Acid Whey as a Replacement for Sodium Caseinate in Spray-Dried Coffee Whiteners

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ABSTRACT

Acid whey from cottage cheese is a by-product that is underutilized. A new use as a replacement for sodium caseinate in spray-dried coffee whiteners was examined. Acid whey was ion-exchanged to a 90% reduction in minerals and ultrafiltered to concentrate protein to 50% of solids in retentate containing 16.6% to 22.6% total solids and used as a total replacement for sodium caseinate. Fifty-two spray-dried coffee whitener formulations were prepared using demineralized acid whey protein concentrate and compared with standard commercial whitener formulations. Optimal stability and functionality were obtained at 1.5% acid whey protein. Dipotassium phosphate was necessary to prevent precipitation of protein exposed to hot acidic conditions of instant coffee. A dipotassium phosphate to protein ratio of 1.0 yielded good stability. The combination of polyoxyethylene sorbitan monostearate and sodium stearoyl lactylate was the only emulsifier system that produced an acceptable coffee whitener. Addition of .5% titanium dioxide was necessary to match desired whitening in coffee as measured with a spectrophotometer. Demineralized acid whey protein was an acceptable replacement for sodium caseinate in spray-dried coffee whiteners and can replace sodium caseinate at a 1:2 ratio. Seven replicates of final formulation produced a functional coffee whitener.

(Key words: acid whey, caseinate, coffee whiteners)

INTRODUCTION

Acid whey from cottage cheese is a by-product that is substantially underutilized. Only a small percentage of the amount available is currently used in human foods. The remainder is used in animal feeds, dumped into municipal sewage treatment systems, or spread on land as fertilizer. As environmental concerns and regulations increase, problems in disposal of acid whey will result in increased disposal costs.

Major factors limiting the use of acid whey are its high ash and acid contents, which produce functional and flavor problems. However, the most acid-stable proteins in milk are in acid whey. Functionality of these proteins as a food ingredient is increased by demineralization and concentration.

Several methods of demineralizing whey are used in commercial production; the most economical for high levels of removal is ion exchange. Therefore, it was used in this study to replace such ions as calcium, magnesium, sodium, and lactate with hydrogen and hydroxyl ions. The added cost of demineralizing means that acid whey protein might only be used to replace a more expensive ingredient or in formulations in which it exhibits unique functional properties. There are many methods that can be used to concentrate whey proteins. However, the most widely used is UF. It was used in this study so that results could be directly applied to existing commercial equipment.

Sodium caseinate in spray-dried coffee whitener is currently an expensive ingredient. Moreover, it has unique functional properties that make manufacture of spray-dried coffee whiteners possible (14). Recent worldwide re-
duction in milk production and in the production of more profitable products has resulted in price increases for sodium caseinate. This makes processed acid whey protein an economical alternative.

Spray-dried coffee whiteners have been readily accepted by consumers due to lower cost, convenience, ease of handling, improved shelf-life without refrigeration, and preference of some consumers for vegetable fat products (14). Coffee whiteners are a substitute for cream, evaporated milk, or fresh milk in coffee, tea, and cocoa products. Also, they are used as bodying agents and flavor enhancers in soups, sauces, and puddings.

Requirements of a dried coffee whitener when used in coffee are rigorous. Coffee has a high acidity, ranging from pH 4.8 to 6.3, in combination with temperatures of 50 to 90°C (9, 19). Coffee whitener must dissolve rapidly with no insoluble particles after brief stirring. There should be no coagulation of the whitener or separation from solution (19). In addition, coffee whiteners must maintain emulsion stability when liquid, as a spray-dried powder, and when reconstituted in hot coffee. Spray-dried coffee whitener was selected for this study due to these additional requirements.

This study was designed to examine the feasibility of totally replacing sodium caseinate in spray-dried coffee whiteners with acid whey protein. Each ingredient in coffee whiteners currently sold on the retail market was evaluated for its effect on the functionality of whey proteins. Using this information, an optimal formula was developed to produce a fully functional coffee whitener using modified acid whey.

**MATERIALS AND METHODS**

**Processing and Formulation**

Commercially prepared, concentrated demineralized whey from cottage cheese was obtained from a local dairy. Acid whey was taken directly from cottage cheese vats, cooled, clarified to remove cheese fines, and commercially demineralized by ion exchange (Techni-Chem, Cherry Valley, IL). To reduce the amount of water transported, the demineralized whey was concentrated by reverse osmosis (Thomas Technical Services, Neillsville, WI) to approximately 14% total solids.

About 1500 L of concentrated, demineralized whey were used for each of four UF trials. A pilot plant DDS model 36 plate and frame UF unit (DDS Filtration, Hudson, WI) equipped with polysulphone membranes was used to concentrate the protein to a target of 50% of the whey solids. Solids were monitored by a hand refractometer. Whey temperature was maintained at 50°C during each trial. In order to achieve a concentration of 50% protein, a diafiltration step was added. When acid whey was concentrated to approximately 22% total solids, 150 L of water at 50°C were added to the system. Retentate was collected in stainless steel containers, cooled to 2°C, and stored at 5°C.

A flow diagram of the processing used to prepare acid whey for formulating spray-dried coffee whiteners is shown in Figure 1. The portion above the dotted line is commercial processing in the cottage cheese plant. Below the line is pilot plant processing used to concentrate the protein and prepare the finished coffee whitener.

The retentate was mixed directly with other ingredients in a 75-L jacketed vessel (Groen Mfg., Elk Grove Village, IL) equipped with direct steam injection and rapid agitation. The procedure used to formulate all coffee whiteners is shown in Figure 2. Steam injection was used to maintain mix temperature at 65°C.

A Gaulin 120 homogenizer (APV Gaulin, Everett, MA) was used to homogenize the mix and as a high pressure pump to supply liquid mix to the spray-dryer at a pressure of 150 kg/cm². Homogenization pressure was a variable in this study. Samples were prepared using liquid product, which had received multiple passes through two-stage homogenization before single-stage homogenization in-line to the dryer. Liquid product at 65°C was supplied to the vertical downdraft dryer and atomized through a Spraying Systems SX 54-17 (Spraying Systems, Wheaton, IL) high pressure spray nozzle. Inlet air temperature was 170°C, and outlet air temperature was 110°C.

Typical composition of spray-dried coffee whitener similar to retail national brands is shown in Table 1. This formulation was used as a starting point for this study and was prepared and processed similar to experimental lots to eliminate differences due to drying ef-
Figure 1. Flow diagram of process used to make a spray-dried coffee whitener using acid whey. Portion above the dotted line is commercial processing. Below the line is the experimental process used in manufacture.
ACID WHEY IN COFFEE WHITENERS

Add water to the UF whey retentate and heat to 65°C using direct steam injection.

Add sodium stearoyl lactylate and titanium dioxide; mix 2 min.

Add corn syrup solids, polysorbate 60, and dipotassium phosphate. Maintain 65°C with steam injection.

Mix lecithin, colors, and flavors with the oil at 55°C. Disperse fat phase into water phase. Maintain 65°C.

Hold 30 min at 65°C.

Homogenization at 70 kg/cm² in-line to spray dryer. Total solids 65%.

Spray-dry to 3.0% moisture.

Figure 2. Flow diagram of process used to formulate liquid mix of coffee whitener ingredients to be spray-dried.

Effects when comparing with whey-based coffee whiteners. However, sodium caseinate was a dry product and was rehydrated with hot water and rapid agitation to disperse and solubilize it properly.

Variables in this study were evaluated for their effect on producing a satisfactory spray-dried coffee whitener. All unsatisfactory coffee whitener was evaluated twice before being eliminated. Ingredients were used at levels recommended by the manufacturer or within legal maxima established by the FDA. A total of 52 coffee whitener formulations were spray-dried with the optimal formulation replicated seven times using acid whey produced on different days.

Partially hydrogenated coconut oil (UNEDO 98; Universal Edible Oils, Chicago, IL) was a constant at 34.0%. Corn syrup solids (Frodex 24; American Maize-Products, Hammond, IN) were varied only to maintain 100% when other ingredients were varied.

The use level of demineralized acid whey protein concentrate was determined on a protein basis and was varied from 1.0 to 13.5%. The other solids in whey, mainly lactose, were used to reduce corn syrup solids. Dipotassium phosphate (FBC Industries, Rolling Meadows, IL) was varied from 0 to 6.7%. The remaining ingredients were varied within small ranges to optimize their effect.

Feathering Resistance

Feathering resistance is the ability of a coffee whitener to resist coagulation of protein in the emulsion and subsequent formation of visible particles that separate from the hot coffee solution. This phenomenon is mediated by calcium ions (6, 22). For the present study, maximum water hardness of 500 ppm was selected based on a water survey conducted by Durfor and Becker (7) and evidence in previous studies (8). Although there are areas of the US with harder water, it is usually treated before use. This level of hardness also appears to be near the maximum that commercial retail coffee whiteners can withstand. Some national

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Acid whey</th>
<th>Sodium caseinate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn syrup solids</td>
<td>56.6</td>
<td>55.4</td>
</tr>
<tr>
<td>Partially hydrogenated vegetable oil</td>
<td>34.0</td>
<td>34.0</td>
</tr>
<tr>
<td>Sodium caseinate</td>
<td>. . .</td>
<td>3.5</td>
</tr>
<tr>
<td>Demineralized acid whey concentrate, 50% protein</td>
<td>3.0</td>
<td>. . .</td>
</tr>
<tr>
<td>Dipotassium phosphate</td>
<td>1.5</td>
<td>2.1</td>
</tr>
<tr>
<td>Sodium silicoaluminate</td>
<td>.5</td>
<td>.5</td>
</tr>
<tr>
<td>Titanium dioxide</td>
<td>.5</td>
<td>. . .</td>
</tr>
<tr>
<td>Mono- and diglycerides[^1]</td>
<td>. . .</td>
<td>1.3</td>
</tr>
<tr>
<td>Polysorbate 60</td>
<td>.4</td>
<td>. . .</td>
</tr>
<tr>
<td>Sodium stearoyl lactylate</td>
<td>.3</td>
<td>.1</td>
</tr>
<tr>
<td>Lecithin</td>
<td>.1</td>
<td>. . .</td>
</tr>
<tr>
<td>Flavors and colors</td>
<td>.1</td>
<td>.1</td>
</tr>
<tr>
<td>Moisture</td>
<td>3.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

[^1]: 52% α-monomiglyceride content (American Ingredients BFP 75 V, Kansas City, MO).
brands will feather at this level, but others will not.

Drinking water from the local municipal system contained approximately 300 ppm hardness expressed as calcium carbonate. To raise this level to 500 ppm, a standard hardness solution was prepared and added to the local water. To a 1-L volumetric flask were added 34.4 g of CaCl₂, 31.6 g of MgCl₂·6H₂O, and distilled water to volume. The flask was shaken until all solids dissolved. One milliliter added to 180 ml of distilled water yielded 230 ppm hardness. This was confirmed using a water hardness test kit (Hach Company, Loveland, CO).

Standard hardness solution was added to 180 ml of cold tap water to raise total hardness to 500 ppm. This required .87 ml of solution. The water solution was heated to 80°C in a 250-ml beaker, and 1.5 g of instant coffee (Maxwell House, Kraft General Foods, White Plains, NY) were added followed by 3 g of coffee whitener, which was quickly stirred into the solution.

The solution was observed immediately and after 5 min for coagulated protein or feathering on the surface and subsurface in the coffee. Appearance of visible feathering was considered unacceptable. All sample preparations were tested a minimum of three times. This was the screening test used for all whitener samples produced. Samples that met this test or had trace amounts of precipitated material were tested further for functional properties such as whitening and emulsion stability.

**Standard Coffee Solution Preparation**

Coffee varies greatly in acidity, concentration, and color. Causes are brand of coffee, age of beans, intensity of roasting, holding time of coffee, and amount of coffee used to prepare the beverage (15). To minimize variability, all analyses other than the feathering test were conducted in a standard coffee solution. Maximum amount of coffee prepared at one time was 1800 ml. Standard coffee solution was prepared by heating 1800 ml of cold tap water to 80°C and adding 15 g of Maxwell House instant coffee. Yield was 10 beakers containing 180 ml of coffee. Smaller amounts were prepared as needed. To avoid changes in pH and color of the coffee, it was used within 5 min after liquification.

**Whitening Index**

A Byk-Gardner color measuring spectrophotometer (The Color Machine, Byk-Gardner, Silver Spring, MD) was used to measure color directly using the Hunter L, a, b color measuring system. The L values have been reported as good indicators of the whitening power of coffee whiteners (3). The L value is the whiteness or lightness of the sample. An L value of 100 is pure white, and an L value of 0 is black.

L values were determined by adding 3 g of test coffee whitener to 180 ml of standard coffee solution at 80°C. The coffee and whitener solution was transferred to an optically pure, glass measuring container for testing. All samples were measured three times, and results were averaged. To verify results, a coffee whitener containing sodium caseinate with a known L value was measured with the samples. Generally, L values must differ by a value of 1 unit before a visual difference can be detected (3).

Whitening power of a coffee whitener was recorded as the difference between L values obtained with coffee alone and coffee with whitener added (ΔL). Color of coffee will change depending on strength, brand, and time of holding hot. Using ΔL reduced the influence of these fluctuations in coffee color.

**Analytical Tests**

Fat in spray-dried coffee whiteners was measured by the Roese-Gottlieb method as modified by Mojonnier (21). Total solids in liquid samples were measured using the Mojonnier method (21). A semi-micro-Kjeldahl method for total protein was used (Labconco Corp., Kansas City, MO) (21, 26). Calcium and magnesium were determined using an atomic absorption spectrophotometer (Varian SpectrAA-10, Springdale, Aust.) (26). Solution pH was determined using an Orion pH meter (Orion pH meter model 407A/F; Orion Research Inc., Cambridge, MA).

**RESULTS AND DISCUSSION**

Sodium caseinate is the most widely used protein in both liquid and powdered coffee whiteners (14). In liquid coffee whiteners, other protein sources, such as soybean protein,
Acid whey can be used at low levels with emulsifiers to produce a stable product (17). In powdered whiteners, the unique functional properties of sodium caseinate are essential to prepare stable dry emulsions (13).

As a part of preliminary investigations for the present study, several vegetable proteins were evaluated. These included soybean protein isolates, wheat protein isolates, and yellow pea protein. Each protein product had a strong, distinctive flavor that was not compatible with coffee. Some produced functional deficiencies such as feathering and poor emulsion stability.

Whey proteins represent a promising replacement for sodium caseinate in spray-dried coffee whiteners. They have a dairy-type flavor and exhibit some of the desired functional properties of coffee whiteners, but they must be modified to replace sodium caseinate. Morr (18) stated that functionality can be improved by increasing protein and decreasing lactose and mineral contents using methods that minimize protein denaturation and interaction. Acid whey was used because large quantities are available and because these proteins are acid stable. Ion exchange removed over 90% of the calcium, which increased heat stability and improved flavor by concomitant removal of sodium and lactate ions.

Coffee is a hot, acidic system that will destabilize many proteins. Coffee pH ranges from 4.8 to 6.3 at temperatures of 50 to 90°C (9, 19). The standard coffee solution used to evaluate whiteners in our study had a pH range of 5.6 to 5.9 and was evaluated at 80°C.

The initial objective of this study was to produce a highly functional protein concentrate with a minimum of denaturation. Harper et al. (11) reported that increased denaturation of whey proteins improved emulsion stability of a liquid whitener but increased feathering and reduced the whitening effect in coffee. All methods used in the present study were, therefore, selected to minimize denaturation. Membrane systems are the best methods to concentrate protein without the denaturing effects of heat. At the same time, solids are increased so that the liquid protein concentrate can be used in a liquid mix to be spray-dried without a further evaporation step.

During commercial demineralization by ion exchange, whey emerged from the cation side at an approximate pH of 2.5. Some protein was lost in this process by being deposited on the resin bed. Again, only the most acid-stable proteins were left in solution. This may be one advantage of ion exchange over electrodialysis for this application, although electrodialysis was not evaluated in this study. After anion demineralization, the whey had a pH of about 6.5 with a mild, fresh, clean dairy-type flavor.

Then, UF was conducted to concentrate protein to approximately 50% of the solids at 50°C to minimize protein denaturation (18). With many whey products, this can be accomplished normally without the addition of water. Because some water had been removed from this whey, it was necessary to add a small amount of water as a diafiltration step to remove additional lactose.

Solids in the UF retentate ranged from 16.63 to 22.64% (mean = 18.77%) in four trials. Protein content ranged from 47.92 to 65.00% (mean = 54.89%) of the whey solids, whereas pH was 6.3 to 6.5. The permeate was discarded.

Solids in the UF retentate were high enough to allow direct substitution as a partial and total replacement for sodium caseinate in a liquid coffee whitener mix to be spray-dried. The coffee whiteners feathered even in coffee made without added hardness. These formulations were totally unacceptable.

Subsequently, a wide range of variables was evaluated to find an optimal formula and use level for acid whey. Two reviews showed the effect of many ingredients on the properties of coffee whitener and its performance in coffee (14, 25). The two most important properties of coffee whiteners are resistance to feathering and whitening effect (4). The extent of feathering depends on calcium concentration, pH, and temperature (24), and feathering is a problem with both dairy creams and coffee whiteners (1, 6, 15, 19, 22). All coffee whiteners were initially screened for feathering resistance using instant coffee made with water containing 500 ppm hardness. Instant coffee is more acidic than fresh brewed coffee (8). If the product passed this test, it was subjected to further testing of functional properties. If it failed twice, the formula was modified. A whey-based coffee whitener that is stable in coffee containing 500 ppm hardness is shown in Figure 3. The whey-based sample on the right shows heavy feathering under the same conditions.
A number of methods have been published to monitor feathering (1, 11, 20, 23). However, most tests are too time-consuming or cumbersome to run on a large number of samples. Generally, any amount of feathering that is visible in coffee is objectionable. Previous studies have shown that the visual feathering test is not subjective (10). Tables herein indicate feathering as present or not present based on a visual inspection.

The most important feature in producing whey-based coffee whiteners with high feathering resistance is the emulsifier system. No stable whey-based whiteners were produced until sodium stearoyl lactylate (SSL) and polyoxyethylene sorbitan monostearate (polysorbate 60) were used. Sodium stearoyl lactylate will form complexes with sodium caseinate through hydrogen bonding (16), and it may be reasonable to expect that the same type of complexing is occurring with whey proteins. Polysorbate 60 functions as an emulsifier, keeping fat globules from coalescing and preventing feathering (6, 22). The effect of various emulsification systems is apparent in Table 2. Both polysorbate 60 and SSL have legal maximum use levels of .4 and .3% of the composition, respectively. Any reduction of polysorbate 60 resulted in feathering. Sodium stearoyl lactylate can be used at .2 to .3% with no adverse effect on feathering resistance. However, mono- and diglycerides had a complete, destabilizing effect. Modification of the emulsifier system from the optimal ratio of SSL and polysorbate 60 or addition of other emulsifiers had similar negative effect on protein stability. Only a combination of .4% polysorbate 60 and .2 to .3% SSL produced acceptable products.

A range of protein concentrations were evaluated, holding dipotassium phosphate and other ingredients constant (Table 3). Higher protein concentrations in whitener blends induced feathering using the hard water test. The L values listed are misleading, because a sample that feathers slightly will reflect more light and register a higher L value. The optimal protein concentration was 1.5% with 2.0% dipotassium phosphate.

Another important factor in protein stability is the protein to dipotassium phosphate ratio.
Higher protein concentrations require larger amounts of dipotassium phosphate to stabilize them against minerals in hard water. Ratios from .75 to 1.50 were evaluated. A concentration as high as 5% protein was stabilized at a protein to salt ratio of 1.25 (Table 4). Stable coffee whiteners containing 1.5% protein had ΔL similar to whiteners containing 4.5 and 5.0% protein. Some whiteners that feathered had higher ΔL. Concentrations of protein as high as 13.5% could not be stabilized and precipitated completely from solution. Moreover, high levels of dipotassium phosphate have been associated with flavor problems (8, 24). Levels of 4% dipotassium phosphate are twice the level typically found in coffee whiteners, and the flavor may be detected by some consumers. Because there was no advantage to higher protein concentrations, the minimum whey protein level, 1.5%, was used for economy. The optimal protein to salt ratio, 1.0, was near the center of the functional range.

A low level of lecithin was used to improve emulsion stability. Without lecithin, feathering occurred. Concentrations as low as .05% improved feathering resistance and emulsion stability; .1% lecithin maximized stability.

Coffee drinkers apparently associate neutralizing of coffee acids and moderation of the flavor of harsh coffee oils with the warm brown color of creamed coffee. Therefore, whitening effect is an important property, if only for psychological reasons (16). Acid whey proteins in coffee whiteners do not produce the same whitening effect in coffee as sodium caseinate in coffee whiteners. Generally, increasing the level of sodium caseinate will increase the whitening effect in coffee (Figure 4). A sodium caseinate control made with 4.2% caseinate whitened almost four L values more than the same formula with 3.5% caseinate.

Homogenization effects on whitening were studied using two stages at maximum pressures of 175 and 42 kg/cm² and two passes through the homogenizer using two stages at 140 and 35 kg/cm². There was no effect by either process measured with whiteners containing 1.5% whey protein. At 5% whey protein, there was a slight improvement in whitening with both homogenization procedures because the whey protein apparently aligned at the fat-water interface and reflected more light.
TABLE 3. Effect of whey protein concentration on coffee whitener performance.

<table>
<thead>
<tr>
<th>Percentage composition</th>
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<td>Trial no.</td>
<td>Whey protein</td>
<td>Nonprotein whey solids</td>
<td>Polysorbate 60</td>
<td>SSL phosphate</td>
<td>Feathering</td>
<td>Δ L Value</td>
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<td>.4</td>
<td>.2</td>
<td>Present</td>
<td>28.2</td>
</tr>
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</table>

1 Other ingredients held constant: moisture, 3.0%; vegetable oil, 34%; lecithin, .05%; and corn syrup solids adjusted to total, 100%. SSL = Sodium stearoyl lactylate.

2 Difference between Hunter L values of black coffee and same coffee with whitener added. Approximately 1 L value difference can be detected visually. Relative values for comparison under conditions of this test.

At the lower protein concentrations, there may be a shortage of protein to cover the fat globules totally but enough to properly emulsify the fat. Moreover, excessive homogenization can result in a serious loss in whitening power because the fat globules are too small to reflect light (16).

A microscopic examination of the liquid mix was not conducted because a lower protein concentration was acceptable in all tests except whitening. Using increased homogenization pressures with the higher protein products yielded only a slight increase in whitening and had the disadvantage of high phosphate levels for protein stabilization. In addition to initial homogenization, liquid mix was forced through an atomizing nozzle in the dryer at 150 kg/cm², which provided a second homogenization. In commercial production, these pressures are as high as 600 kg/cm². Therefore, fat droplet size in the liquid mix is not representative of fat droplets in dry whiteners.

All trial products were compared with sodium caseinate controls produced on the same equipment, which eliminated variation due to equipment or processing conditions.

Whitening effect of acid whey protein and sodium caseinate was studied. A sample of demineralized acid whey protein concentrate containing 5.30% whey protein was compared...

TABLE 4. Optimization of dipotassium phosphate concentration and ratio of whey protein to buffering salt in whey-based, spray-dried coffee whiteners.

<table>
<thead>
<tr>
<th>Percentage composition</th>
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<td>Trial no.</td>
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<td>Whey protein</td>
<td>Nonprotein whey solids</td>
<td>Protein: salt ratio</td>
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<td>1.5</td>
<td>1.6</td>
<td>.75</td>
<td>. . .</td>
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</table>

1 Other ingredients held constant: moisture, 3.0%; vegetable oil, 34%; lecithin, .05%; sodium stearoyl lactylate, .2%; polysorbate 60, .4%; and corn syrup solids adjusted to total, 100%.

2 Approximately 1 Hunter L value difference can be detected visually. Relative values for comparison under conditions of this test.

3 Contains .3% titanium dioxide.

with a 5.30% caseinate solution. Five grams of each solution were added to 180 ml of standard coffee solution, and whitening was measured. The standard coffee with no whitener had an L value of 3.3, the whey solution was 6.7, and sodium caseinate was 9.4 with the highest L value being the most white sample. A difference of 1 L value can be detected visually.

These results are probably due to conformational differences in the structure of these proteins. The increased whitening observed with higher levels of sodium caseinate is because excess caseinate forms a type of submicelle structure at the interface due to its hydrophobic nature. This submicelle reflects more light, giving a whiter appearance. van Eijk (25) observed that whitening power comes mainly from a well emulsified and finely dispersed fat and protein in the colloidal state. Studies by Aneja (2) showed that fat produced 2.2 times the whitening effect in coffee as that produced by solids-not-fat.

To achieve desired whitening effect with acid whey protein, titanium dioxide was necessary. The effect of different levels of added titanium dioxide is shown in Figure 4. As titanium dioxide was increased, corn syrup solids were adjusted to maintain 100%. All other ingredients and processing conditions were kept constant. Two national brands of retail coffee whiteners and half and half are shown for comparison. The retail coffee whiteners whiten substantially more than similar products from this research. Commercially, the liquid mix is subjected to more severe processing conditions during mixing and spray-drying at pressures as high as 600 kg/cm². These processing conditions produce smaller fat globules and produce more interactions between the fat, emulsifiers, and casein, which align at the fat-water interface. These interactions and small globules will reflect more light, producing more of the whitening effect in coffee.

The optimal level of each ingredient was combined to produce a successful spray-dried coffee whitener using acid whey. This formula was replicated seven times using four different lots of acid whey. This product (Table 1) was compared with a typical retail coffee whitener made with sodium caseinate. Major differences are protein, titanium dioxide, and emulsifier system. Flavor and colors are optional ingredients used in both products to increase consumer appeal.

After a successful formula was produced, it was stressed to estimate the effect of commercial processing. Samples of demineralized whey protein concentrate were rapidly heated by direct steam injection to 85°C and held for 20 to 45 min. No differences in functional properties of coffee whiteners made with these heat-treated protein concentrates were detected. The heat stability of whey is greater when calcium is removed (5, 12). After processing, this whey protein is very stable and should be able to withstand additional stresses in commercial production.

The pH shift that occurred in coffee when a coffee whitener was added was similar for experimental whey-based whiteners and caseinate controls. The standard coffee solution had a pH range of 5.6 to 5.9. A retail whitener or a control containing sodium caseinate increased pH to a range of 6.45 to 6.6. The range for acid whey protein-based whiteners in coffee was 6.4 to 6.65. This indicated that the
buffering effect of the acid whey-based coffee whiteners was similar to that of products currently being produced.

Commercial spray-dried coffee whiteners range from 15 to 35% fat. This study used whiteners with 35% fat as a control, which represents premium products. Information developed can be applied to other fat levels. In addition, coffee whiteners as high as 50% fat are used in food service for cooking and baking and are reliquified for use as a liquid creaming agent. Fully functional coffee whiteners were prepared with fat contents as low as 15%. In whey-based whiteners with fat contents of 47%, feathering resistance was reduced. These higher fat products are usually reconstituted and used as a liquid coffee whitener. However, titanium dioxide is insoluble and will settle out of a reconstituted product, rendering it unacceptable. Acid whey may have an application in higher fat products that are not used as a coffee whitener but as a fat source for cooking and baking. Acid whey also may be used as a carrier for some spray-dried shortening powders, which contain 75% vegetable oil.

CONCLUSIONS

Acid whey from cottage cheese manufacture can be used as a replacement for sodium caseinate in spray-dried coffee whiteners. The functionality and value of acid whey was increased by ion exchange and UF. These processes reduced the high mineral and acid content and increased the concentration of high quality protein, respectively. The result is an application for a current waste product to replace a more expensive ingredient.

The dairy industry has a major problem concerning the disposal of acid whey and its impact on the environment. Only a small portion of the acid whey produced in the US is used profitably in human foods. This new application could substantially increase this amount.

Demineralized acid whey protein concentrate has a fresh dairy-type flavor that is complementary to a coffee whitener. With addition of titanium dioxide, it replaced all desired attributes of sodium caseinate in spray-dried coffee whiteners. Seven replicates of the final coffee whitener formulation were prepared to confirm test results.

REFERENCES
