



Particle size distribution in a heat-processed beverage prepared from roasted peanuts

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Fractional filtration was used to measure particle size in peanut beverages which were either bottle-processed (2 min at 72°C or 8 min at 111°C) after homogenization (20.7×10^6 Pa at 72°C) or kettle-pasteurized (2 min at 72, 77 or 82°C) before homogenization (20.7×10^6 Pa at 72, 77 or 82°C). To prepare beverages, partially-defatted roasted peanuts were milled and wet-blended, slurries were filtered through screens with 34 μm mesh size, and filtrates were blended with sucrose, salt (sodium chloride) and stabilizer. After 14 days' storage, beverages contained 99.8 to 99.9 g/100 g total solids with diameters $< 34 \mu\text{m}$. Harsher bottle-processing conditions or higher homogenizing temperatures, respectively, increased or decreased particle size. Homogenizing after heat treatment reduced the size of particles. Weights of particles retained on screens with 104-, 74- and 53- μm openings from peanut beverages which were kettle pasteurized at 77 or 82°C, then homogenized (20.7×10^6 Pa) at 77 or 82°C were similar ($p \leq 0.05$) to those retained from commercial low-fat and full-fat cows' milk but less than those retained from commercial chocolate low-fat milk or chocolate drink. Results indicate that the experimental beverages would be less chalky than commercial chocolate low-fat milk and chocolate drink. © 1997 Published by Elsevier Science Ltd on behalf of the Canadian Institute of Food Science and Technology

Keywords: peanut beverage, particle size, chalkiness, fractional filtration, roasted peanuts.

INTRODUCTION

There is an increasing demand for oilseed beverages as alternative sources of dietary protein, especially in countries where dairy products are expensive or in limited supply. Extensive studies have been carried out to improve the sensory attributes of beverages prepared from aqueous extracts of unroasted peanuts and soybeans (Schmidt *et al.*, 1978; Chompreeda *et al.*, 1989; Galvez *et al.*, 1990; Lee & Beuchat, 1992). A major undesirable characteristic of oilseed beverages is chalkiness (Kuntz *et al.*, 1978; Rubico *et al.*, 1987), the sensation of coating on a consumer's mouth and throat.

The sensory attribute 'smoothness' has been described as the feel on soft tissues (Szczeniak, 1979), and is inversely proportional to the force required to overcome

the frictional resistance offered by food components as they move over the skin of the oral cavity (Kokini, 1987). When beverages are being consumed, frictional resistance is influenced by size, mass, density and distribution of the particles, and by the nature of the medium in which the particles are dispersed. As frictional resistance increases, smoothness decreases, and terms such as chalky and grainy are used to describe the sensation of mouthfeel.

Particulate characteristics of animal milk products arise mainly from casein micelles, fat globules, whey proteins and lactose molecules. In addition to protein and fat, imitation milks prepared from oilseeds contain cellulose particles from cell wall fragments which promote chalkiness (Kuntz *et al.*, 1978). Procedures utilized to improve smoothness in milk products and oilseed beverages include various heat-processing protocols, homogenizing parameters, filtration and microparticu-

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lation. Size and distribution of particles in beverages are measured by various techniques including wet-sieving (Rubico *et al.*, 1987), electrical impedance (Schmidt *et al.*, 1978), photographic images such as scanning and transmission electron microscopy (Holcomb *et al.*, 1992), photon correlation spectroscopy (Paquin *et al.*, 1991) and evaluation of laser diffraction patterns (Banon & Hardy, 1992).

Chalkiness in oilseed beverages is related to size distribution of particles, which may be influenced by the nature of the complexes formed during heat-processing. In a previous study, in which we evaluated the effects of heat processing methods on selected physical properties of a peanut beverage (Hinds *et al.*, 1997a), defatted peanuts were wet-milled and slurries were filtered through a 34- μm mesh screen. However, knowledge of particle size in heat-processed products would be necessary in order to select processing parameters which would give rise to a smooth beverage. The objectives of this study were to evaluate the effects of two heat processing methods on particle size distribution in a beverage prepared from partially-defatted roasted peanuts.

MATERIALS AND METHODS

Materials

Roasted (163°C for 20 min), dry-blanched and electronically sorted Florunner cultivar peanut (*Arachis hypogaea*) seeds (49 g fat 100 g⁻¹ seed, dry basis) were donated by Specialty Brands, Dromedary Plant, Woodbury, GA, USA. A blend of kappa:iota carrageenan (3:1, w:w, Benlacta CM-61B[®], Shemberg USA, Searsport, ME) and hydrogenated mono-diglyceride (Emuldan HV52K[®], Grinsted Products, Inc., Industrial Airport, KS) were donated by the respective companies. Granulated refined cane sugar, non-iodized salt and commercial beverages [Kroger[®] Vitamin D (whole) milk, Kroger[®] low-fat milk, Yoo-hoo[®] chocolate flavored drink, Kroger[®] chocolate low-fat milk] were purchased from a local supermarket. Polyester screen materials (mesh nos. 126, 143, 280, 275 and 380) with openings of 125, 104, 74, 53 and 34 μm , respectively, were purchased from McMaster Company (Atlanta, GA). Sections of PVC pipes (81 and 87 mm i.d.) and cement (Oatey regular clear cement for PVC, Oatey, Cleveland, OH) were purchased from a local hardware store.

Beverage preparation

Roasted (163°C for 20 min) and blanched peanuts were obtained from Specialty Brands, Dromedary Plant, Woodbury, GA, USA. The peanuts were partially defatted (24.5% fat, dry basis) at 27.6×10^6 Pa for 5 min using a Carver Press (Model M, Fred S. Carver, Inc.,

Menomonee Falls, WI), finely ground in a Morehouse mill (Morehouse Industries, Los Angeles, CA), wet blehded (1:8, w:v), and filtered through a 34 μm polyester mesh. The filtrate was mixed with sucrose (3%) and salt (0.05%) and heated in a steam-jacketed kettle. Stabilizers CM [carrageenan (0.02% Benlacta CM-61B[®]) or HV [hydrogenated monodi-glyceride (0.2% Emuldan HV52L[®])] were added to the slurry at 63°C which was then heated to 72°C. The heated slurry was subjected to homogenizing and thermal processing to obtain a bottle-pasteurized or kettle-pasteurized beverage. For bottle-pasteurized beverages, each batch was homogenized at 72°C and 20.7×10^6 Pa before being bottled. Samples were then heat-processed at 72°C for 2 min or 111°C for 8 min. Kettle-pasteurized beverages were heated at 72, 77 or 82°C for 2 min, homogenized (20.7×10^6 Pa) at the same temperature at which they were pasteurized, bottled and capped. Beverages containing either CM or HV and heated in the kettle only to achieve a temperature of 72°C (without additional heat treatment and homogenization) served as controls.

Physical analysis

Solids contents (g 100 mL⁻¹) in peanut beverages and commercial beverages were determined according to procedures explained by Hinds *et al.* (1996b) after samples were held at 1°C for 7 d. After 14 days at 1°C, particle size distribution in the beverages was determined by fractional filtration as described below. Triplicate determinations per treatment were carried out for each test.

Particle size measurement

Polyester screen materials (mesh nos. 126, 143, 208, 275, and 380) with mesh openings of 125, 104, 74, 53, and 34 μm , respectively, were used to fabricate sieves. A circular layer of polyester screen material was cemented to the base of a 41-mm length of PVC pipe (81 mm i.d.). The screen material was then secured with a 44-mm length of PVC pipe (87 mm i.d.) which also served as a permanent collar (Fig. 1). The sieve was then heated for 24 h in a Tenney Benchmaster dryer (Model Tenn Trol[®] II, Tenney Engineering Inc., Union, NJ) set at 50°C to ensure complete drying of the adhesive. A small pump to apply air pressure was constructed using PVC pipe (50 mm, 87 mm i.d.) to form the frame. The piston consisted of PVC (118 mm, 81 mm i.d.), at one end of which was affixed a PVC collar (28 mm, 87 mm i.d.) onto which a circular sheet of polystyrene (87 mm diameter) was cemented.

Particle size was determined by fractional filtration. Five tared sieves containing screens with mesh openings ranging from 34 to 125 μm were used for each replicate. Each sieve was placed on the rim of a 1-litre beaker and held firmly in position by its collar. A 25-g aliquot of a

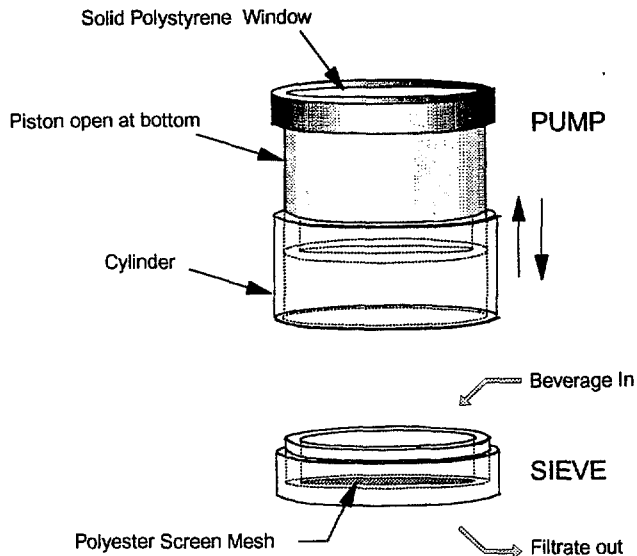


Fig. 1. Schematic of fractional filtration of particles in peanut beverage.

beverage of known solids content was poured into the 126-mesh (125- μm opening) sieve. Tap water (30°C) was used to wash particles < 125 μm diameter through the sieve. The filtrate was poured into the 143-mesh (104- μm opening) sieve through which particles < 104 μm diameter were passed. Filtration operations through the remaining sieves were continued in sequence (in descending order of mesh diameter openings) until all particles with diameters < 34 μm were washed through the 380 mesh sieve. Rate of filtration was increased by resting the frame of the pump on the collar of the sieve and manually applying a gentle pumping action on the piston. Each sieve containing particulate materials was covered with a polystyrene lid (100 mm diameter), then dried (*ca* 6 h) at 50°C (Tenney Benchmaster dryer) on a perforated rack to constant weight to determine the weight of particles retained.

When particles retained on a sieve were $\leq 5\text{ mg}$, their weight was also verified using an inspection procedure in which the quantitative distribution of particles retained on the test sieve and on standard sieves were compared visually. Standard sieves used for comparison were prepared as follows. Samples of slurry used to prepare the peanut beverage were filtered sequentially through sieves with 125 to 34- μm openings. The residue on the sieve with 34- μm diameter opening was dried to a powdered form. Aliquots of this dried peanut meal equivalent to 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5 and 5.0 mg were weighed separately into tared Petri dishes. The contents of each Petri dish were suspended in tap water and transferred into a clean sieve (34- μm opening). The sieve was covered with a polystyrene lid (100 mm diameter), then dried at 50°C for 8 h on a perforated rack. The dried sieve and particulate material served as a standard. To verify the weight of particles

($\leq 5\text{ mg}$) retained from a beverage sample, each test sieve with particulates was compared with each of the nine standard sieves using a magnifying glass. The weight of solids retained on a sieve was expressed as mg g^{-1} total solids in the beverage sample. Particle size distribution in commercial beverages was also determined.

Statistical analysis

ANOVA (General Linear Models procedure) and significant differences between means ($p \leq 0.05$, Duncan's Multiple Range test) were determined using the SAS computer package (SAS Institute, 1985).

RESULTS AND DISCUSSION

The solids ($\text{g } 100\text{ mL}^{-1}$) content in the peanut beverage samples (Table 1) was within the range observed for commercial low-fat cows' milk (10.7 ± 0.02), whole cows' milk (11.7 ± 0.02), chocolate low-fat milk (15.2 ± 0.01) and chocolate flavored drink (14.2 ± 0.05). Weights of particles ($\text{g } 100\text{ g}^{-1}$ total solids) in peanut beverages with particle diameter < 34 μm are listed in Table 1. Values of 99.96 ± 0.00 , 99.95 ± 0.013 , 99.85 ± 0.004 , and 99.75 ± 0.016 , respectively, were observed in commercial low-fat cows' milk, whole cows' milk, chocolate low-fat milk and chocolate flavored drink. During beverage preparation, unheated peanut slurries were filtered through screens with 34- μm diameter openings. However, not all particles in the controls and heat-processed peanut beverage samples were $\leq 34\text{ }\mu\text{m}$ diameter (Table 1). This indicates that heat treatment and homogenization influenced particle size.

Characteristics of the bottle-processed beverage suggest that, with harsher processing conditions (111°C), larger complexes were formed in formulations containing HV than in those containing CM (Table 2). HV, a mono-diglyceride blend, emulsifies by reducing surface tension between oil and water interfaces (Pomeranz, 1991), and probably facilitated the formation of hydrophilic protein-lipid complexes with diameters > 34 μm . Homogenizing after kettle-pasteurizing appeared to be effective in breaking down most of the complexes (> 34 μm) that were formed during pasteurizing. Higher kettle-pasteurizing temperatures would likely have promoted the formation of protein complexes. However, beverages pasteurized at 77 or 82°C contained similar weights of particles with diameters < 34 μm (Table 1), indicating that higher homogenizing temperatures probably facilitated dissociation of complexes which were formed during pasteurizing. Soybean beverages with smoother mouthfeel have been obtained using a homogenization temperature of 82°C vs 16°C (Nelson *et al.*, 1976).

Kettle-pasteurized beverages containing CM and homogenized at 72°C contained significantly less

Table 1. Total solids (g 100 mL⁻¹) and solids (g 100 g⁻¹ total solids, <34 μm diameter) in peanut beverage after 14 days' storage at 1°C^a

Property	Emulsifier ^b	Control	Bottle-processed ^c		Kettle-pasteurized ^c		
			72°C	111°C	72°C	77°C	82°C
Total solids (g 100 mL ⁻¹)	CM	12.6 ± 0.02d	12.6 ± 0.07d	12.6 ± 0.01cd	12.8 ± 0.49cd	13.4 ± 0.17b	13.3 ± 0.41b
	HV	13.0 ± 0.03c	13.0 ± 0.03c	13.0 ± 0.02c	13.9 ± 0.27a	13.8 ± 0.03a	13.8 ± 0.28a
Solids (g 100 g ⁻¹ total solids, < 34 μm diameter)	CM	99.93 ± 0.005a	99.91 ± 0.005a	99.88 ± 0.005a	99.84 ± 0.024b	99.90 ± 0.004a	99.90 ± 0.015a
	HV	99.92 ± 0.000a	99.92 ± 0.005a	99.79 ± 0.050b	99.89 ± 0.006a	99.91 ± 0.000a	99.91 ± 0.001a

^aMeans (± standard deviations) of triplicate determinations. Means for the same property with the same letter are not significantly different at $p \leq 0.05$.

^bStabilizer type: CM = kappa:iota carrageenan (3:1, w:w); HV = hydrogenated mono-diglyceride.

^cProcessing time at 111°C was 8 min. All other samples were processed for 2 min.

particles with diameters <34 μm than corresponding samples containing HV (Table 1). CM, which contains kappa-carrageenan, stabilizes by forming threadlike networks and protein-polysaccharide complexes (Modliszewski, 1984), and homogenizing at 72°C (compared with 77 to 82°C) was less effective in dissociating these complexes. Formulations containing CM and kettle-pasteurized at 72°C contained less particles with diameters <34 μm than similar formulations which were bottle-processed at 72°C. The presence of 3, 6-anhydride groups on k- and i- carrageenan molecules favor formation of intermolecular helical conformations in aqueous systems above 50°C (Pomeranz, 1991; Samant *et al.*, 1993). During kettle-pasteurizing, beverages were stirred continuously and this may have increased the formation of intermolecular networks by CM.

None of the peanut beverages or commercial beverages contained particles ≥ 125 μm in diameter. Table 2 shows the distribution of particles (mg g⁻¹ total solids) with diameters which ranged from 34 to 124 μm. Beverages prepared by Rubico *et al.*, (1987) from unroasted partially-defatted peanuts contained particles > 150 μm diameter and were assigned scores of 90 to 100 (on a 1 to 150 scale) for chalkiness. Optimum quality soymilk prepared by Kuntz *et al.*, (1978) contained 0.1 to 0.2 and 1.0 to 1.2 mg g⁻¹ total solids with diameters > 150 μm and 105 to 149 μm, respectively. Soymilk formulations were assigned mean scores for chalkiness of 1.6 on a scale in which 1 and 7 represented imperceptible and pronounced chalkiness, respectively. Kuntz *et al.*, (1978) observed that particles (105 to 149 μm diameter) in soymilk which were retained by a 150-mesh screen were primarily responsible for chalkiness and they predicted

Table 2. Distribution of particles (mg g⁻¹ total solids) with diameter > 34 μm in peanut and commercial beverages^a

Beverage	Treatment	Processing ^b Temperature (°C)	Emulsifier ^c	Diameter of particles (μm)			
				104 to 124	74 to 103	53 to 73	34 to 52
Peanut	Control		CM	0.1 ± 0.0c	0.1 ± 0.1d	0.1 ± 0.1d	0.5 ± 0.0c
			HV	0.1 ± 0.0c	0.1 ± 0.0d	0.1 ± 0.0e	0.5 ± 0.0c
	Bottle-processed	72	CM	0.1 ± 0.0c	0.1 ± 0.0d	0.2 ± 0.1cd	0.5 ± 0.0c
			HV	0.1 ± 0.0c	0.1 ± 0.0d	0.1 ± 0.0e	0.5 ± 0.1c
	Bottle-processed	111	CM	0.3 ± 0.0bc	0.1 ± 0.0d	0.3 ± 0.1c	0.5 ± 0.0c
			HV	1.8 ± 0.7a	0.1 ± 0.0d	0.1 ± 0.0e	0.1 ± 0.0d
	Kettle-pasteurized	72	CM	0.1 ± 0.0c	0.2 ± 0.0c	0.3 ± 0.1c	1.0 ± 0.3a
			HV	0.1 ± 0.0c	0.1 ± 0.0d	0.2 ± 0.1de	0.7 ± 0.1bc
	Kettle-pasteurized	77	CM	0.1 ± 0.0c	0.1 ± 0.0d	0.2 ± 0.0cde	0.6 ± 0.1bc
			HV	0.1 ± 0.0c	0.1 ± 0.0d	0.1 ± 0.0e	0.6 ± 0.0bc
Kettle-pasteurized	82	CM	0.1 ± 0.0c	0.1 ± 0.0d	0.1 ± 0.0e	0.7 ± 0.1bc	
		HV	0.1 ± 0.0c	0.1 ± 0.0d	0.1 ± 0.0e	0.6 ± 0.1bc	
Commercial	Whole milk (pasteurized)	—	—	0.2 ± 0.1c	0.1 ± 0.0d	0.1 ± 0.0e	0.1 ± 0.1d
	Low-fat milk (pasteurized)	—	—	0.1 ± 0.0c	0.1 ± 0.0d	0.1 ± 0.0e	0.1 ± 0.0d
	Chocolate milk	—	—	0.3 ± 0.0bc	0.3 ± 0.1b	0.4 ± 0.0b	0.5 ± 0.0c
	Chocolate drink	—	—	0.4 ± 0.1b	0.5 ± 0.2a	0.7 ± 0.0a	0.9 ± 0.0ab

^aMeans (± standard deviations) of triplicate determinations. Means for the same particle diameter (column) followed by the same letter are not significantly different at $p \leq 0.05$.

^bProcessing time at 111°C was 8 min. All other peanut beverage samples were processed for 2 min.

^cStabilizer type: CM = kappa:iota carrageenan (3:1, w:w); HV = hydrogenated mono-diglyceride.

that if all particles were $< 105 \mu\text{m}$ diameter, chalkiness would be imperceptible. In our study, the controls, peanut beverage bottle-processed at 72°C , kettle-pasteurized beverage and commercial low-fat milk contained 0.1 mg g^{-1} total solids with diameters of 104 to $124 \mu\text{m}$ (Table 2), suggesting that they would impart little or no chalky mouthfeel. Preliminary sensory screening of the peanut beverages by eight trained panelists indicated that the kettle-pasteurized samples had a smoother mouthfeel than the bottle-processed ones.

Peanut beverage containing CM and bottle-processed at 111°C had a particle retention on the $104\text{-}\mu\text{m}$ screen similar to that of commercial chocolate milk and chocolate drink. The significantly higher proportion of particles with diameters of 104 to $124 \mu\text{m}$ in peanut beverages containing HV and bottle-processed at 111°C suggests that larger lipid-protein complexes were formed by the emulsifying action of HV than by the stabilising action of CM.

Schmidt *et al.*, (1978) observed a significant reduction in chalkiness when beverages prepared from either unroasted peanuts or soybeans were sieved through 250-mesh ($60\text{-}\mu\text{m}$ diameter openings) screens. In our study, particles with diameters of 53 to $124 \mu\text{m}$ (instead of $60 \mu\text{m}$) in peanut beverages and commercial beverages were determined (Table 2). Controls, beverages kettle-pasteurized at 77 or 82°C , and formulations containing HV which were either bottle-processed or kettle-pasteurized at 72°C , were characterized by a distribution of particles with diameters of 53 to $124 \mu\text{m}$ that were similar to those of commercial low-fat and whole cows' milks (Table 2). On the other hand, more particles were retained from commercial chocolate low-fat milk and chocolate drink on 104- , 74- and $53\text{-}\mu\text{m}$ screens than from peanut beverages, except those which were bottle-processed at 111°C . These observations and those of Schmidt *et al.*, (1978) indicate that peanut beverages bottle-processed at 72°C or kettle-pasteurized at 72 , 77 or 82°C would be less chalky than commercial chocolate low-fat milk and chocolate drink, and may be similar in smoothness to commercial low-fat and whole cows' milks.

Controls, peanut beverages kettle-pasteurized at 77 or 82°C , and formulations containing HV which were either bottle-processed or kettle-pasteurized at 72°C had particle retention similar to that of commercial low-fat and whole (cows') milks on all screens except $34\text{-}\mu\text{m}$ screens on which significantly fewer particles were retained from the commercial milks (Table 2). Higher viscosity of the dispersion medium in beverages decreases the chalkiness perceived from particles of similar sizes (Kokini, 1987). Viscosities of commercial cows' milks were 2.0 ± 0.0 cps compared with 2.0 ± 0.0 to 2.4 ± 0.0 and 6.4 ± 0.91 to 7.4 ± 0.35 cps for controls and kettle-pasteurized (77 or 82°C) peanut beverages, respectively (Hinds *et al.*, 1997a). Formulations con-

taining HV that were bottle-processed or kettle-pasteurized at 72°C had viscosities of 8.4 ± 0.44 and 2.1 ± 0.0 cps, respectively (Hinds *et al.*, 1997a). These observations indicate that peanut beverages which were kettle-pasteurized at 77 or 82°C , as well as those containing HV and kettle-pasteurized at 72°C would impart a less chalky mouthfeel than commercial chocolate drink which contained the most particles with diameters $> 34 \mu\text{m}$ (Table 2) and had a viscosity of 4.9 ± 0.06 cps (Hinds *et al.*, 1997a).

The relative viscosities and particle size distribution also suggest that peanut beverages which were kettle-pasteurized at 77 or 82°C , as well as those containing HV and kettle-pasteurized at 72°C may impart a mouthfeel similar to that of commercial cows' milk. However, the influence on overall mouthfeel or relative densities of particles with diameters 34 to $52 \mu\text{m}$ needs to be confirmed by a trained sensory panel. Pasteurizing at 77 to 82°C compared with 72°C would promote longer shelf-life. Therefore, beverages which are kettle-pasteurized at 77 to 82°C , then homogenized, would be expected to have optimum mouthfeel and shelf-life and would impart a less chalky mouthfeel than reported for soymilk (Kuntz *et al.*, 1978) and peanut beverage (Rubico *et al.*, 1987). Information on particle size distribution will be important for further research to produce a peanut beverage with optimal combinations of small particle size, smooth mouthfeel, viscosity similar to full-fat milk, physical stability, roasted peanut flavor, and reasonable shelf-life. Samples from the optimization study will be evaluated thoroughly by trained sensory panelists.

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