In areas where conditions permit, irrigation is a method of disposal of whey. McDowall and Thomas (24) indicated that one acre of pasture land can accept at least 5,000 gallons of undiluted whey, provided there is a period of about 14 days between dosings. Sharrett et al. (37) showed that when properly applied, whey could increase the fertility of the soil; however, this method of utilization is limited by the fact that whey production is fairly concentrated in certain regions and land for disposal of the whey may not be available. This method of whey disposal also causes odor problems unless the process is carefully administered.

Whey Utilization

Feeding whey to livestock was one of the earliest means of whey utilization. Raw liquid whey was used for pig and calf feed if the stock were kept near the cheese factory. Since the livestock were often remotely located from the cheese factory, condensed and dried whey became the more practical product to ship or feed. Condensed whey of 35-50% solids was found by Tufft (43) to be an excellent chicken feed. Condensed as well as dried whey is useful in feeding chickens because of the effects of lactose in preventing coccidiosis and the beneficial effects of riboflavin and other nutrients on the growth of chicks. Becker et al. (11) successfully used dried whey as an ingredient in pig feed. Danielson et al. (14) used a mixture of dried skimmilk and dried whey in pig starter rations. An excess of whey in the pig's diet was found to have a laxative effect.

Many methods have been suggested for converting whey into a feedstuff suitable for ruminants. High-nitrogen feeds from whey have been developed by Arnott et al. (8) and Czarnetzky (12) for feeding cattle. However, Hazzard et al. (21) found that dairy cows fed high-nitrogen feeds often had lower milk and butterfat production than cows on control diets.

Although raw, concentrated or dried whey is a useful livestock food supplement, the use of whey for this purpose is limited because of cost and nutritional considerations. Using whey solids in the manufacture of food products for human consumption is more efficient, from the human nutritional standpoint, than feeding whey solids to animals and then consuming the animals as food to gain the nutrients present in the whey.

There are many ways in which whey, either plain or modified, can be used in food products. The utilization of whey in food and non-food products is reviewed by Webb and Whittier (54, 55) and Wix and Woodbine (56, 57). The chemical and physical properties, as well as the flavors of food, in many instances are claimed to be improved by the addition of whey solids. Webb and Whittier (55) report that one of the largest outlets for whey solids is in the production of process cheese foods, where plain condensed or dried whey solids are added to the emulsified cheese mixture. Badad et al. (9) used whey protein in process cheese food production. Ziemba (60) reported on the production of a free-flowing stabilized whey powder that gives soft body characteristics to cheese foods and spreads. A whey cheese popular in Scandinavia is called Mysost or Primost (50). "Albumin" cheese, commonly known as Ricotta or Ziger, is made by precipitating the proteins of whey in the presence of acid at elevated temperatures.

The baking industry is the largest single potential user of whey solids (4). Much work has been reported on the use of whey solids in all types of bakery products (1, 4, 18, 22, 32, 60). Whey solids are used in bread, rolls, fermented sweet products, cakes and other baked goods. The lactose promotes desirable browning, while the heat-coagulable proteins contribute to structure during baking. Cakes, cookies and doughnuts are more tender and keep their softness longer if whey is included in the mix.

Whey also has been used successfully in confections (1, 6, 51). Webb and Whittier (55) formulated a whey fudge which contained 43 per cent sweetened condensed whey. The sweetened condensed whey used in the fudge formulation was manufactured according to the method of

Ramsdell and Webb (29). This method consists of condensing a mixture of fresh whey and sugar. Processing whey in this manner preserves the whey in a form directly usable in sweet foods.

Whey proteins help provide emulsion stability in soups and soups containing whey solids are more natural in color than soups made with milk solids (53). Since there are only small amounts of casein present in whey, the use of whey solids in acid fruits, fruit juices and soups is advantageous to reduce curd formation which normally would occur during processing if milk solids were used. Ramsdell and Webb (30) found that as much as 25% of the total solids of spray-dried soups could be substituted with whey without the development of a whey flavor.

Whey protein has foaming properties which can be compared to those of egg albumin and Ramsdell and Webb (29) suggested that modified whey can be whipped for use in food preparations. However, whey protein cannot be used in products in which air must be incorporated by whipping and a firm structure set up by heat coagulation. Rogers et al. (31) modified cheese whey and spray-dried sweet whey to produce an edible foaming and aerating agent having many of the properties of egg albumin, gelatin and soya derivatives.

Numerous other uses for whey solids have been developed. Whey has been incorporated in products such as instant potatoes, salad dressings, starch puddings, sauces, dips and comminuted meat products. Detailed information about some of these uses for whey are to be found in the text by Whittier and Webb (59).

The components of whey have been modified, allowing whey solids to be used in a greater variety of products. The fat can by hydrolyzed with lipases, the lactose fermented, proteins modified or minerals removed (7). Whey can be blended with milk to produce a mixture which has beneficial properties of both the milk and the whey. Barnes et al. (10) produced an edible high-acid powder by blending cultured condensed cottage cheese whey with skimmilk and spray drying the blend. By demineralizing whey, an infant food has been made which has a composition close to that of human milk. Stribley (41) reports that by using electrodialysis, the salt content of whey can be reduced to a level whereby whey can be used in the manufacture of special baby food formulas which closely resemble the composition of human milk.

The major constituent of whey is lactose. Lactose has been used in infant foods, pharmaceuticals, the production of lactic acid, riboflavin and ethyl alcohol. Lactose also has many non-food uses. In an extensive review Whittier (58) discusses the production and utilization of lactose.

Usage of sweet whey in foods has grown rapidly since 1954 when U. S. Extra Grade Dry Whey was defined in the Federal Register (45). These standards on flavor, color, sediment, moisture, acidity and bacterial count assure that U. S. Extra Grade Dry Whey will be of uniform high quality. Dry sweet whey has been used in ice cream since World War II. Many state standards now allow whey in one form or another to be added to ice cream and/or sherbet. Federal definitions and standards published in October, 1963 do not include whey as an optional ingredient in ice cream, but the definitions do include whey as an optional ingredient in sherbet (49).

Nielsen (27) indicated that the most commonly used level of whey solids in ice cream is 20 per cent of the serum solids. Whey at this level gives satisfactory body and texture characteristics to ice cream. Leighton (23) showed that 19 to 65 per cent of the serum solids of ice cream can be added as whey solids without the danger of sandiness. The percentage serum solids that can be replaced with whey depends upon the fat and serum solids content of the mix. Rosenberger and Nielsen (33) summarized the advantages for using spray-dried whey powder in ice cream as follows: (a) Cost --- whey solids are cheaper than other common serum solids; (b) Improvement in the whipping ability; (c) Dispersibility; (d) Good body and texture and a slower melt-down. The chief disadvantage of using whey powder is that the flavor of ice cream may be slightly inferior to ice cream made from fresh cream and concentrated skimmilk.

Good quality sherbets can be made by using whey solids in place of the milk solids normally used in sherbet manufacture (5). Gholson et al. (17) indicated that pineapple, orange and raspberry sherbets, in which as much as 90 per cent of the serum solids was replaced with whey solids were very desirable in all respects. Potter and Williams (28) made an extensive study on the use of whey in sherbets. Sherbets were made from fresh fluid whey obtained from the manufacture of cheddar, swiss and cottage cheese. Condensed, sweetened condensed and dried whey were also used to make sherbets. The addition of whey to sherbet greatly improved whipping ability. Excessive overrun, caused by the addition of whey to sherbet, could be avoided by adding 0.6 to 2 per cent fat to the sherbet mix. Homogenization reduced the ability of the added fat to retard whipping. The non-heat-coagulable protein fraction of whey was found to be responsible for the unusual whipping properties of whey sherbets.

Potter and Williams (28) found that citric acid was not necessary to acidify sherbet mix when cottage cheese whey replaced the milk solids normally used. Savings in citric acid approximating 10 cents per 100 pounds of sherbet base could be realized if cottage cheese whey was used as a source of solids. No whey flavor was carried over to the finished product when a good quality whey was used. Since most of the acid coagulable casein is not present in whey, sherbet containing whey solids showed no tendency to curdle.

Potter and Williams (28) used fluid cottage cheese whey in sherbet manufacture. Fluid whey is inconvenient and uneconomical to handle, ship or store. Powder made from cottage cheese whey because of its hygroscopicity, tends to clump and "ball" in conventional spray drying equipment and is difficult to handle in pneumatic conveyors. Foam spray drying as developed by Hanrahan and Webb (19) produces a powder which is easily and economically handled. The relative ease of producing and handling foam spray-dried whey makes the use of dried acid whey in sherbet manufacture attractive.

Sherbet Formulation

The choice of sherbet formula will depend upon individual preferences for sweetness, texture and body, milk solids content and acidity. A good sherbet should contain about 25 to 35 per cent carbohydrate according to Frandsen and Arbuckle (16). By replacing 20 to 25 per cent (w/w) of the sucrose with dextrose, Dahlberg (13) indicates that surface crystallization of sucrose is prevented. As demonstrated by Ross (36) a sherbet with the correct amount of sweetness and total sugar content can be made using 20 per cent cane sugar and 8 per cent corn syrup solids. Ross (34) stated that as the percentage of sugar used in the formula is increased, body and texture improve, flavor becomes more distinct and the acid gives a sharper flavor to the sherbet.

Federal regulations now require that sherbets contain milk solids (49). These solids contribute desirable properties to sherbets. Day et al. (15) suggested that the level of total milk solids should be about 4 to 5 per cent (w/w) of the sherbet formula. Solids-not-fat improve body and texture and tend to prevent a weak body and coarse texture (35). Too high a milk solids-not-fat (MSNF) content reduces the intensity of fruit flavor and is therefore usually limited to 3 per cent or less. The usual fat content of sherbet is in the range of 1 to 2 per cent. When the MSNF content of a sherbet is held constant the rich flavor increases directly with increasing fat content.

Stabilizers are important in sherbets to improve shelf life and control overrun. There are many sherbet stabilizers available, such as the vegetable gums, pectins and propylene glycol alginate. The choice of stabilizer and amount to use depends on overrun desired and the body and melt-down characteristics sought by the manufacturer (44).

The amount of fruit that must be contained in sherbets now is under Federal regulation (49). For a fine fruit flavored sherbet only the best fruit juice or puree should be used, possibly in conjunction with a pure flavor essence.

One of the most important considerations in the production of sherbet is acidity. Unless the acidity of each batch is carefully controlled the fruit flavor will not be at an optimum. The desired acidity is dependent upon the type of fruit sherbet made. Day et al. (15) suggested that the most desirable acidity in a sherbet is 0.55 to 0.60%, expressed as citric acid. Frandsen and Arbuckle (16) recommended that the titratable acidity of sherbet should be 0.35 to 0.52 per cent, expressed as lactic acid. Preferably the acidity should be 0.47 to 0.52 per cent or in a pH range of 3.6 to 3.8. Each batch of sherbet should be titrated for acidity just prior to the addition of citric acid and then standardized to the desired acidity or pH. Shortledge (38) advised that pastel shades in foods are the most appetizing. The color of a sherbet should not be darker than the color of the base fruit.

The percentage of overrun that is presently acceptable in most consumer markets is 35 to 45 per cent (16). Color, pH and overrun are characteristics which vary widely according to the area in which the sherbet is manufactured and sold.

EXPERIMENTAL PROCEDURE

The purpose of this research was to determine if foam spray-dried cottage cheese whey could be effectively used as a source of serum solids in sherbets. Once the feasibility of using such whey was established the remaining trials were directed toward ascertaining the maximum replacement of normal serum solids consistent with good flavor, body and texture. When acid whey is added to sherbet mix there is a reduction in the quantity of citric acid needed to lower the pH of the mix to the desired level. In all trials the amount of citric acid needed to bring the pH of the base mix to 3.7 was determined.

Condensing: Fresh cottage cheese whey was obtained from the Michigan State University dairy plant and filtered through a single gauze faced 6 1/2 inch Rapid-Flo filter disk to remove small pieces of curd which were present in the whey. The whey was preheated to 115 F, concentrated in a 16 inch Rogers vacuum pan to 40-50 per cent total solids and immediately foam spray-dried.

Production of a Cultured High-Acid Whey: Several batches of whey were cultured before concentration to ascertain whether any additional acidity or other fermentation products might have beneficial effects on the flavor of sherbets to which such whey was added. Fifty gallon lots of fresh cottage cheese whey were inoculated with a 1 per cent inoculum of either *Lactobacillus bulgaricus* or *Streptococcus thermophilis* and incubated at 45 or 37 C, respectively, for 24 hours.

Drying: The cottage cheese whey concentrate was foam spray-dried using the nitrogen injection technique described by Hanrahan and Webb (19). A Rogers co-current horizontal inverted tear-drop dryer equipped with a Spraying Systems type SBC 6 nozzle with a 0.040 inch orifice diameter was used for drying. Atomization pressure was 1000 lbs./sq. in. with nitrogen injected under a pressure of 1050 lbs./sq. in. at a rate of 2.0 cubic ft./gal. as the concentrate left the high pressure pump. Inlet air and exit air temperature averaged 260 F and 185 F, respectively, during spray drying. The powder was collected and stored in polyethylene bags.

Pasteurization and Homogenization: The pH of sherbet mixes containing whey solids is markedly lower than the pH of mixes containing serum solids which are normally used in sherbet manufacture. Since the pH of mixes containing whey was low, trials were run to determine if this lower pH would cause coagulation or precipitation and preclude the pasteurization temperature normally used on such products.

Mixes were made containing only the following basic ingredients: cream, sucrose, corn syrup solids, stabilizer and water. These mixes were heated to 165 F, held for 30 minutes, subjected to two stage homogenization at 2500 psi and immediately cooled to 33 F using a surface cooler. Other mixes were made which included whey and/or nonfat dry milk (NDM) as one of the basic ingredients. These mixes were pasteurized at 150 F or 160 F for 30 minutes or flashed at 175 F, followed by homogenization and cooling. The cooled mixes were then aged at 34 F for 24 hours before freezing.

Freezing: Additional serum solids, if needed, fruit juice, flavor, color and citric acid were added to the sherbet mix. The sherbet mixes were frozen in an Emery Thompson 2 1/2 gallon batch freezer to approximately 45 per cent overrun and hardened at -25 F in moving air. The frozen samples were transferred to a freezer cabinet at 2 to 5 F for observation of body and texture changes.

Sherbet Formulation: The formula used in making sherbets was 20% sucrose, 8% corn syrup solids, 0.5% stabilizer, 1.5% fat and 3.5% serum solids. Table 1 indicates the general formula used in making the sherbets employed in all trials. Orange, lemon and raspberry

TABLE 1. Sherbet formula used in all trials.

Amount used (lbs)	Ingredients
20.0	sucrose
8.0	frodex (42% dextrose equiv.)
3.8	cream (40% cream)
3.4	NDM (3.2% moisture)
0.5	stabilizer
64.3	combined weight of water, fruit etc.

sherbets were made. The optimum amount of fruit, flavor and color to add was determined in advance and this amount was used in all subsequent trials. In preparing ten pound batches of orange sherbet mix, 254.2 g of pure 4:1 frozen orange juice concentrate, 9.9 g of natural orange and 2.8 g of orange color were added prior to freezing. When lemon sherbet mixes were made, 170.2 g of frozen lemon juice, 8.7 g of natural lemon flavor and 2.7 g of yellow color were added. Just prior to freezing raspberry sherbet mixes, 300 grams of fresh frozen raspberry puree and 4.5 grams of natural raspberry flavor were added. In all cases commercial 50% citric acid solution was used to adjust the pH of the mix to 3.7 or 3.5.

Foam spray-dried cottage cheese whey was substituted at various levels for the NDM normally used in preparing sherbet mixes. The percentage of the total serum solids that was replaced with whey solids was considered the level of substitution. Therefore, 100 per cent substitution of the serum solids with whey solids could not be accomplished since the cream contributes approximately 5.5 per cent of the total serum solids. Table 2 illustrates the formula of a sherbet mix which has essentially all of the serum solids substituted with whey solids.

TABLE 2. Sherbet formula with 94.5 per cent of the serum solids substituted with whey solids (10 lb. batch).

Amount used (lbs)	Ingredients
2.0	sucrose
0.8	frodex (42% dextrose equiv.)
0.38	cream (40% cream)
0.34	whey solids (3% moisture)
0.05	stabilizer
6.43	combined weight of water, fruit, etc.

Some of the sherbet mixes were prepared with the serum solids, in the form of dry whey and/or NDM, added after pasteruization and cooling.

The milk and/or whey solids were incorporated before the addition of the fruit, flavor, color and citric acid. Other sherbet mixes were prepared in such a manner that whey and/or NDM was added prior to pasteurization. Comparisons were made between sherbets prepared with whey solids incorporated into the mix either prior to or following pasteurization.

ANALYTICAL PROCEDURES

Total Solids Determination: To determine the total solids of liquid whey, condensed whey and sherbet the Mojonnier procedure was followed (26). Total solids on NDM or whey powder were determined by the Cenco Moisture Balance Method (26).

pH Measurements: pH determinations were made on liquid whey, condensed whey and reconstituted whey powder. When preparing sherbet mixes, pH readings were taken both prior to and following serum solids addition and after the addition of fruit juice, flavor and color. A pH meter was also used to indicate when the correct amount of citric acid had been added to attain the desired pH in the sherbet mix. Since the sherbet mixes just prior to freezing had relatively low temperatures a buffer solution of known concentration and at the temperature of the mix was used to standardize the pH meter.

pH measurements were made with a Beckman Zeromatic pH meter using a calomel half cell and a glass electrode.

Determination of Titratable Acidity: The acidity of fluid and concentrated whey was found according to the procedure outlined by the Milk Industry Foundation (26). Whey powder acidity was obtained using the method recommended by the American Dry Milk Institute (2).

The titratable acidities of frozen sherbets, expressed as citric acid, were determined on fluid sherbets following equilibration at room temperature. After mixing, a 9 gram sample was weighed and titrated to a pH of 8.4 (phenolphthalein endpoint), using the pH meter to indicate the endpoint.

Bulk Density: The bulk density of a powder was determined by weighing an empty 100 ml. graduated cylinder, filling with powder to the mark, tapping the cylinder at intervals to settle powder, weighing the cylinder plus powder and calculating the bulk density as g/ml. (20).

Organoleptic Evaluation: The flavor, body and texture evaluations of the sherbets were made by experienced judges. All samples were coded, individually criticized and placed according to their relative preference compared to other samples.

Microbiological Determinations: In several experiments the serum solids or whey solids were added after pasteurization. Since the finished sherbet would then contain dairy ingredients which technically had not been pasteurized during mix processing, the assessment of microbial populations seemed desirable. Standard plate counts for total and coliform organisms were made to determine the bacteriological quality of both whey powders and the finished sherbets (3, 26).

RESULTS

The fresh cottage cheese whey collected for processing had a total solids content of 6 to 7 per cent; immediately following concentration to 25 to 55 per cent total solids, the whey was foam spray-dried. Analyses were made to determine the pH, total solids and titratable acidity of the fresh whey and concentrate used in producing the various foam spray-dried powders. Titratable acidity, moisture and bulk density were determined on the whey powders used in preparing sherbet mixes (Appendix 1a - 5a). The resulting powders had low bulk densities and moisture contents, were free flowing and readily soluble in the mixes to which they were added. Foam spray-dried cottage cheese whey is hygroscopic unless crystallization techniques are employed, and must be packaged and stored to avoid moisture absorption.

The titratable acidity of cottage cheese whey obtained from the cheese vat was 0.45 to 0.53 per cent, expressed as lactic acid. Culturing whey with L. bulgaricus or S. thermophilis raised the acidity of the whey, thus enabling production of high acid powders. When L. bulgaricus was used to culture whey the acidity was raised to 0.70 to 0.96 per cent and the corresponding whey powders made from such whey had acidities of 11.86 to 12.50 per cent on a dry basis. Plain foam spray-dried cottage cheese whey powders had acidities of 5.93 to 6.68 per cent. When whey was cultured with S. thermophilis the titratable acidity increased only slightly over that observed in the original whey. Powder made by foam spray drying whey cultured with S. thermophilis had a titratable acidity of 7.00 per cent.

In preparing sherbets wherein whey was substituted for the serum solids normally used, individual batches of mix were processed. These mixes were designed so that 25, 50, 75 or 94.5 per cent of their serum solids were replaced by foam spray-dried plain or cultured cottage cheese whey. A control containing NDM as the only concentrated source of serum solids was included in every group.

The pH of mixes with added serum solids was observed and recorded before the addition of fruit and flavor. The pH of the base mix, before addition of fruit juice and flavor, decreased as the content of dried cottage cheese whey increased (Tables 3 to 5). The extent to which the pH of the mix is lowered is also dependent upon the acidity of the whey powder employed. The lower pH of the base mixes containing whey results in a reduction of the quantity of citric acid needed to lower the pH of the sherbet to the desired level.

The data contained in Table 6 illustrate average reductions in the quantity of citric acid needed to lower the pH of orange, lemon and raspberry sherbets to 3.7. The greatest reduction in the quantity of citric acid required was noted in lemon sherbets, followed by orange and raspberry. In some orange, lemon and raspberry sherbets, reductions in the quantity of citric acid required were as high as 42, 54 and 30 per cent respectively.

When sherbets were adjusted to a lower final pH of 3.5 more citric acid was required than sherbets adjusted to 3.7. Orange sherbets

TABLE 3. Properties of orange, lemon and raspberry sherbet prepared with various amounts of foam spray-dried cottage cheese whey and adjusted to a pH of 3.7 with citric acid after addition of flavor.

Substitution of serum solids with whey solids (per cent)	Reaction of basic mix before addition of flavor or color (pH)			Quality of sherbet stored at 2 to 5 F			
				Flavor at		Body and texture at	
	Orange[a]	Lemon[a]	Raspberry[b]	0 days	60 days	0 days	60 days
0	6.90	6.65	6.80	good	good	smooth	sl. coarse
25	6.35	6.10	6.50	good	good	smooth	sl. coarse
50	5.90	5.65	5.92	good	good	smooth	sl. coarse
75	5.40	5.35	5.60	good	good	smooth	sl. coarse
94.5	5.10	5.15	5.30	good	good	smooth	sl. coarse

[a] For data on whey used in this trial consult Appendix, Table 1a.

[b] For data on whey used in this trial consult Appendix, Table 5a.

TABLE 4. Properties of orange, lemon and raspberry sherbet prepared with various amounts of foam spray-dried cottage cheese whey cultured with L. bulgaricus.

Substitution of serum solids with whey solids (per cent)	Reaction of basic mix before addition of flavor or color[a] (pH)			Quality of sherbet stored at 2 to 5 F			
				Flavor at		Body and texture at	
	Orange[b]	Lemon[b]	Raspberry[c]	0 days	60 days	0 days	60 days
0	6.40	6.80	6.90	good	good	smooth	sl. coarse
25	5.50	5.75	6.30	good	good	smooth	sl. coarse
50	4.65	5.00	5.30	good	good	smooth	sl. coarse
75	4.30	4.35	4.99	good	good	smooth	sl. coarse
94.5	4.20	4.18	4.30	good[d]	good[d]	smooth	sl. coarse

[a] pH of lemon and raspberry sherbets adjusted to 3.7 with citric acid after the addition of flavor. Orange sherbet was adjusted to a pH of 3.6.

[b] For data on whey used in this trial consult Appendix, Table 2a.

[c] For data on whey used in this trial consult Appendix, Table 3a.

[d] Judges criticized sample as "slight fermented".

TABLE 5. Properties of orange sherbet prepared with various amounts of foam spray-dried cottage cheese whey cultured with *S. thermophilis*.

Substitution of serum solids with whey solids (per cent)	Reaction of basic mix before addition of flavor or color[a,b] (pH)	Quality of Flavor at 0 days	Quality of Flavor at 60 days	Quality of Body and texture at[c] 0 days	Quality of Body and texture at[c] 60 days
0	6.40	good	good	smooth	sl. coarse
25	5.90	good	good	smooth	sl. coarse
50	5.65	good	good	smooth	sl. coarse
75	5.20	good[d]	good[d]	smooth	sl. coarse
94.5	5.10	good[d]	good[d]	smooth	sl. coarse

[a] For data on whey used in this trial consult Appendix, Table 4a.

[b] pH of sherbet adjusted to 3.5 with citric acid after addition of flavor.

[c] Stored at 2 to 5 F.

[d] Judges criticized sample as having a "whey flavor".

TABLE 6. The average reduction in quantity of citric acid needed to lower the pH of some sherbets to 3.7.

Serum solids substituted with plain cottage cheese whey solids (per cent)	Average reduction of citric acid (per cent)		
	Flavor of Sherbet		
	Orange	Lemon	Raspberry
25	18	21	11
50	22	27	13
75	26	29	16
94.5	32	50	26

containing whey replacing 25, 50, 75 and 94.5 per cent of the normal serum solids required 10, 12, 16 and 26 per cent less citric acid respectively. Lemon sherbets adjusted to a final pH of 3.5 and with whey substitution levels identical to those of the orange sherbets showed reductions in quantity of citric acid required of 5, 10, 18 and 30 per cent respectively.

Sherbet mixes prepared substituting whey which had been further cultured with L. bulgaricus before drying had lower pH values than mixes containing noncultured whey solids. Results of these trials on orange, lemon and raspberry sherbets are recorded in Table 4. At 75 and 94.5 per cent serum solids substitution in orange sherbets 36 and 54 per cent less citric acid, respectively was needed to adjust the pH to 3.6. Lemon sherbet containing the same serum solids substitution required 46 and 55 per cent less citric acid. Raspberry sherbets prepared in the same manner required 28 and 43 per cent less citric acid.

Whey powders prepared from liquid whey cultured with S. thermophilis were used in making sherbet (Table 5). A similarity was noted in pH values for base mixes containing whey solids prepared by drying whey cultured with S. thermophilis and the pH values of base mixes containing plain whey solids substituted for milk solids. Orange sherbets made with 25, 50, 75 and 94.5 per cent of the serum solids replaced with such powders required 8, 12, 20 and 24 per cent less citric acid, respectively, to adjust their pH to 3.5. The above percentage reductions in citric acid are almost identical to those reductions in citric acid are almost identical to those reductions in citric acid obtained when plain whey solids were substituted for the normal serum solids in orange sherbets adjusted to the same pH. Therefore, there is no advantage gained by culturing whey with S. thermophilis prior to spray drying.

When foam spray-dried cottage cheese whey was added to cold mixes the powder went into solution easily. After incorporation of the whey powder the mix was allowed to stand in the cold for a short period of time to permit the collapse of the unstable foam which results when foam spray-dried products are reconstituted. Sherbet mixes not allowed to stand in the cold occasionally exhibited a tendency to foam slightly on meltdown. Foaming naturally was not observed in sherbets to which whey solids had been added prior to pasteurization of the mix.

Following freezing of the flavored mixes to approximately 45 per cent overrun, hardening at -25 F and tempering in a cabinet held at 2 to 5 F, all samples were evaluated for flavor, body and texture after 0 and 60 days storage in the cabinet (Tables 3 - 5). The data in Table 3 indicate typical results obtained from 35 trials in which over 700 pints of sherbet were made. All of the samples of sherbet which contained varying amounts of foam spray-dried plain cottage cheese whey were considered good by the judges, as were the corresponding controls. There was no unanimity of agreement as to which sample might be considered superior to the others. Often, the samples chosen as best were those containing 75 and 94.5 per cent substitutions; however, all judges agreed that differences were slight. After two months storage in a cabinet at 2 to 5 F all samples were slightly coarse in texture. Meltdown of the control and other samples was similar and uniform.

Sherbets made with various amounts of the serum solids replaced with foam spray-dried whey powder prepared from cultured whey were evaluated as to flavor, body and texture. The texture and body of sherbets prepared with the above type of whey solids were comparable to plain whey sherbets. Sherbets containing *L. bulgaricus* whey solids at the 94.5 per cent level of substitution were often described by the judges as having a "slight fermented" flavor. At the 75 and 94.5 per cent level of serum solids substitution with *S. thermophilis* whey solids the judges detected a "whey flavor".

This research conclusively demonstrates that good sherbets can be made by substitution of serum solids with foam spray-dried plain cottage cheese whey. Satisfactory sherbets can also be prepared using foam spray-dried *L. bulgaricus* cultured cottage cheese whey in substitution of as high as 75 per cent of the original serum solids of the basic sherbet formula. However the slight advantage of using cultured whey in sherbet is definitely offset by the added expense and inconvenience of preparing such whey.

Trials were conducted in which the acid whey solids were added before and after pasteurization of the mix in order to ascertain if sherbets of equally good body and texture characteristics could be produced by either method of incorporation. Identical methods of pasteurization, homogenization and cooling were followed for these mixes. Pasteurization conditions were varied to determine if the type of heat treatment would influence the production of a tactual flavor. Judges evaluated the mixes before the addition of color and flavor for a tactual flavor (Tables 7 and 8). At the 25 and 50 per cent substitution levels a "slightly chalky" flavor was detected which was independent of the heat treatment to which the mixes had been subjected. When the mixes were frozen and evaluated judges were unable to differentiate between any of the samples, regardless of the heat treatment used. All of the sherbets were judged as good irrespective of when the serum solids were added or the heat treatment used. When comparisons were made between sherbets prepared with whey solids added prior to pasteurization and cooling, the sherbets prepared by the latter method were smoother. When the samples were individually judged no objectionable tactual flavor was detected. Only when direct comparisons were madewas a difference in smoothness detected. Therefore, good sherbets can be made by either method, with the smoothest sherbets resulting when the whey solids are added after pasteurization.

Samples of sherbet were allowed to warm to room temperature. These melted samples were then titrated to a pH of 8.4 using a pH meter and calomel and glass electrodes. The titratable acidity of the melted sherbet was then calculated. Acidities ranged between 0.49 and 0.69 per cent, expressed as citric acid and were dependent upon the final pH to which the sherbet had been adjusted.

TABLE 7. Effect of whey solids added after pasteurization on the observed tactual property in sherbets and their respective mixes.

Substitution of serum solids with whey solids (per cent)	Degree of tactual flavor observed[a]					
	Pasteurization temperature, F.					
	150		160		175	
	sherbet	mix	sherbet	mix	sherbet	mix
0	-	-	-	-	-	-
25	-	-	-	-	-	-
50	-	-	-	-	-	-
75	-	-	-	-	-	-
94.5	-	-	-	-	-	-

[a] slight chalky +, none -.

TABLE 8. Effect of whey solids added prior to pasteurization on the observed tactual property in sherbets and their respective mixes.

Substitution of serum solids with whey solids (per cent)	Degree of tactual flavor observed[a]					
	Pasteurization temperature, F.					
	150		160		175	
	sherbet	mix	sherbet	mix	sherbet	mix
0	-	-	-	-	-	-
25	-	+	-	+	-	+
50	-	+	-	+	-	+
75	-	-	-	-	-	-
94.5	-	-	-	-	-	-

[a] chalky +, none -.

The total solids of some of the orange, lemon and raspberry sherbets were determined. Average percentages of 36.50, 34.78 and 38.40 were found for orange, lemon and raspberry sherbet, respectively.

In many of the trials whey solids were added to sherbet mixes either before or after pasteurization. In either case the bacteriological quality of the ingredient added is of importance, and particularly so if the ingredient is added after pasteurization. Therefore, the bacteriological quality of the foam spray-dried whey used in making sherbets was determined. No special precautions to prevent bacterial contamination were exercised in handling the liquid whey during concentration and drying. Coliform tests were negative for all powders. A bacterial estimate of not more than 50,000 per gram as determined by the standard plate count is the Federal Standard for U. S. Extra Grade Dry Whey and U. S. Extra Grade Nonfat Dry Milk (45, 46). Whey powders produced for use in sherbets had relatively low bacteria counts (Table 9). Powders made from cultured whey, in

TABLE 9. Bacteriological quality of various whey powders after two weeks storage.

Sample no.	Type of whey	Standard plate count at 35C
1	plain	<3000
2	cultured, *L. bulgaricus*	<3000
3	plain	400
4	cultured, *S. thermophilis*	700
5	plain	650
6	plain	<3000
7	cultured, *L. bulgaricus*	11000
8	cultured, *L. bulgaricus*	2320

some instances, had counts comparable to those obtained from plain whey powders.

Sherbets which contained whey solids were examined for bacteriological quality. Comparisons were made between sherbets made with foam spray-dried cottage cheese whey added prior to pasteurization and those sherbets made with whey solids added following pasteurization to determine if the whey powders added after pasteurization would increase the standard plate count of the sherbet. The Michigan Ice Cream Law states that sherbet shall not contain more than 75,000 bacteria per gram (25). The data obtained on the bacteriological quality of sherbets prepared with various amounts of foam spray-dried cottage cheese whey indicates that the counts were relatively low (Table 10). All sherbets exhibited negative coliform tests.

TABLE 10. Bacteriological quality of sherbets prepared with various amounts of foam spray-dried cottage cheese whey added prior to or following pasteurization.

Substitution of serum solids with whey solids (per cent)	Standard plate count at 35 C — Serum solids added: prior to pasteurization	Standard plate count at 35 C — Serum solids added: following pasteurization
0	3000	<3000
0	2900	<3000
94.5	3000	6400
94.5	3000	<3000
75	790	<3000
75	300	5500
50	510	<3000

DISCUSSION

Large, porous, highly dispersible particles are produced by the foam spray drying technique of Hanrahan and Webb (19). Bulk density is, among other factors, directly related to particle size. With particles of uniform large size large voids exist between particles and bulk density is low. Powders produced for use in sherbets in this research had average bulk densities of 0.35 g/ml when water pump nitrogen was injected at a rate of 2 cu. ft./gal. of concentrate before drying. Other factors which affect bulk density of the powder produced are total solids of the concentrate, dimensions of the nozzle orifice and drying conditions. Cottage cheese whey powders with bulk densities of 0.55 g/ml have been produced by injecting a minimum amount of nitrogen. For the purposes of this research a powder was desired which would be readily soluble and processing conditions were selected accordingly, albeit at the sacrifice of high bulk density.

Whey powders produced by any straightforward spray drying techniques are very hygroscopic. The hygroscopic tendency of these powders can be partially eliminated by inducing lactose crystallization before or during drying by adaptation of one of the producers suggested by Whittier and Webb (59). After foam spray drying, a second stage consisting of moisture pickup, lactose crystallization and redrying will produce a more stable powder. An alternative method is the crystallization of lactose in the concentrated whey followed by spray drying of the resultant slurry. Powders produced by either method are easier to handle and store than those having all of the lactose in the amorphorus state.

The sherbet formulation used in this study was the result of combining formulas known to produce good quality sherbets (15, 34, 36, 38). The amount of fruit juice or puree needed to impart fine flavor was determined by trial and error. The flavors contributed by the natural frozen fruit juices were generally fortified with natural fruit essences.

When foam spray-dried cottage cheese whey is substituted for the serum solids in sherbets the pH of the base mix, before the addition of the fruit juice and flavor, decreases as the amount of dried cottage cheese whey is increased. The extent the pH is lowered depends upon the titratable acidity of the powder and the amount of dried whey added to the mix. The titratable acidity of the powder depends upon the acidity of the original whey. In cultured whey the presence of additional acidic fermentation products causes the titratable acidity of powders made from such whey to be higher than the acidity of those powders obtained by foam spray drying plain cottage cheese whey. Additional acidity in the original whey does not always mean that the powder produced from such whey will have a corresponding increase in titratable acidity. By comparing the data obtained from two cultured wheys that were foam spray-dried, it can be seen that the acidity of cultured whey no. 2 is less than the acidity of cultured whey no. 8 (Tables 2a and 3a, Appendix). The powders produced from these cultured wheys have approximately the same titratable acidity. A possible explanation for the similar acidities is the increasing vapor temperature of the whey in the vacuum pan as concentration progresses and accompanying loss of volatile acidity. Also the fermentation pattern of volatile acids produced may well vary with the culture used, so that one lot of whey may have greater or less volatile acidity than another.

Reductions in the quantity of citric acid needed to lower the pH of the sherbets to the desired level was found to vary with the citrus flavor used, desired final pH of sherbet, type of whey used to replace the serum solids and percentages of serum solids replaced. The last two factors affecting percentage reductions have been discussed previously.

Orange, lemon and raspberry mixes containing fruit, flavor, and with 0-94.5 per cent of their serum solids replaced have typical pH values of 4.9 to 4.3, 4.7 to 4.0 and 5.8 to 4.6, respectively. The percentage reduction of citric acid is dependent upon the difference between the amount of citric acid used to reach the desired pH in the control mixes and the amount used in the mixes containing whey. The greater percentage reduction in citric acid used in the lemon flavored sherbet mixes is attributed to the fact that the lemon juice plus dried whey at the 94.5 per cent substitution level brings the sherbet mix through a buffering zone, thus substantially reducing the amount of citric acid needed to adjust the mix to the desired pH. Mixes containing orange and raspberry juice plus dried whey at the 94.5 per cent substitution level did not overcome this buffering capacity to as great an extent as did the more acidic lemon juice.

Among the samples containing whey solids added after pasteurization there was noted a tendency for slight foaming during meltdown. This was presumably due to liberation of air and injected nitrogen in the spray-dried foam particle and can be eliminated by allowing the mix to stand under agitation in the cold for a short period of time before freezing the mix. Foaming was not a problem in samples containing whey solids which had been added prior to pasteurization, since the air and injected nitrogen in the spray-dried foam particle is liberated during pasteurization.

Potter and Williams (28) reported that good quality sherbets could be made using fresh fluid cottage cheese whey as a source of serum solids instead of the milk solids normally used. Sugar, stabilizer, flavor and enough 40 per cent cream to yield a fat content of 2 per cent in the finished sherbet were added to fluid acid whey. Sherbets made in this manner had a whey solids content of 4 to 5 per cent and required no additional citric acid to adjust the mix to a rather low selected titratable acidity of 0.37 per cent. A sherbet containing cottage cheese whey with a titratable acidity of 0.53 per cent as the major source of serum solids had a final pH of 4.49 and a titratable acidity of 0.37 per cent expressed as lactic acid. By using cottage cheese whey in this manner in sherbets a savings in citric acid approximating 10 cents per 100 pounds of sherbet base could be realized. Whey sherbets possessed a smooth texture and no whey flavor existed in the finished sherbet made from whey that had not developed more acidity than was originally produced in the normal cheese making process.

The inconvenience of handling and storing liquid whey in many plants and the great difficulty encountered in conventionally spray drying of cottage cheese whey has restricted the use of cottage cheese whey in sherbets. Use of the nitrogen injection technique described by Hanrahan and Webb (19) to foam spray dry cottage cheese whey eliminated these handling and storage problems. Foam spray-dried whey powders are free flowing, highly dispersible and upon reconstitution yield a clean, acid-flavored whey.

Sherbets made with 94.5 per cent of their serum solids replaced with whey powder had a whey solids content of 3.3 per cent. The pH values of sherbet bases containing 94.5 per cent of their serum solids replaced with foam spray-dried plain cottage cheese whey were in the pH range of 5.30 to 5.00. If whey cultured with *L. bulgaricus* was foam spray-dried and used in place of plain cottage cheese whey powder at the 94.5 per cent level of substitution, pH values in the range of 4.30 to 4.18 were obtained. The pH considered desirable in the finished sherbets was 3.7. Therefore, citric acid or some other edible acid was still needed to attain this pH regardless of the type or quantity of whey used.

Batches of whey were cultured with either *L. bulgaricus* or *S. thermophilis* before concentration to ascertain whether any additional acidity or fermentation product might have beneficial effects on the flavor of sherbets containing solids prepared from such whey. Whey additionally fermented with *S. thermophilis* was found to contribute an undesirable flavor to the finished sherbet. Whey cultured with *L. bulgaricus* was successfully used to substitute up to 75 per cent of the serum solids. At levels above 75 per cent a "slight fermented" flavor could sometimes be detected. As previously noted these cultured wheys did not substantially further reduce the citric acid needed to adjust the pH of the mix to 3.7 and would therefore be impractical to prepare.

When whey solids were added to the unpasteurized sherbet base, replacing 25 or 50 per cent of the normal milk solids, a tactual flavor defect occasionally was observed in the unfrozen mix. This defect was not observed in unfrozen mixes at the 0.75 or 94.5 per cent substitution levels or at any substitution level in the frozen sherbet. In sherbet bases having 25 or 50 per cent of their normal milk solids replaced with whey solids there is a greater amount of casein present than in those mixes with 75 or 94.5 per cent of their normal milk solids replaced with whey solids. Under the conditions of pH and heat that exist when pasteurizing a mix containing whey solids the possibility exists that some of the casein precipitates and is detectable as a tactual flavor only in those mixes containing relatively large amounts of normal milk solids. Apparently the texture of the frozen sherbet masks the tactual flavor present in the unfrozen mix.

After hardening the frozen sherbets at -25 F., the samples were transferred to a freezer cabinet at 2 to 5 F. for observation of body and texture changes. At temperatures of 2 to 5 F. a greater quantity of water in the sherbet would be equilibrating as ice-water than at a lower storage temperature. After two months storage at these temperatures all sherbet samples were slightly coarse in texture. Temperatures in the 2 to 5 F. range are optimum for lactose crystallization in a sherbet; nevertheless, lactose crystals were not observed in any of the sherbets.

The bacteriological quality of whey powders is especially important if this product is to be used in food for human consumption. At the present time there are no Federal Standards for specific grading requirements for cottage cheese whey. The specific grading requirements for U. S. Extra Grade spray-dried sweet whey specifies that the powder should not have a bacterial estimate greater than 50,000 per g (45). U. S. Extra Grade nonfat dry milk should have a bacterial estimate not greater than 50,000 per g (46). The bacterial estimates of plain foam spray-dried cottage cheese wheys that were produced for use in this research were less than 3000 per g by the standard plate count. Cultured whey that had been foam spray-dried had higher bacterial estimates, with the highest plate count being 11,000 per g. By comparing the bacterial estimates of cottage cheese whey powders with the estimates set as maximum for Extra Grade sweet whey and nonfat dry milk the whey powders produced in this research had bacterial estimates substantially below those specified for dry sweet whey and nonfat dry milk.

The bacteriological quality of sherbets made with various amounts of whey solids was good. Bacterial extimates of frozen sherbets made with whey solids were well below the 75,000 bacteria per g that Michigan Law sets as maximum (25). Sherbets that were made with whey solids added after pasteurization exhibited a maximum of 6,400 organisms per g.

SUMMARY AND CONCLUSIONS

Sherbets were prepared using plain or cultured foam spray-dried cottage cheese whey solids to substitute for 25, 50, 75 and 94.5 per cent of the original serum solids in the basic sherbet formula. Cultured cottage cheese whey solids were prepared by foam spray drying liquid whey that had been cultured with either S. thermophilis or L. bulgaricus. Sherbets were prepared from mixes to which the serum solids, in the form of whey powder, were added prior to and following pasteurization. Samples of sherbet were evaluated for flavor, body and texture at 0 and 60 days storage. The bacteriological quality of sherbets and the wheys used in preparing these sherbets was determined.

Satisfactory sherbets were prepared using plain cottage cheese whey solids in substitution of 94.5 per cent of the normal milk solids in the sherbet base. Substitutions of as high as 75 per cent of the original serum solids with L. bulgaricus whey solids were possible without producing an off flavor. Whey solids made from cottage cheese whey cultured with S. thermophilis contributed no beneficial properties to sherbets in which they were used.

Sherbets exhibiting excellent flavor characteristics and possessing smooth body and texture were made when the whey solids were incorporated in the base mix before and after pasteurization. Those sherbets prepared with whey solids added after pasteurization were smoother than sherbets made with whey solids added prior to pasteurization.

Average reductions of 32, 50 and 26 per cent of the normal citric acid usage can be accomplished in orange, lemon and raspberry sherbets respectively when 94.5 per cent of their serum solids have been replaced with plain cottage cheese whey solids. The amount of reduction is a function of the acidity and amount of whey used, the type of fruit used for flavoring and the final pH desired.

Foam spray-dried cottage cheese whey with low bacterial populations were produced. Bacterial estimates were less than 3,000 per gram in plain whey powders and never exceeded 11,000 per gram in cultured whey powders.

Sherbets which had whey solids substituted for their serum solids before and after pasteurization exhibited low bacterial estimates.

APPENDIX

TABLE 1a. Some properties of plain cottage cheese whey no. 6.

Total Solids	
original whey	6.29%
concentrate	53.27%
pH	
original whey	4.90
concentrate	4.30
Titratable Acidity	
original whey	0.46%
concentrate	3.17%
powder	0.61%
Moisture, Powder	2.40%
Bulk Density, Powder	0.35g/ml

TABLE 2a. Some properties of cottage cheese whey no. 2 cultured with *L. bulgaricus*.

Total Solids	
original whey	6.46%
concentrate	22.24%
pH	
original whey	4.80
cultured whey	4.40
concentrate	3.70
Titratable Acidity	
original whey	0.42%
cultured whey	0.69%
concentrate	3.35%
powder	1.15%
Moisture, Powder	1.50%
Bulk Density, Powder	0.20g/ml

TABLE 3a. Some properties of cottage cheese whey no. 8 cultured with *L. bulgaricus*.

Total Solids	
original whey	6.64%
concentrate	40.13%
pH	
original whey	4.70
cultured whey	3.90
concentrate	3.70
Titratable Acidity	
original whey	0.53%
cultured whey	0.96%
concentrate	5.12%
powder	1.16%
Moisture, Powder	1.00%
Bulk Density, Powder	0.28g/ml

TABLE 4a. Some properties of cottage cheese whey no. 4 cultured with *S. thermophilis*.

Total Solids	
original whey	7.26%
concentrate	40.37%
pH	
original whey	4.75
concentrate	4.55
Titratable Acidity	
original whey	0.53%
cultured whey	0.58%
concentrate	2.98%
powder	0.65%
Moisture, Powder	1.30%
Bulk Density, Powder	0.18g/ml

TABLE 5a. Some properties of plain cottage cheese whey no. 5.

pH	
reconstituted powder	4.73
Titratable Acidity	
powder	0.61%
Moisture, Powder	3.00%
Bulk Density, Powder	0.36g/ml

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