Shortenings Encapsulated with Oilseed Proteins[1]

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ABSTRACT

Shortenings encapsulated with sodium caseinate or with soy, peanut, or cottonseed protein isolates were evaluated for physical and functional characteristics. All shortenings encapsulated with oilseed proteins had equivalent or better flow properties than did shortenings encapsulated with sodium caseinate. Electron microscopy indicated that each particle was a spherical agglomerate of subparticles that were hollow spheres. The shortening was entrapped in the protein matrix of the shell. Fat was more easily recovered from encapsulated shortenings prepared with oilseed proteins than from those with sodium caseinate. All shortenings encapsulated with oilseed proteins produced cake batters with less aeration, but cake volumes and crumb textures were equivalent to cakes prepared with conventional plastic shortening. Shortenings encapsulated with sodium caseinate produced cakes with significantly lower quality than did conventional shortening. Oilseed proteins, particularly peanut protein isolate, produced encapsulated shortenings with excellent flow properties and functionality in cake baking.

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"Encapsulated," "protected," or "powdered" vegetable shortenings are particularly useful as baking shortenings and coffee whiteners because of their desirable bulk handling characteristics; easy metering, mixing and dispersing properties; improved ingredient stability; and high material flowability (Cameron et al 1959, Robinson and Bronson 1954). Encapsulation is a process in which emulsions of liquid fat, sodium caseinate, and carbohydrate (microcrystaline cellulose or corn syrup solids) are spray-dried, thereby converting oils, emulsifiers, or shortenings from liquid or plastic forms to dry flowable powders with up to 85% fat content (Balassa and Fanger 1971, Hayashi and Takama 1968). The resulting dry shortening mixes with other dry ingredients with minimal effort and energy. Powdered shortenings are often preferred in dry bakery mixes because the fat phase disperses quickly and easily in the batter (Cameron et al 1954). Robinson and Bronson (1954) report that encapsulation also slows development

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of oxidative rancidity. Although the shortening must be adequately protected to ensure flowability, it also must be released at an appropriate time during batter preparation in order to function.

Encapsulated fats have also been used in animal feeds to protect unsaturated fatty acids from microbial hydrogenation in the rumen while releasing the fat for absorption in the small intestine (Scott et al 1971). Increased polyunsaturation and improved flavor of beef, mutton, and milk have been achieved (Edmondson et al 1974, Ford et al 1975, Plowman et al 1972).

The success of encapsulating materials has been attributed to their film-forming capacities. Sodium caseinate, egg albumin, gelatin, gums, and starches have been used. Although uses of gluten and soy protein have been suggested, no published reports document the suitability of vegetable proteins in this application. The objective of this study was to compare the performance of soy, peanut, and cottonseed proteins with that of sodium caseinate as encapsulating materials for shortening in high-ratio layer cakes.

MATERIALS AND METHODS

Encapsulation Procedure

Encapsulated shortenings were produced by the procedure of Hayashi and Takama (1968), spray-drying an oil-in-water emulsion of shortening, carbohydrate, and protein ingredients. The fat was a commercial emulsified cake shortening (PS-23, Anderson Clayton Foods) containing 4.0% monoglycerides and diglycerides, 2.8% propylene glycol monoesters, and 0.5% polysorbate 60. Encapsulating media were corn syrup solids (24 dextrose equivalent) and sodium caseinate or oilseed proteins. Peanut and soy protein isolates were produced by alkaline extraction and isoelectric precipitation (Smith and Circle 1972). Cottonseed proteins were isolated in two fractions, nonstorage and storage protein (Lusas et al[3]). Encapsulated samples contained 75% fat, 15–21% corn syrup solids, 2–8% protein, and 2% moisture.

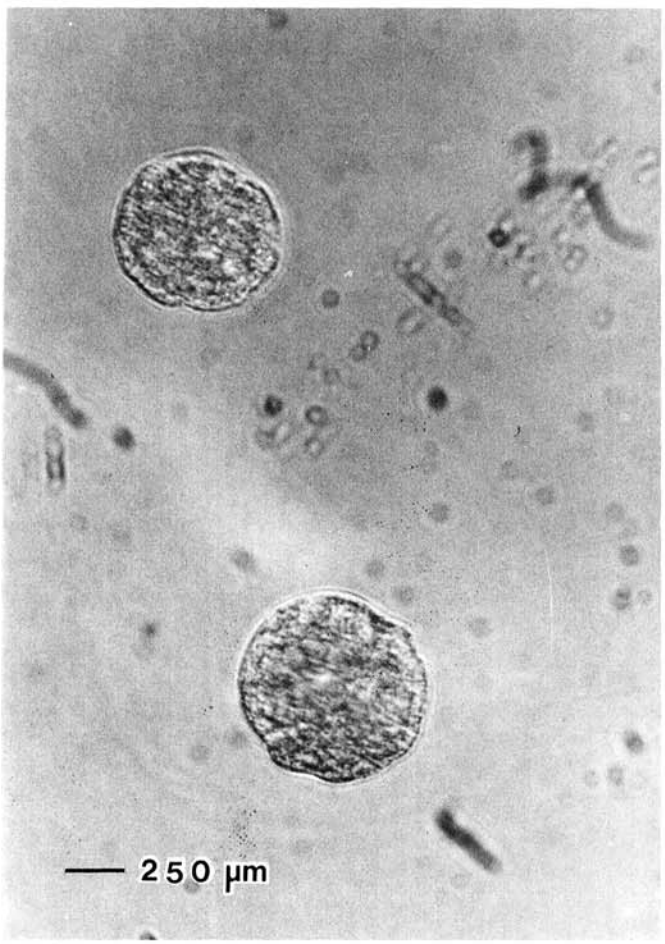

Fig. 1. Light microscopy of shortening encapsulated with 2% sodium caseinate. (×40)

Flowability

Flow properties of encapsulated shortenings were evaluated by measuring the rate of flow through an orifice (Peleg 1977, White et al 1967). Flow through an orifice 1.5 cm in diameter was measured while it was subjected to vibration at 3,600 strokes per minute with a stroke length of 1.6 mm. The time required for approximately 250 cc of sample to pass through the orifice was used to calculate the volume flow rate.

Microscopy

Encapsulated samples were examined by scanning electron microscopy to examine surface topography and by transmission electron microscopy to differentiate fat from protein in the capsule. A Hitachi, model U35, scanning electron microscope was used, with samples prepared by methods described by Taranto et al (1978). A Hitachi, model HU 11A, transmission electron microscope was used on samples fixed with osmium tetraoxide embedded in resin and sectioned. The sections were stained with magnesium uranyl acetate and then with lead citrate and were mounted on observation grids.

Oil Protection

A series of five hexane rinses was used to quantify the protection of oil. Samples (2 g) of encapsulated shortenings suspended on Whatman No. 41 filter paper in a vacuum funnel were rinsed with 50 ml of hexane in each extraction stage. The amount of oil extracted in each stage was determined gravimetrically after solvent removal on a steam bath.

Baking Performance

Functionality in baking systems was evaluated by baking high-ratio white-layer cakes according to AACC Method 10-90 (1969) with a slight mixing modification to accomodate the use of encapsulated shortenings and frozen egg whites. Half the liquid egg whites was added in the second mixing stage and the remaining half in the third mixing stage. The formula was adjusted to maintain constant levels of protein and sugar, taking into account the composition of the encapsulated shortening. Cakes were baked for 25 min at 190 ± 3°C. Cake volumes were determined by rapeseed displacement and scored according to AACC Method 10-90. Batter specific gravity was determined by weighing the amount of batter required to fill a standard (150-ml) cup.

RESULTS AND DISCUSSION

Protein was found to be a vital functional component, although relatively small amounts (2%) were required for preparation of encapsulated shortenings. Attempts to produce an encapsulated

[3] E. W. Lusas, J. T. Lawhon, S. P. Clark, S. W. Matlock, W. W. Meinke, D. W. Mulsow, K. C. Rhee, and P. J. Wan. 1977. Potential for edible products from glandless cottonseed. Conference on Glandless Cotton: Its Significance, Status and Prospects. Dallas, TX, December 13-14.

TABLE I
Effect of Type and Level of Protein on the Flow Rate of Encapsulated Shortenings

	Protein (cm^3/sec)				
				Cottonseed	
Level[a] (%)	Sodium Caseinate	Soy	Peanut	Storage	Nonstorage
2	10.0 fg[b]	11.2 efg	19.7 b	16.0 c	11.0 efg
4	11.2 ef	16.4 c	15.1 cd	12.0 ef	11.4 efg
8	9.5 g	13.1 de	22.4 a	14.3 cd	15.2 cd

[a] The zero level of protein failed to result in capsule formation.
[b] Means followed by the same letter showed no significant difference ($P > 0.05$).

shortening without protein failed because no capsule formation occurred. At protein levels of 2% and above, capsule formation containing 75% fat was successful with oilseed proteins as well as with sodium caseinate.

All shortenings encapsulated with oilseed proteins possessed flow properties equivalent to or better than those made with sodium caseinate (Table I). Encapsulated shortenings made with peanut protein flowed nearly twice as fast as did their sodium caseinate counterparts. Peanut protein is highly soluble in its native state and may possess better film-forming capacity, resulting in more complete capsule formation. A relationship between protein level and flow rate could not be established. Based on limited data, the protein level necessary for maximum flow rate appeared to vary with each source of protein. Materials with greater volume flow rates should flow more uniformly and faster in conveying, metering, packaging, feeding, and mixing equipment.

Although the general shape of encapsulated shortening particles was spherical (Fig. 1), examination of surface topography using scanning electron microscopy techniques indicated that each particle was actually an aggregate of subparticles (Fig. 2). Shortenings encapsulated with 2% sodium caseinate, cottonseed protein, and soy protein (Fig. 2) were more extensively fused than was their 2% peanut protein counterpart. In general, samples with more extensive subparticle fusion had slower volume flow rates.

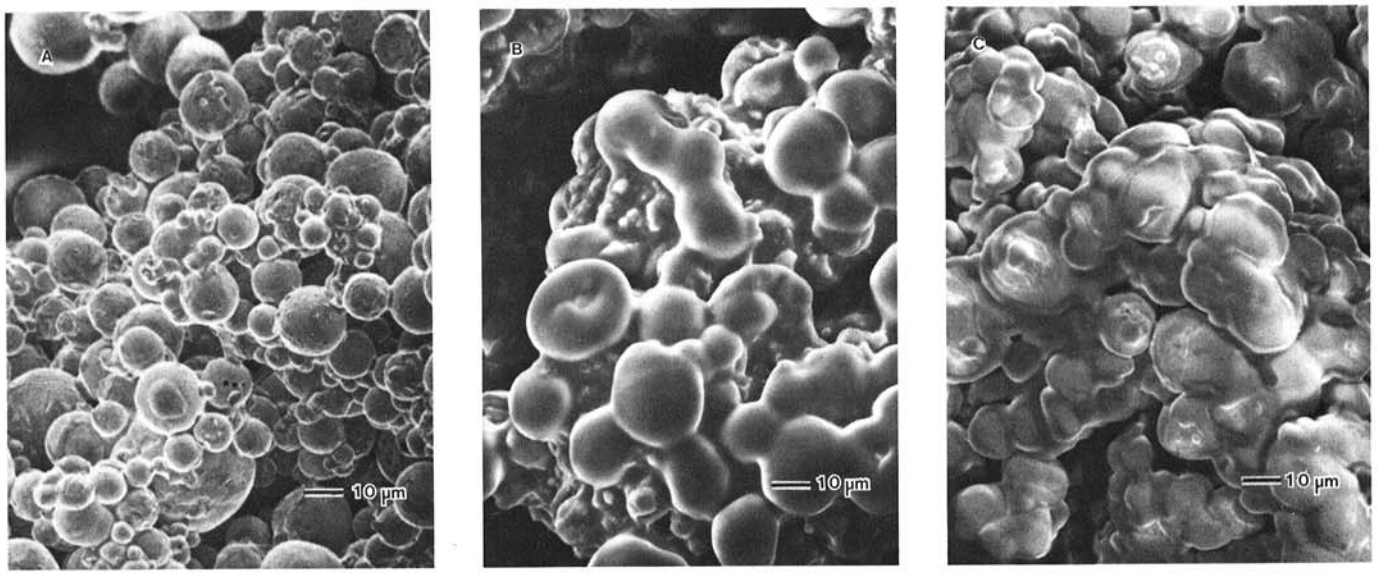

Fig. 2. Scanning electron microscopy of encapsulated shortenings. **A,** 2% peanut protein; **B,** 2% sodium caseinate; **C,** 2% soy protein. (×260)

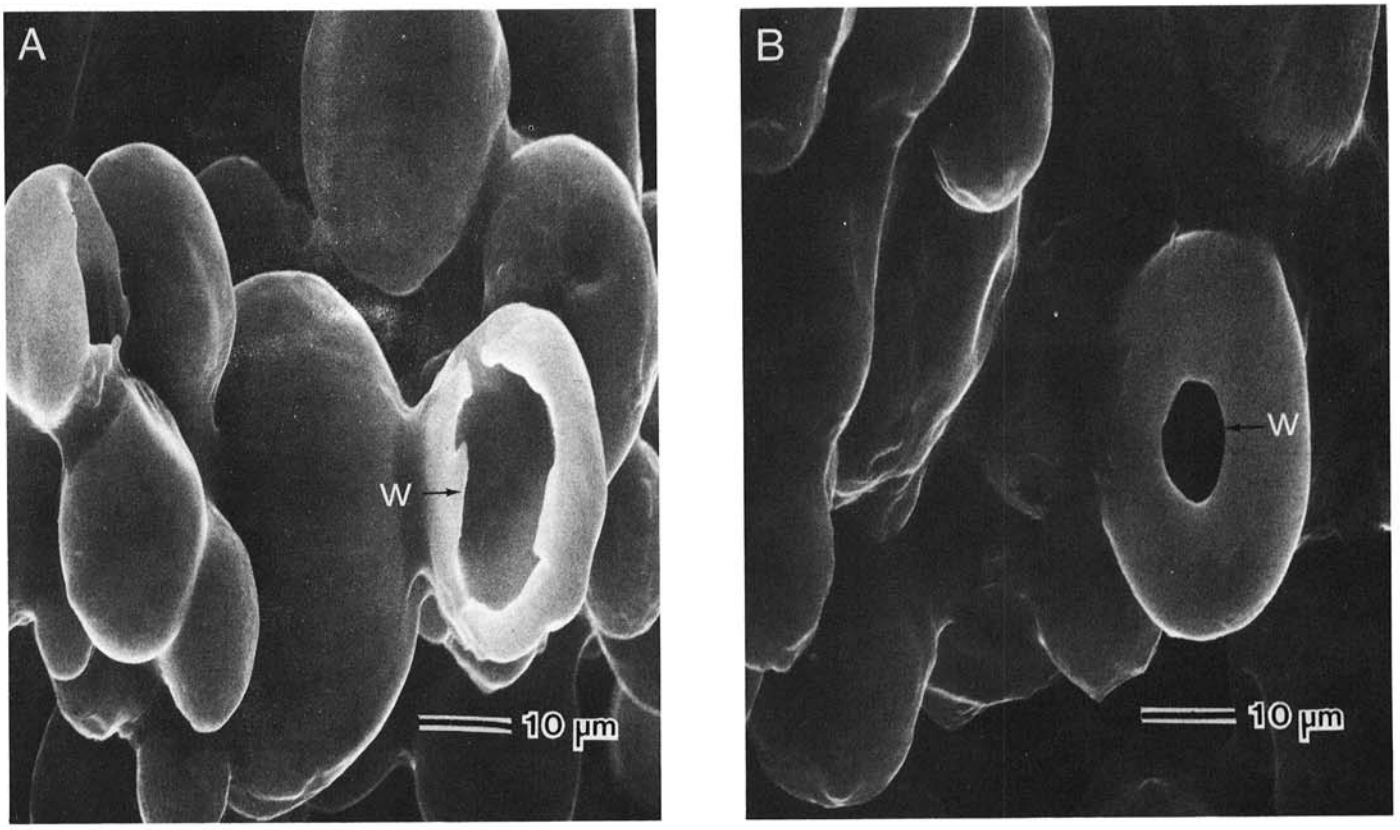

Fig. 3. Scanning electron microscopy of wall structures of encapsulated shortenings. **A,** 8% cottonseed protein; **B,** 2% peanut protein. **W** = shell wall. (×900)

Increased subparticle fusion may allow greater interparticle contact and more surface-to-surface interaction, producing increased internal friction, cohesion, and tendency to bridge.

Each subparticle appeared to be a hollow shell containing an air cell. Figure 3A shows a shell probably mechanically damaged and Fig. 3B, a shell incompletely formed. In both cases the center appeared to be an air cell and not fat, as might be presumed. The shortening was assumed to be entrapped in the shell. Examination of the shell with transmission election microscopy confirmed that the shell was composed of oil droplets entrapped in a protein matrix (Fig. 4).

Solvent rinsing tests were used to evaluate the protection of oil provided by various wall materials (Fig. 5). Although nearly all the shortening could be extracted from the capsules with voluminous hexane, the rate of extraction provided an indication of the amount of protection. Oilseed proteins provided significantly less protection than did sodium caseinate. No significant differences in protection were observed among oilseed proteins. Increasing the level of protein from 2 to 8% slightly improved the protection provided by oilseed proteins. Increasing the concentration of sodium caseinate from 2 to 4% significantly increased protection, but further increases from 4 to 8% increased protection only slightly. Should additional protection be desired, the capsules may be treated with formaldehyde to increase oil protection (Scott et al 1971).

Although encapsulation with oilseed proteins can successfully produce flowable powdered shortenings, these ingredients must also be functional to have practical value. Functionality of encapsulated shortenings in cake baking has been assumed to require release of the shortening during mixing to facilitate the aeration of the batter and the formation of nuclei for leavening action. However, batters made with encapsulated shortenings

TABLE II
Quality of Cakes Made with Shortenings Encapsulated with Various Proteins[a]

Protein Type	Batter Specific Gravity (g/cm^3)	Cake Volume (cm^3)	Cake Score[b]
Conventional shortening	0.73 d[c]	1,152 ef	92 h
Sodium caseinate	0.77 c	986 g	69 i
Soy	0.90 a	1,167 ef	90 h
Peanut	0.87 b	1,207 e	90 h
Cottonseed			
Storage[d]	0.91 a	1,180 ef	88 h
Nonstorage[d]	0.91 a	1,194 e	92 h

[a] Protein level, 4%.
[b] Determined by AACC method 10-90.
[c] Means followed by the same letter showed no significant difference ($P > 0.05$).
[d] Produced yellow crumb color in layer cakes.

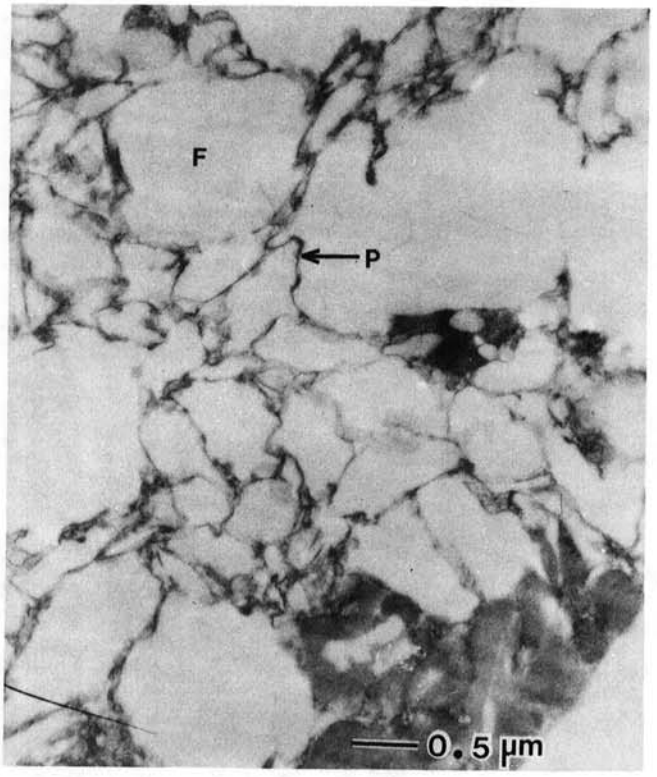

Fig. 4. Transmission electron microscopy of shortening encapsulated with 2% sodium caseinate. Protein stains black. **F** = fat, **P** = protein. (×21,500)

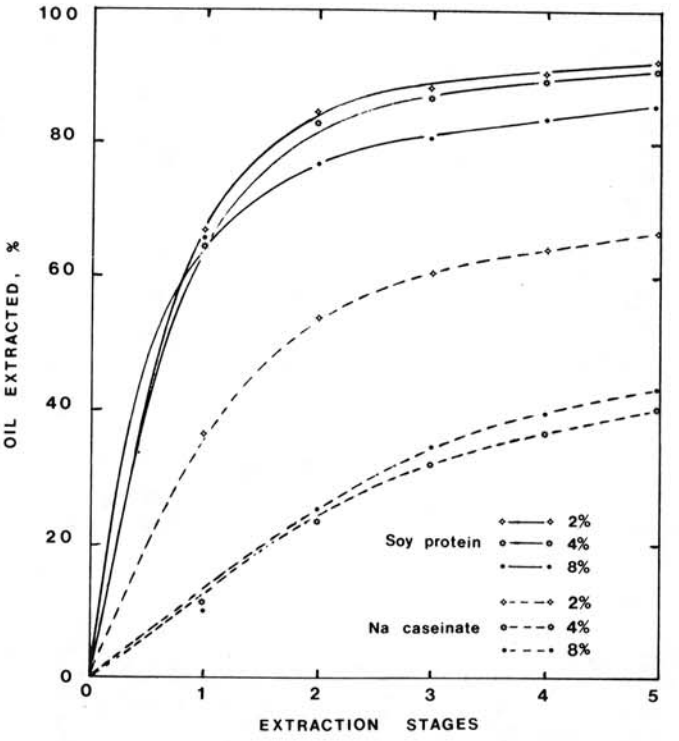

Fig. 5. Extraction of fat with hexane.

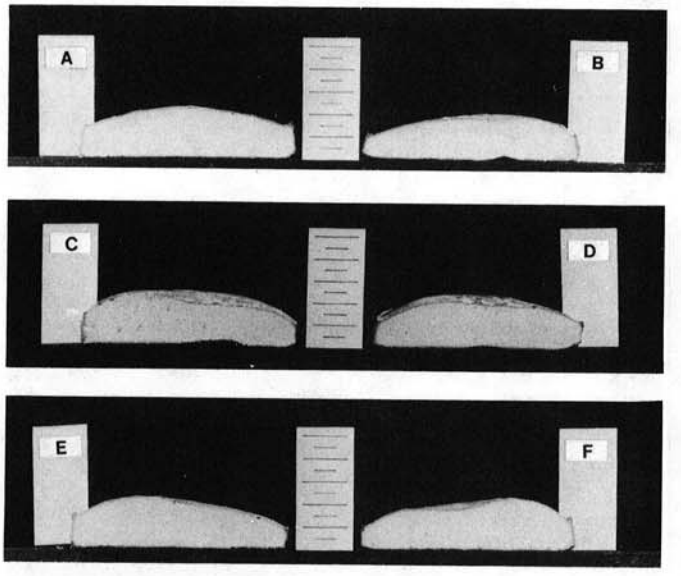

Fig. 6. Cakes made with encapsulated shortenings. **A,** conventional unencapsulated shortening; **B,** 4% sodium caseinate; **C,** 4% cottonseed storage proteins; **D,** 4% cottonseed nonstorage proteins; **E,** 4% peanut protein; **F,** 4% soy protein.

TABLE III
Effect of Protein Level of Encapsulated Shortenings on Cakes

Protein Type	Level (%)	Batter Specific Gravity (g/cm^3)	Cake Volume (cm^3)	Cake Score[a]
Sodium caseinate	2	0.81 c[b]	981 e	77 g
	4	0.77 c	986 e	69 g
	8	0.84 bc	1,101 de	86 fg
Peanut	2	0.84 bc	1,201 d	88 f
	4	0.87 ab	1,207 d	90 f
	8	0.91 a	1,179 d	88 f

[a] Determined by AACC method 10-90.
[b] Means followed by the same letter showed no significant difference ($P > 0.05$).

produced cakes with good volume and crumb texture despite the extraordinarily high specific gravities of the batters (Table II). Shortenings encapsulated with sodium caseinate resulted in cake batters with specific gravities nearly the same as those of cake batters made with conventional unencapsulated shortening; however, both cake volume and score (Table II, Fig. 6) were significantly lower. All shortenings encapsulated with oilseed proteins had significantly higher batter specific gravities than did those prepared with shortenings encapsulated with sodium caseinate or with conventional unencapsulated shortening, but cake volumes and scores were equivalent. We cannot explain how batters prepared with shortenings encapsulated with oilseed proteins produced good cakes although the batters were poorly aerated and why shortenings encapsulated with sodium caseinate produced poor cakes although achieving good batter aeration.

Sodium caseinate provided the shortening with better protection against solvent extraction than did oilseed proteins. Poorer performance in cake baking by shortenings encapsulated with sodium caseinate may be the result of incomplete or untimely release of the shortening because of excessive protection. The preferable method would be to protect the shortening sufficiently to achieve desirable flow properties of dry ingredients yet render it easily releasable during the preparation of cake batter.

Among those shortenings encapsulated with oilseed proteins, shortenings in peanut protein possessed the best functionality in cake baking and the best flow properties. In additional experiments, three levels of peanut protein and sodium caseinate were examined to determine the effect of protein level on cake quality (Table III, Fig. 7). At 2, 4, and 8% protein in the capsules, peanut protein gave batters with higher specific gravities and better cake volumes and scores than their sodium caseinate counterparts. Increasing the level of peanut protein did not improve functionality.

This study indicates that oilseed proteins, particularly peanut protein, may be better suited for making encapsulated shortenings for cake baking than is sodium caseinate, which is presently used in commercially available encapsulated shortenings. Encapsulated shortenings made with oilseed proteins flowed better and produced better cakes than did shortenings encapsulated with sodium caseinate.

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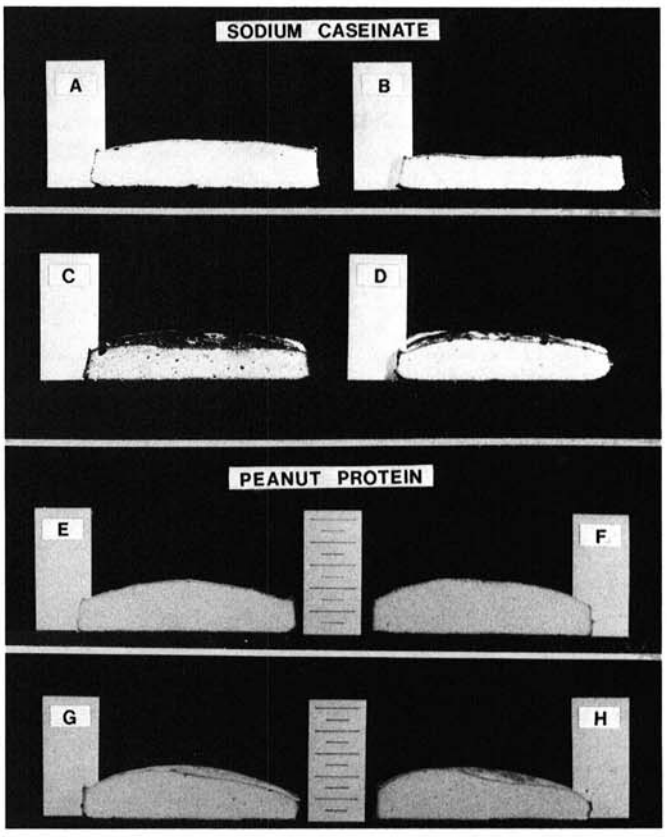

Fig. 7. Cakes made with shortenings encapsulated with different levels of protein. **A,** conventional unencapsulated shortening; **B,** 2% sodium caseinate; **C,** 4% sodium caseinate; **D,** 8% sodium caseinate, **E,** conventional unencapsulated shortening; **F,** 2% peanut protein; **G,** 4% peanut protein; **H,** 8% peanut protein.

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