Formulation of Nondairy Coffee Whiteners with Cottonseed Protein Isolates

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ABSTRACT

Nondairy coffee whiteners were prepared on a pilot scale using four different glandless cottonseed protein isolates prepared by different processes. Bulk density, whitening capacity, cream separation and oil retention capacity of the whiteners were compared to those formulated with sodium caseinate and a commercial whitener. Glandless cottonseed protein isolates, prepared by conventional and aqueous extraction processes, are poor ingredients for coffee whitener production, showing poor whitening capacity, separation of proteins through sedimentation and separation of fat as a cream layer in a mixture with aqueous coffee. Succinylated cottonseed proteins showed many markedly improved characteristics as coffee whiteners. Ca. 50% replacement of sodium caseinate with succinylated cottonseed protein isolate did not affect the quality of whiteners compared to that of 100% sodium caseinate-based whitener.

INTRODUCTION

Coffee whiteners are one of the fastest growing food products on the market today. Nondairy powdered whiteners especially have been accepted by consumers for several reasons, such as economy, ease of handling, improved shelf life and the preference of consumers for vegetable products.

It is important that coffee whiteners have the development of a desirable color change through formation of a complex between their protein and the so-called "caffetannic acids", and have desirable cream-like flavor without "feathering" in the hot coffee (1). In addition, they need rapid dispersibility in hot coffee. The primary function of protein in these products is to provide emulsification and some whitening power, and to improve flavor by contributing a flavor of their own and by reducing the acridity of the tannic acids (2). Good quality whiteners are obtained by using sodium caseinate at 1.5-3.0% of total whitener ingredients. Some vegetable protein products yield less stable emulsions than caseinate, particularly with respect to syneresis. Emulsion stability of the protein can be affected by many factors (3) including processing methods.

In this study, powdered coffee whiteners were formulated with cottonseed protein isolates prepared by various processes. The feasibility of using the resulting protein isolates for ingredients of a coffee whitener was investigated by replacing sodium caseinate with cottonseed proteins.

EXPERIMENTAL PROCEDURES

Five different types of protein isolates used as starting protein sources are listed in Table I. All isolates, except commerical sodium caseinate, were prepared from glandless cottonseed kernels using our pilot plant facilities. The aqueous processed isolate was prepared from full-fat flour (4), and the other isolates were prepared from hexane-defatted flour. In all cases, protein extraction was conducted at pH 10, and the protein was precipitated at pH 4.5. M-I and M-II denote two protein isolates succinylated at 40% and 54% of total free amino groups of cottonseed proteins, respectively. The succinylated cottonseed protein isolates were prepared by methods described by Choi et al. (5).

The formula used to prepare the nondairy coffee whiteners is presented in Table II. Corn syrup solids (Prodex 24D from American Maize Products), emulsifiers (demodans and Panodan SD from Grinsted Co.), a fat (Duromel from Durkee) and a stabilizer (carrageenan) were included in the formula.

The procedure used to formulate coffee whiteners in the pilot plant is shown in Figure 1. All steps in the procedure are almost identical to current commercial practices, with omission of instantization of the powder after spray drying, which ensures fast wettability by increasing particle size. Since an instantizer was not available, spray-dried whitener powder were simply stored in glass containers until need for subsequent experiments. Deionized water was used in this experiment unless otherwise mentioned.

Protein, fat and ash contents were determined by standard AOAC methods (6). Bulk density of whitener powders represents the ratio between weight and unit volume (g/mL) of the powder. Sample powders were filled in 50 mL cylinders with constant tapping, and the weight of 50 mL powder was determined. Particle size of whiteners was determined by sieving and expressed as % wt passed through a 115 mesh sieve by constant shaking in an Alpine Air Jet Sieve (200 lab type).

Whiteness of whitener powders was expressed as Hunter

TABLE I

Preparation of Protein Isolates

Isolate	Procedures
Aqueous	Extraction of full-fat cottonseed flour at pH 10; precipitation at pH 4.5.
Conventional	Extraction of hexane-defatted cottonseed flour at pH 10; precipitation at pH 4.5.
M-I	Extraction of defatted cottonseed flour with succinic anhydride at pH 10; precipitation at pH 4.5.
M-II	Same as M-I procedure, but at a higher succinic anhydride concentration.
Na-Caseinate	A commercial product.

TABLE II

Coffee Whitener Formula

Ingredient	Composition
Protein isolate	6.00
Solid corn syrup	26.80
Fat[a]	16.00
Emulsifier I[b]	0.60
Emulsifier II[c]	0.20
Carrageenan	0.25
K_2HPO_4	0.30
Water, up to	100.00

[a]Partially hydrogenated soybean oil.
[b]Dimodans from Grinsted Company.
[c]Panodan SD from Grinsted Company.

Color Difference Meter "L" values. Whitening capacities of whiteners are also expressed as L-values of coffee-whitener suspensions. The whitener (1.35 g) was added to 50 mL of hot coffee (coffee/water: 0.75% w/v) and the color was measured immediately after mixing. The temperature of the coffee was about 85-90 C.

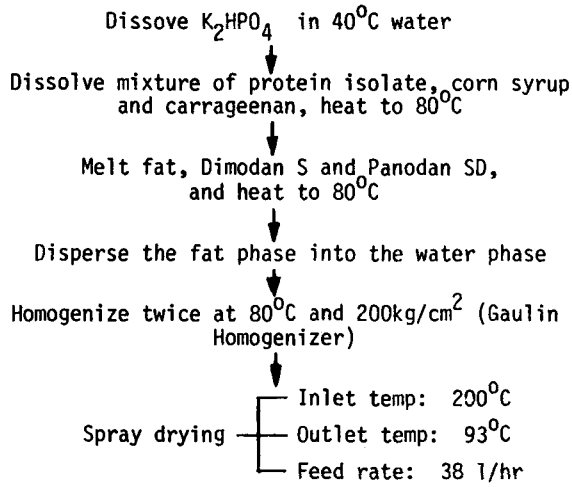

FIG. 1. Flow-diagram for preparation of coffee whiteners in pilot plant scale operation.

Separation of the whitener in aqueous coffee was performed as follows: the whitener (3.75 g: approximately one teaspoon) was suspended in 75 mL of hot coffee (0.75% w/v) and suspension was transferred into a 100-mL cylinder immediately after mixing. Volumes of cream and precipitation layers were determined after 13 min. Temperature during measurement was 80-85 C.

Fat retention capacity of the whiteners was determined by washing out 5 g whitener with 50 mL hexane in a Soxhlet extractor. The amount of fat was then determined by weighing the residue after evaporation of solvent. The degree of fat retention was expressed as weight of extracted fat from 5 g whitener.

RESULTS AND DISCUSSION

Selected chemical compositions and physical properties of the experimental coffee whiteners and a commercial product are shown in Table III. Relatively speaking, experimental coffee whiteners had higher protein and lower ash and sugar contents than the commerical product. No signifi-

TABLE III

Composition and Physical Properties of Coffee Whiteners

	Composition (%)				Physical properties	
Protein source	Protein	Fat[d]	Ash	Sugar	Bulk density (g/mL)	Sieving[e] test (%)
Aqueous isolate	9.1	24.4	1.00	15.5	0.34	92
Conventional isolate	9.8	25.8	1.38	11.9	0.38	93
M-I Isolate[a]	9.4	21.1	1.37	12.2	0.29	94
M-II Isolate[b]	9.4	13.9	2.02	11.9	0.29	97
Na-Caseinate + M-II[c]	10.0	5.0	0.96	11.3	0.26	96
Na-Caseinate	8.5	5.5	1.04	11.9	0.26	97
Commercial whitener	2.8	1.4	2.55	14.9	0.50	55

[a]40% succinylated cottonseed protein isolate.
[b]54% succinylated cottonseed protein isolate.
[c]1:1 mixture, w/w.
[d]Hexane-extractable fat.
[e]% wt passed through a 115 mesh sieve.

TABLE IV

Hunter "L" Values and Whitening Capacity of Coffee Whiteners[a]

	"L" Values			Loss of whiteness by filtration (%)
Protein source	Powder	In coffee[e]	After filtration[f]	
Aqueous isolate	84.8	14.7	5.9	60
Conventional isolate	84.9	14.4	9.2	35
M-I Isolate[b]	87.0	22.5	16.5	26
M-II Isolate[c]	85.6	24.7	21.6	13
Na-Caseinate + M-II[d]	88.8	43.1	39.0	10
Na-Caseinate	93.3	43.7	42.0	4
Commercial whitener	92.0	42.0	33.0	21
Black coffee	27.5	7.8	8.0	0

[a]Hunter "L" value of standard white: 94.2.
[b]40% succinylated cottonseed protein isolate.
[c]54% succinylated cottonseed protein isolate.
[d]1:1 mixture, w/w.
[e]Whitener (1.35g) in 50 mL coffee (0.75%, w/v).
[f]Filtrate through Whatman no. 1 filter paper.

TABLE V

Separation Test of Formulated Coffee Whiteners[a]

Protein source	Cream layer (mL)	Precipitated protein layer (mL)
Aqueous isolate	2	28
Conventional isolate	3	24
M-I Isolate[b]	7	0
M-II Isolate[c]	6	0
Na-Caseinate + M-II[d]	2	0
Na-Caseinate	1	0
Commercial whitener	1	0

[a]Whitener (3.75g) was suspended in 75 mL of hot coffee (0.75%, w/v), and mixed. Cream and precipitation layer volumes were determined after 13 min.

[b]40% succinylated cottonseed protein isolate.

[c]54% succinylated cottonseed protein isolate.

[d]1:1 mixture, w/w.

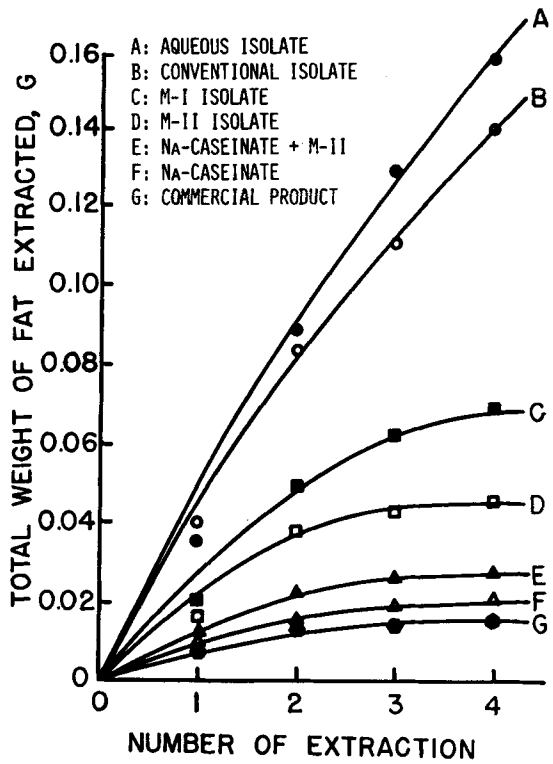

FIG. 2. Fat extractability of coffee whitener with hexane. (5 g whitener was extracted with 50 mL hexane each time.)

cant differences in protein, ash and sugar contents existed among experimental whiteners. However, considerable differences were found in the amount of hexane-extractable fat, indirectly indicating the extent of microencapsulation of fat droplets by protein films or levels of protein-fat binding. Sodium caseinate showed good fat retention capacity. Oil retention capacities of whiteners were increased by formulating them with succinylated protein isolates. The higher the succinylation, the higher the fat retention capacity. The 1:1 mixture of sodium caseinate and succinylated cottonseed protein isolate (M-II) resulted in oil retention capacity almost equal to that of sodium caseinate alone.

The commercial whitener had a higher bulk density and bigger particle size than the experimental whiteners (Table III). More than 90% of experimental whiteners consisted of particle sizes smaller than 115 mesh, while only 55% of the commercial whitener passed through the 115 mesh screen under the same operating conditions. There is little doubt that instantization of commercial products plays a major role in making these two physical properties markedly different from those of experimental products, which were not instantized.

Bulk densities of whiteners prepared with aqueous and conventional isolates were slightly higher than those of other experimental whiteners. However, no significant difference in particle size was noticed among the experimental products, suggesting that a direct correlation between protein sources and particle size of final products may not exist. In fact, denser particles can be produced by simple mechanical procedures such as instantization, regardless of protein sources.

Table IV summarizes data on whiteness of coffee whitener powders and their whitening capacity in hot coffee. Whiteness is expressed as "L" values, compared to a standard white plate with an "L" value of 94.2. Commercial and sodium caseinate-based coffee whiteners showed the highest "L" values, while the aqueous extraction and conventional isolate-based whiteners showed the lowest "L" values. When these whiteners were dispersed in hot coffee, (1.35 g [approximately one teaspoonful] whitener in 50 mL (about one cup) of hot coffee containing 0.75% coffee) the sodium caseinate and sodium caseinate plus M-II based whiteners showed higher "L" values than commercial whitener. Unmodified isolate-based whiteners had the lowest "L" values, while the succinylated isolate-based whiteners had intermediate whiteness. The black coffee had an "L" value of 7.8. The fact that 50% replacement of sodium caseinate with modified cottonseed protein isolate (M-II) did not affect the whitening capacity may result in the manufacture of low-cost coffee whiteners and similar products in the future.

Filtration of coffee and whitener mixtures through Whatman no. 1 filter paper to remove suspended particles showed similar whitening properties to those of unfiltered mixtures, although overall whiteness had decreased depending upon the source of protein. Reduction in whitening capacity through filtration was the highest for the aqueous-based whitener and lowest for the sodium caseinate-based whitener. The data presented in Table IV strongly suggest that coffee whiteners, with equal or better whitening capacity than commercial whiteners, can be manufactured using succinylated cottonseed protein isolate. Data also suggest that the degree of protein modification plays a major role, i.e., the whitener which contained M-II (54% succinylated isolate) had better whitening capacity than the one containing M-I (40% succinylated isolate and had lesser of the whitening capacity after filtration). In fact, considerably less loss of whitening capacity was observed than for the commercial product.

Table V summarizes results from fat separation tests. If protein lacks good colloidal dispersibility and stability, the protein matrix formed through microencapsulation in aqueous systems, tends to separate from the aqueous phase forming precipitates at the bottom, and entrapped fat droplets rise to the top of the aqueous phase. Whiteners containing aqueously extracted or conventionally isolated proteins separated into cream, aqueous and sedimentation layers 13 min after mixing with hot coffee. All other whiteners did not show sedimentation under the same experimental conditions; however, whiteners containing succinylated protein developed moderate separation of cream, probably caused by floating of whitener particles because of the lack of instantization. The large number of sedimentation layers formed by whiteners containing unmodified isolates indicates poor colloidal dispersibility and stability of these proteins.

As discussed earlier, production of coffee whiteners involves microencapsulation of fat droplets by a thin protein film. Therefore, well encapsulated fat should not be easily extracted with organic solvents like hexane. On the other hand, poorly encapsulated fat, or simple mixtures of fat and protein without binding, would be easily extracted with such solvents, indicating poor fat retention capacity.

Figure 2 shows the amount of fat extracted from the whiteners by repeated washings with hexane. The whiteners containing unmodified protein isolate exhibited poor fat retention capacity, while whiteners containing sodium caseinate and mixtures of sodium caseinate and M-II isolate and commercial whitener showed high fat retention capacities. Clearly, modification by succinylation made substantial improvement in fat retention capacities of glandless cottonseed proteins. Melnychun and Stapley reported that acylated proteins were suitable for use in coffee whitener formulation (7).

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REFERENCES

1. Leo, A., and J.J. Betscher, Food Prod. Dev. 4(4):70 (1970).
2. Knightly, W.H., Food Technol. 23(2):37 (1969).
3. McMeekin, T.L., and M.L. Groves, Physical Equilibrium of Milk Protein, in Fundamentals of Dairy Chemistry, edited by B.H. Webb and A.H. Johnson, Avi Publishing Co., Westport, CT, 1965.
4. Rhee, K.C., Annual Progress Report of Food Protein Research & Development Center, Texas A&M University, 1979, p. 27.
5. Choi, Y.R., E.W. Lusas and K.C. Rhee, J. Food Sci. 46(3):954 (1981).
6. Official Methods of Analysis of the Association of the Official Analytical Chemists, 13th edn., AOAC, Washington, DC, 1980.
7. Melnychyn, P., and R.B. Stapley, U.S. patent 3,764,711 (1973).

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