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MIGRATION OF PHOSPHATIDES IN PROCESSING DAIRY PRODUCTS

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SUMMARY

The effect of stirring, pasteurization, homogenization, and condensing on the migration of the phosphatides from the fat globule membrane to the skimmilk has been studied. Any form of agitation apparently causes a migration. The greatest change in the distribution of the phosphatides occurs during condensing, where the turbulence encountered is great and prolonged. Homogenization at or below 2,000 p.s.i. causes a migration of phosphatides away from the fat globule surface, but at higher pressures the migration is reversed until at a pressure of 8,000 p.s.i. the amount of phosphatide associated with the fat phase is approximately equal to that in the untreated milk.

The material located on or near the surface of the fat globule in milk has been under investigation for over a century (1). A recent review (7) of the major work carried out during this period indicates that an adequate physical picture of the milk constituents in this interfacial zone and the changes they undergo during processing is still lacking.

The limitation of knowledge in this area necessitates added information to comprehensively and concisely explain the effect of the changes in the fat globule membrane during processing on the properties of finished dairy products.

This paper presents quantitative information on the changes in the concentration of the phosphatides associated with the fat globules caused by the various operations used in the processing of dairy products. Particular emphasis is centered on those operations utilized prior to desiccation in the production of foam-dried whole milk, since the chemical and physical basis for the unique properties of this material have been under extensive investigation in these laboratories for a considerable time.

MATERIALS AND METHODS

Total phosphatide concentration associated with the intact fat globules isolated by centrifugation was determined prior to each processing step. After processing, the phosphatide concentration in the centrifugally isolated fat phase was redetermined and compared with values obtained using untreated milk. All reported values of phosphatide concentration in the skimmilk fractions were obtained by difference.

All work was carried out using fresh morning milk from a herd at the Agricultural Research Center, Beltsville, Maryland. The milk was delivered to the laboratory in full, slosh-proof cans and standardized to 3.3% fat before experimental use.

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Centrifugation was used to isolate the fat phase from samples of fresh and processed milk. Concentrated or dried products were reconstituted to original solids concentration with distilled water before centrifugation. Unhomogenized samples were centrifuged in a field of 515 × G for 2 hr. at 4.4° C. All homogenized samples were centrifuged in a field 20,000 G for 1 hr. at 4.4° C. In these instances both the cream layers and the sediment were collected for phosphatide determinations.

Phosphatide was determined by assaying for phosphorus in the ash obtained from a sample of the lipids extracted by the standard Mojonnier procedure. Three extractions were used instead of the prescribed two. Approximately 3 g. of the extracted and dried lipid was used for each analysis. The accurately weighed samples mixed with 3 g. ashless filter papers were ashed in Vycor evaporating dishes at 550° C. The resultant ash was dissolved in 5 ml. of 1 : 1 HCl with H_2O v/v and quantitatively transferred to 100-ml. volumetric flasks. After bringing up to volume with distilled water, the phosphorus in 5-ml. aliquots was determined by the Kuttner and Cohen method (8). Optical densities of the colored solutions were determined, using a Klett-Summerson colorimeter equipped with a 5,000A filter. The phosphorus content of the extracted lipids in milligrams per gram fat was multiplied by 25.0 to give milligrams of phosphatide per gram fat (8).

In pilot plant operations use was made of a Cherry-Burrell Model CC35 spray pasteurizer, a Mallory type heater, and a Manton-Gaulin Model K3-75 homogenizer. Where required, milk was concentrated using a Rogers single-effect pan.

RESULTS

The effect of the temperature of the milk on the migration of phosphatides from the fat globule surface induced by simple stirring is shown in Table 1. These data were obtained by stirring samples of raw whole milk for 1 min. in a modified Waring blendor (3), at temperatures of 10, 20, 40, and 50° C. At 10° C. very little phosphatide moved from the fat globule surface during the stirring period. At 20° C. nearly 46% of the phosphatide initially associated with the fat phase had migrated into the aqueous phase. As temperatures were raised above this point, a slight but consistent decrease in migration was noted.

TABLE 1

Migration of phosphatides in milk during stirring at various temperatures

Treatment	Phosphatide concentration % total in cream	Phosphatide concentration % total in skim	% Total phosphatides migrating from cream during stirring period
No agitation 10° C.	64.4	35.6	0.0
1 min. stirring 10° C.	59.2	40.8	5.2
1 min. stirring 20° C.	34.9	65.1	29.5
1 min. stirring 40° C.	40.3	59.7	24.1
1 min. stirring 50° C.	40.9	59.1	23.5

TABLE 2

Migration of phosphatides in milk during pasteurization

Pasteurization	Mg. phosphatide/100 g. 3.3% fat milk					% Total phosphatides migrating from cream during pasteurization
	Whole milk	Cream		Skim		
		Raw	Pasteurized	Raw	Pasteurized	
145° F.—30 min.	20.4	14.1	11.2	6.3	9.2	14.2
145° F.—30 min.	21.0	13.6	11.2	7.4	9.8	11.4
145° F.—30 min.	19.8	13.2	9.9	6.6	9.9	16.7
145° F.—30 min.	19.7	13.6	10.2	6.1	9.5	17.3
165° F.—15 sec.	21.1	13.9	12.6	7.2	8.5	6.2
165° F.—15 sec.	22.8	14.2	13.2	8.6	9.6	4.4
165° F.—15 sec.	20.5	14.2	12.9	6.3	7.6	6.3
165° F.—15 sec.	19.8	13.9	12.9	5.9	6.9	5.1

Milk samples pasteurized by various time and temperature combinations may be bacteriologically similar but physically different. Table 2 presents data showing the extent of phosphatide migration from the fat globule surface during two different pasteurizing treatments. Even though the agitation in the spray pasteurizer was relatively mild, its extended duration effected more change than the short period of high turbulence encountered in the Mallory type heater.

Condensation in a single-effect evaporator exposes milk to violent agitation for considerable periods of time. This type of processing also causes a shift of phosphatide from the fat globules to the aqueous phase, as shown in Table 3. The longer evaporating times used to produce the 50% solids concentrates effected the greatest change. The variance in results obtained with different samples of milk can be correlated with the time required by the operator to obtain the stated solids concentration.

A study of the effect of homogenization on the distribution of phosphatides in milk was complicated because the treatment produces fat protein complexes which sediment in a centrifugal field (2). As the homogenization pressure increased, the amount of fat recovered as cream decreased (4). Table 4 shows the

TABLE 3

Migration of phosphatides during the condensation of milk pasteurized 165° F.—15 sec.

Treatment	Phosphatide concentration % total				% Total phosphatides migrating from cream during condensation
	Pasteurized milk		Concentrate		
	Cream	Skim	Cream	Skim	
Pasteurization plus condensation to 26% total solids	56.2	43.8	31.0	69.0	25.2
	55.6	44.4	46.0	64.0	19.6
	52.3	47.7	27.0	63.0	15.7
Pasteurization plus condensation to 50% total solids	49.1	50.9	21.1	78.9	28.0
	53.9	46.1	17.7	82.3	36.2
	53.5	46.5	19.0	81.0	34.5

TABLE 4

Change in distribution of phosphatides during the homogenization of milk before and after concentration

Processing	Phosphatide concentration (% Total phosphatides in milk)			Change in % total phosphatide in skim fraction during processing
	Cream	Sedimenting fat protein complex	Skim	
Untreated milk	65.1	0.0	34.9	0.0
Homogenized—2,000 p.s.i.	34.3	14.4	51.3	+16.4
Homogenized—4,000 p.s.i.	31.4	18.3	50.3	+15.4
Homogenized—6,000 p.s.i.	33.1	20.6	46.3	+11.4
Homogenized—8,000 p.s.i.	34.9	25.7	39.4	+ 4.5
50% solids concentrate homogenized—2,000 p.s.i.	30.9	22.9	46.2	+11.3
50% solids concentrate homogenized—4,000 p.s.i.	24.6	32.0	43.4	+ 8.5
50% solids concentrate homogenized—6,000 p.s.i.	26.3	61.7	12.0	−22.9
50% solids concentrate homogenized—8,000 p.s.i.	24.0	63.4	12.6	−22.3

effect of homogenization on the distribution of the phosphatides in milk. Low-pressure homogenization increases the phosphatide concentration in the aqueous phase. Higher pressures reduce the migration to the aqueous phase and increase the amount of phosphatide in the sedimenting fat protein complex. Homogenizing concentrated milk intensifies these effects, as shown. It is of interest that in single-strength milk homogenized at 8,000 lb. p.s.i. the phosphatide concentration in the skim is nearly the same as in untreated milk (Figure 1).

DISCUSSION

The migration of phosphatides from the fat globule surface zone to the aqueous phase apparently occurs to some extent whenever milk undergoes mechanical agitation. This effect, possibly first noted by Jenness (6), later studied in more detail and discussed by Greenbank and Pallansch (3), has recently been further verified by the work of Koops and Tarassuk (9).

These observations all serve to emphasize the fact that the design of dairy equipment can influence the physical structure of the products obtained therefrom. Those pieces of apparatus which subject the milk moving through them to the highest level of mechanical agitation should deplete the phosphatides associated with the fat globules to the greatest extent.

Whether this translocation of the phosphatides can serve as a basis for dairy product improvement is still open to question. However, Thurston and coworkers (12) definitely established the fact that homogenization at moderate pressures and stirring prevent the development of oxidized flavors in market

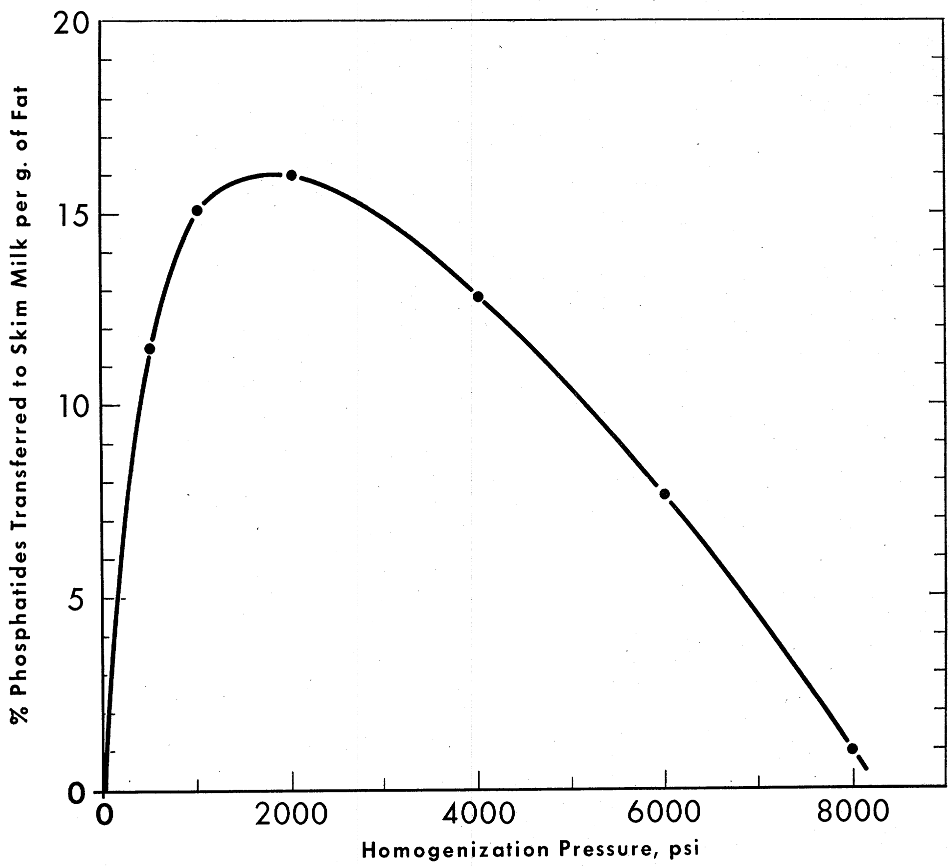

FIG. 1. The migration of the phosphatides of whole milk, with increasing homogenization pressures.

milk. Holm, Greenbank, and Deysher (5) found that milk powder made from homogenized milk had a longer storage life than similar products made from unhomogenized material. These latter authors assumed that the improved keeping quality resulted from a decrease in uncovered fat in the powder. In both instances cited, the observed increase in oxidative stability may have resulted from the redistribution of the phosphatides by the homogenization treatment employed (Figure 1).

It is possibly significant that some groups are presently improving the dispersibility of spray-dried whole milk by the addition of phosphatides to the product. It is possible that violent agitation of the milk during the processing steps prior to drying would achieve similar results.

Along with its practical aspects, the data presented in this paper have some theoretical significance. The relative ease with which phosphatides can be removed from the fat globule surface demonstrates that a large fraction of the phosphatides initially associated with the fat in fresh milk are held by weak forces.

The ordered picture of the fat globule surface, presented by some authors (7), in which a phosphatide film on the fat surface is covered by layers of protein to produce a fat globule membrane, can be questioned.

It is more reasonable to suspect that the bulk of the fat globule surface may be covered by a film of a highly surface-active protein whose exposed groups interact with phosphatides, and phosphatide containing protein-lipid complexes such as described by Morton (11). The force of mechanical agitation plus the thermal agitation present at moderate temperatures is sufficient to rupture a large percentage of these bonds.

When the surface of the fat phase is greatly extended by high-pressure homogenization a situation is created in which new lipid protein complexes are formed which again bind additional phosphatides.

The effect of phosphatide distribution on the properties of foam-dried and spray-dried whole milk, and the factors responsible for the formation of sedimentable phosphatide containing lipid-protein complexes during high-pressure homogenization, are being investigated in the Dairy Products Laboratory of the Eastern Utilization Research and Development Division.

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