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Agriculture Development and Diversity Project

Market Potential for Food Grade Goat Whey

(Final Report)

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Introduction

Six or seven Wisconsin cheese plants currently process over 12 million pounds of goat milk into specialty cheeses and sales are increasing significantly each year. However, cheese plants processing goat milk are currently facing problems with whey disposal. Whey processors that routinely take whey from plants processing cow's milk will not accept goat whey. Goat whey can not be commingled with cow's whey for recovery of whey components for food use. Presently, those plants processing goat milk are landspreading whey to dispose of it. This limits the return per cwt. of milk for those plants and also contributes to potential environmental problems that they must deal with.

Thus, there is a critical need to develop process technology for recovery of food grade components from goat whey. The past three years, we have been developing process technology to recover food grade products from goat and sheep whey. We have determined whey composition from the manufacture of several specialty goat cheeses throughout the production season (1). We have also evaluated the functionality of goat whey proteins in relation to cow whey proteins (2). We have developed prototypes of food grade whey products from goat whey on a laboratory scale (1,2). However, to get the market started for goat whey products, we must start with the greatest commodity that we currently have available, that being the whole whey itself.

The objectives of this study were: 1) to scale-up the laboratory process to produce a significant quantity of dried goat whey on a commercial basis, 2) to evaluate the market potential for a food grade dried goat whey product, and 3) to share the results of this study with cheesemakers, producer cooperatives, and food technologists so as to encourage the use of goat whey from specialty cheese production.

Production of Goat Dry Sweet Whey

By the time the project was approved in 1998, we were getting toward the end of lactation for many of the producers. Therefore, we decided to wait until the beginning of the 1999 milking season to ensure that we had good quality whey with good flavor qualities for our trial. Initially we were planning to make a drying run of 10,000 lb. of whey, which would have given us about 300-400 lb. of dry goat whey for evaluation. Unfortunately, in the fall of 1998, the custom processor that was to conduct the drying run for us decided that they no longer were interested in making a small drying run of 10,000 lb. of whey and they would require 5000 gallons of whey at the minimum. Since this volume of whey would require 2-3 days of production for the cheese plant, we decided to down-size our drying run in order to produce a quality dry goat whey product for assessment.

On June 7, 1999, we obtained approximately 120 gallons of separated goat Cheddar whey from Mt. Sterling Cheese plant. The whey was trucked to Babcock Hall on the University of Wisconsin campus and stored at 40°F until concentration. Since we could not find a small scale evaporator in southern Wisconsin, we decided to concentrate the whey using reverse osmosis. Within 24 hours after whey drain, we vat-pasteurized the whey at 145°F for 30 minutes and then cooled the whey to 120°F. The whey was then concentrated with a single element reverse osmosis system using an Osmonics Desal AF3838C1766 reverse osmosis membrane. The whey feed temperature was maintained at 120°F and pressure was set at 300 psi. The initial flux rate was 1.8 liters/min. The initial solids concentration of the whey was 5.9%. The retentate was continuously recycled to the feed tank. The whey permeate being discharged contained 1.1-1.5 % solids throughout the process. When the pressure on the membrane reached 350 psi and the flux rate had dropped to 200 ml/min, the concentration process was discontinued. We obtained approximately 20 gallons of retentate containing 16.8% solids. The retentate was cooled to 40°F and stored at that temperature until the drying run was conducted one day later.

The goat whey permeate was transported to Lomira, WI and dried on the pilot tower spray dryer at Grande Cheese Co. Technology Center. The spray dryer was set up with a single atomization nozzle and atomization pressure of 2000 psi. The inlet temperature on the dryer was 353-360°F and the outlet temperature was 190-199°F. The product temperature coming off the process was 100°F. There was a small amount of buildup on the dryer wall due to the hygroscopic nature of the whey. We obtained approximately 20 lb. of dry sweet whey from the trial. The dry whey was double-bagged in polyethylene to ensure a moisture-tight package.

Composition of Goat Dry Sweet Whey

Composition of the dry sweet whey was determined using the analytical procedures outlined in the Standard Methods of Analysis for whey and whey products (3). The composition of the dry sweet goat whey is outlined in Table 1 along with typical analyses of dry sweet cow whey.

Table 1

Composition of Dry Sweet Whey

Constituent	Goat	Cow[a]
Protein, N X 6.38 (%)	17.5	13.1
Milkfat (%)	1.0	1.0
Moisture (%)	3.4	5.0
Total ash (%)	8.8	8.3
Lactose (%, by difference)	69.3	72.6
Titratable acidity (%)	.27	.12

[a] Values are from Ref. (3).

Composition of the goat dry sweet whey is fairly similar to cow dry sweet in fat, moisture, ash and lactose. The protein content may be slightly increased in the goat whey because of the use of the reverse osmosis concentration process. Since we were losing some solids in the permeate, we may have shifted the composition slightly in favor of the larger sized components, e.g., proteins and fats. The higher titratable acidity is most likely due to the 24 hour delay in pasteurizing the whey. Since the whey was not concentrated, by evaporation, up to 60% solids and lactose allowed to crystallize, the dry whey produced was very hygroscopic. In future runs, the whey should be concentrated to 50-60% solids and the lactose in the concentrate allowed to crystallize for 16-20 hours before spray drying. With the lactose crystallized, a non-hygroscopic whey can be produced that is not as subject to caking.

Applications for Goat Dry Sweet Whey

We evaluated the dry sweet whey in several types of applications to try to determine potential markets for the goat whey product. We first determined the flavor and odor of the dry whey product, as outlined in the Standard Methods procedure (3), to assess the potential for use as added solids in blended milk or whey-based drinks. The dry whey was reconstituted to a 6.5% solids solution with distilled water. The odor of both reconstituted goat whey and cow whey was fresh and dairy-like in character. The flavor of the goat whey was slightly salty and had a very slight goaty note while the flavor of the cow whey was slightly scorched. The dry whey would be a good source of additional solids to be used in flavored dairy drinks and other goat dairy products, e.g., yogurt and ice cream.

In the second trial, the dry goat whey was compared with dry cow whey in biscuits as outlined in the procedure of Potter and Zaehringer (4). The recipe used was as follows:

Flour	220 grams
Baking powder	10
Sugar	8.4
Salt	6
Dry whey	33
Hydrog. veg. fat	47
Skimmilk	200 ml.

The fat and sifted dry ingredients were blended with 150 quick strokes to the consistency of corn meal. The skimmilk was added all at once and incorporated with 30 quick strokes. The dough was then rolled out to a thickness of ½ inch on a lightly floured board and 2½ in. diameter biscuits were cut with a floured cutter. Biscuits were placed on a heavy aluminum baking sheet and baked for 11 minutes in a 450°F oven. Goat whey and cow whey biscuits were placed on the same baking sheet to ensure equivalent heat treatments during the baking process. For sensory evaluation, the biscuits were judged at room temperature by a four-member trained taste panel. Panelists used a linear semistructured quantitative descriptive analysis scale (five-point) to evaluate crumb color, crumb texture, crust texture, odor, and flavor. Results are shown in Table 2.

Table 2

Mean Scores for Quality Characteristics of Biscuits
Containing Dry Sweet Whey

Characteristic	Goat	Cow
Crumb color	2.67^{b}	3.78^{a}
Crumb texture	2.92	3.17
Crust texture	2.98	3.30
Odor	3.55	3.55
Flavor	3.00	3.38

^{a,b} Values for characteristics with different superscripts are different ($P<0.05$). Characteristics without superscripts were not significantly different.

Biscuit dough with the added goat whey was softer and stickier than the cow whey biscuits. This required a slight increase in the amount of flour needed to roll out the dough and handle the biscuits. This may have caused the observed decrease in baked volume for the goat whey biscuits. The crust and crumb color on the biscuits was the only characteristic that was significantly different between the cow whey and goat whey in this application. The odor and flavor of the goat whey biscuit was equivalent to that with cow whey. The increased protein in the goat whey may have retained more moisture in the biscuit dough. This may have contributed to the softness of the dough and possibly retarded the browning of the crust.

In the third trial, dry goat whey was compared with dry cow whey in yellow cake mixes as outlined by Best (5). The recipe used was as follows:

Cake flour	113.5 grams
Salt	3.5
Baking powder	7.0
Sugar	136.0
Dry sweet whey	11.3
Nonfat dry milk	2.5
Shortening	17.0
Margarine	17.0
First water	57.0
Vanilla	2.0
Egg	57.0
Second water	62.2

All cakes were made by the one-bowl method. First, the dry ingredients were weighed and placed in the mixing bowl. Second, the shortening and sugar were added. After the first amount of water and vanilla were added, the ingredients were mixed with a Hobart mixer on number 2 speed for 3 minutes. After this, the egg and second amount of water were added in three portions during an initial minute of mixing on number 2 speed. The bowl was scraped and the batter was mixed for 3 minutes. The batter was then poured into 8-inch aluminum cake pans and baked in a 350°F oven until the cake sprang back to the pressure of a finger (25-30 min.). The cakes were allowed to remain in the pans for 15 minutes before removing to cooling racks. Once cooled, the cakes were placed on paper plates and covered with aluminum foil and held for tasting the next day. The cakes were cut into 8 serving pieces and presented to a four-member trained taste panel. Panelists used a linear semistructured quantitative descriptive analysis scale (five-point) to evaluate crust color, moistness, texture, crumb structure, flavor and overall preference. Results are shown in Table 3.

Table 3

Mean Scores[a] for Quality Characteristics of Yellow Cakes
Containing Dry Sweet Whey

Characteristic	Goat	Cow
Crust color	2.8	3.5
Moistness	3.0	3.2
Texture	3.4	3.3
Crumb structure	2.7	2.8
Flavor	3.3	3.6
Overall preference	3.5	3.9

[a] Means for each characteristic were not significantly different between goat and cow whey ($P<0.05$).

Both cakes were very acceptable and there were no noted differences in batters during mixing or off-odors during the baking process. The crust of the goat whey cake seemed slightly sticky immediately after cooling but was not significantly different at the time of evaluation the next day.

In the fourth trial, dry goat whey was compared with dry cow whey in the production of caramel. The formulation used was a modification of the recipe as outlined in the DMI Dairy Ingredient Manual for Whey Ingredients (6). Our formulation used butter in place of partially hydrogenated coconut oil and was as follows:

Sugar	106.2 grams
Corn syrup (42 DE)	102.0
Butter	45.0
Water	21.0
Nonfat dry milk	12.6
Dry sweet whey	12.6

Ingredients were combined and cooked to the soft ball stage (245°F). The candy was then poured into aluminum foil pans and allowed to cool. The dry cow whey produced a typical caramel color and flavor while the dry goat whey produced a caramel with very light color and lacked the typical caramel flavor. The body and consistency of the two caramels were equivalent.

Based on the results of these trials, we found that the dry goat whey was comparable to dry cow whey in functionality in bakery applications. The flavor of the dry goat whey was very pleasing and there were no off-flavors or odors in any of the applications studied. In most of the trials, the dry goat whey did not seem to brown or color as well as cow whey. There was a slight difference in the lactose content of the goat whey, as versus cow whey, but not as great as the color differences observed. The goat whey did contain more protein which may have held more moisture in the system during baking and thus retarded browning. Goat whey also contains much higher levels of α-lactalbumin (1) that aids in forming better emulsions. We did not observe and significant differences in the air cells in the cakes but there may have been better retention of moisture in the dough and batters due to the higher levels of α-lactalbumin. In future applications, the usage level of the dry goat whey may be reduced slightly to match the performance of dry cow whey. In conclusion, dry goat whey could be used in most applications that currently use dry cow whey with no significant difference in functional properties. Further work needs to be conducted to determine the reason that goat whey does not brown as well as cow whey. In some applications in which browning is a concern, goat whey could be substituted for cow whey to provide lighter colored products.

Market Potential for Goat Dry Sweet Whey

With the production of this dry goat whey and trials in various food applications, we have shown that goat dry sweet whey is certainly a viable product. During our trials, we did have contact with several interested food companies looking for supplies of dry goat whey. Current markets exist for goat whey products and it's a question as to whether goat dry sweet whey fulfills the compositional and nutritional requirements. Some markets may demand a demineralized product and others may require a higher protein product. However, markets do currently exist for goat dry sweet whey if it could be produced at a reasonable cost.

Part of the current problem in developing a market for dry goat whey is the supply of goat sweet whey. Custom spray drying plants in the upper Midwest require minimum drying runs of 6000-10,000 lb. of powder. This represents 10,000-15,000 gallons of goat sweet whey for a minimum-sized run. At the current time, the one cheese plant that is producing sweet whey from Cheddar and Jack cheese is producing about 5000 gallons of whey every 2 days during the flush season. The other goat cheese plants in Wisconsin are producing acid whey which is more difficult to process as a dry whey. Once 10,000 gallons of sweet whey could be accumulated over a 2-3 day period, the production of goat dry sweet whey would be feasible. Current drying costs at custom processors runs between $0.45-0.60 per lb. of powder. To produce a quality whey product, the separated whey would need to be pasteurized after separation and pasteurized whey could be stored for no more than 2-3 days at temperatures below 40°F before concentrating and drying. To produce a stable non-hygroscopic whey, the whey would need to be concentrated to 50-60% solids, with vacuum evaporation, and the concentrate held for 16 hours to allow for the crystallization of lactose before drying. Minimum capital expenditures required to produce dry sweet whey on a custom basis, at this time, would be a separator, whey pasteurizing unit and refrigerated tank to hold up to 10,000 gallons of pasteurized separated whey. Some savings in storage tanks and shipping costs might be experienced with preconcentration with an RO membrane unit.

Production of Goat Dry Acid Whey Protein Concentrate (WPC)

Since 60-65 % of the goat whey produced in Wisconsin plants is acid whey, the question remained as to what the potential market would be for acid whey. The project was extended for another year to allow the evaluation of the potential for goat acid whey. In our discussion with whey processors, there was general agreement that acid whey by itself is difficult to dry and is very hygroscopic. Acid whey from cow milk cheese plants generally have restricted markets and most goes toward animal feeds. The unique composition of goat whey proteins, however, could provide some opportunities for food and nutraceutical uses of goat WPC (2).

Since the Center for Dairy Research was planning to put a pilot plant in place to produce whey product prototypes, we were planning to wait until the equipment was available in June 2000. Unfortunately, problems developed in getting equipment in from Europe and the project was delayed. So we went ahead with existing equipment that was available in Madison.

On August 22, 2000, we obtained approximately 80 gallons of filtered goat acid whey from Bresse Bleu cheese plant in Watertown. The whey was trucked to Babcock Hall on the University of Wisconsin campus and stored at 40°F until concentration. We concentrated the whey using the Center for Dairy Research pilot ultrafiltration system. Within 24 hours after whey drain, we vat-pasteurized the whey at 145°F for 30 minutes and then cooled the whey to 120°F. The whey was then concentrated with a double element ultrafiltration system using an membrane with a cutoff of 12,000-14,000 molecular weight. The whey feed temperature was maintained below 120°F and pressure was set at 35-50 psi. The initial solids concentration of the whey was 5.9%. The retentate was continuously recycled to the feed tank. When the flux rate had dropped to 200 ml/min, the concentration process was discontinued. We obtained approximately 16 gallons of retentate containing about 12% solids. The retentate was cooled to 40°F and stored at that temperature until the drying run was conducted one day later.

The goat whey retentate was dried on the UW Food Science Department's large tower spray dryer in Babcock Hall. The spray dryer was set up with a single atomization nozzle and atomization pressure of 1500 psi. The inlet temperature on the dryer was 375°F and the outlet temperature was 190°F. The product temperature coming off the process was 100°F. There was a small amount of buildup on the dryer wall due to the hygroscopic nature of the WPC. We obtained approximately 14 lb. of dry sweet whey from the trial. The dry whey was double-bagged in polyethylene to ensure a moisture-tight package.

Composition of Goat Dry Acid WPC

Composition of the dry acid WPC was determined using the analytical procedures outlined in the Standard Methods of Analysis for whey and whey products (3). The composition of the dry sweet goat whey is outlined in Table 4.

Table 4

Composition of Goat Acid WPC

Constituent	Goat
Protein, N X 6.38 (%)	33.5
Milkfat (%)	2.5
Moisture (%)	4.8
Total ash (%)	9.3
Lactose (%, by difference)	49.9

Applications for Goat Acid WPC

We evaluated the dry acid WPC in several types of applications to try to determine potential markets for the goat whey product. We first determined the flavor and odor of the dry acid WPC, as outlined in the Standard Methods procedure (3), to assess the potential for use as added solids in blended milk or whey-based drinks. The dry whey was reconstituted to a 6.5% solids solution with distilled water. The odor of the reconstituted goat WPC was fresh and dairy-like in character, with a slight fermented note. The flavor of the goat WPC yielded a dairy protein slavor with a slight tang to it. The flavor of commercial cow WPC used for comparisons was slightly gluey or casein-like. The dry acid WPC would be a good source of additional solids to be used in flavored dairy drinks and other goat dairy products, e.g., yogurt and sherbet.

In the second trial, the dry acid whey was compared with cow WPC in biscuits as outlined in the procedure of Potter and Zaehringer listed above (4). The recipe used 16.5 g of WPC and 16.5 g of lactose instead of the dry whey above. Mixing, baking and storage were similar to the sweet whey trial. For sensory evaluation, the biscuits were judged at room temperature by a four-member trained taste panel. Panelists used a linear semistructured quantitative descriptive analysis scale (five-point) to evaluate crumb color, crumb texture, crust texture, odor, and flavor. Results are shown in Table 5.

Table 5

Mean Scores for Quality Characteristics of Biscuits
Containing Dry Acid WPC

Characteristic	Goat	Cow
Crumb color	3.2[b]	3.9[a]
Crumb texture	3.1[a]	2.2[b]
Crust texture	3.2	2.8
Odor	3.5	3.5
Flavor	3.2	3.2

[a,b] Values for characteristics with different superscripts are different ($P<0.05$). Characteristics without superscripts were not significantly different.

Biscuit dough with the added goat WPC was softer and stickier than the cow WPC biscuits. This required a slight increase in the amount of flour needed to roll out the dough and handle the biscuits. The crust and crumb color on the biscuits and the crumb texture were the only characteristics that were significantly different between the cow WPC and goat WPC in this application. The goat WPC biscuit had a lighter and fluffier texture than the cow WPC biscuits. The odor and flavor of the goat WPC biscuit was equivalent to that with cow WPC.

In the third trial, dry goat WPC was compared with dry cow WPC in yellow cake mixes as outlined by Best (5). The recipe used was as outlined above with 5.7 g of WPC and 5.6 g of lactose used instead of 11.3 g of dry whey. All cakes were made by the one-bowl method as outlined above. Once cooled, the cakes were placed on paper plates and covered with aluminum foil and held for tasting the next day. The cakes were cut into 8 serving pieces and presented to a four-member trained taste panel. Panelists used a linear semistructured quantitative descriptive analysis scale (five-point) to evaluate crust color, moistness, texture, crumb structure, flavor and overall preference. Results are shown in Table 6.

Table 6

Mean Scores[a] for Quality Characteristics of Yellow Cakes Containing Dry Sweet Whey

Characteristic	Goat WPC	Cow WPC
Crust color	2.1^b	3.5^a
Moistness	2.6	2.9
Texture	2.6	2.6
Crumb structure	2.6	3.1
Flavor	3.0	2.4
Overall preference	2.5^b	3.2^a

[a,b] Values for characteristics with different superscripts are different ($P<0.05$). Characteristics without superscripts were not significantly different.

The goat WPC cake was significantly lighter in crust color and had a slight tartness to the flavor that impacted the overall preference scores. There were no noted differences in batters during mixing or off-odors during the baking process. The crust of the goat whey cake seemed slightly sticky immediately after cooling but was not significantly different at the time of evaluation the next day.

Based on the results of these trials, we found that the dry goat acid WPC was comparable to dry cow sweet WPC in functionality in bakery applications. The flavor of the dry goat WPC was very pleasing but had a slight tartness that showed up in bland products such as biscuits. In most of the trials, the dry goat WPC did not seem to brown or color as well as cow WPC. This was also observed in the goat dry sweet whey above. Goat whey contains much higher levels of α-lactalbumin than cow whey (1) that aids in forming better emulsions. We did observe a lighter and softer crumb structure in the cakes with goat WPC. In conclusion, dry goat WPC could be used in most applications that currently use dry cow whey with no significant difference in functional properties. Further work needs to be conducted to determine the reason that goat whey and goat WPC does not brown as well as cow whey. In some applications in which browning is a concern, goat WPC could be substituted for cow WPC to provide lighter colored products.

Market Potential for Goat Acid Whey

A company in Canada already is producing a freeze-dried goat's whey protein concentrate from acid whey as a food supplement. This product, CALCIMIL, is advertised as being an outstanding source of proteins and calcium. However, there have been no trials to determine functionality of that product in baking or food processing applications. We have produced small quantities of both sweet and acid WPC from goat whey in the laboratory (2). Generally, the functional properties of sweet goat WPC is significantly better than acid WPC. However, acid goat WPC was equivalent in foaming and emulsifying properties to that of cow WPC. Acid WPC contained less α-lactalbumin and more serum albumin than the sweet goat WPC. The results of this current study show that whey protein products recovered from goat acid whey are comparable to current commercial WPCs in functional properties. Both dry sweet goat whey and acid WPC are viable whey products for potential commercial usage in both the dairy and bakery industry.

Current processing costs for producing 34% WPC in small plants ranges from $.60 to $.90 per lb of powder. Current volumes of acid goat whey being produced may not warrant the custom production of acid WPC. However, the UF concentrate from acid whey could be blended with sweet goat whey to supply enough goat whey solids to produce a high protein dry goat whey product at custom spray dryers requiring minimum runs of 6,000-10,000 lb. drying runs. After the pilot drying equipment is in place at the Center for Dairy Research, we will evaluate the potential for combining various ratios of sweet and acid whey to determine whether portions of acid whey could be used in a dry whey product without the use of ultrafiltration or diafiltration to reduce the amount of acid and ash in the finished dry goat whey product.

Outreach Efforts with this Project

Results of this project have shown that goat whey products have equivalent functional properties when compared to cow whey products. The initial markets for dry goat whey products would be goat milk products, e.g., ice cream and yogurt, that would require addition goat milk solids for quality products. As markets are developed and processing equipment is put in place, additional markets taking advantage of the functional qualities and nutraceutical properties of sweet goat WPC (2) could be developed to take advantage of the added value. Results of this project will be shared with each of the Wisconsin cheese plants processing goat milk. We will continue to work with those plants to facilitate development of any potential markets for goat whey products. Once the CDR pilot whey processing equipment is in place, we will be able to run developmental trials for the plants to help establish their potential products for marketing.

Results of this study will also be reported in trade publications to encourage evaluation of the potential use of goat whey in specialty products. Research efforts will be directed toward the cheese plants in Wisconsin to help initiate the production of a dry whey product as soon as possible. Potential markets do exist for dry goat whey products. We just need to get the volumes of whey increased to the point that the custom processing of goat whey is economically feasible or it is economically feasible for the goat cheese plants to put in whey processing equipment.

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