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DISPERSIBILITY OF FOAM-DRIED FAT-CONTAINING MILK PRODUCTS

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SUMMARY

It was found that foam-dried whole milk could be stored for at least 1 yr. at 73° F. without losing its excellent dispersibility. However, some loss was found when the material was stored at 100° F. Forewarming at 190° F. for 2, 5, and 8½ min. caused no significant change in initial dispersibility, but after storage at 100° F. for 1 mo. the dispersibiltiy was found to vary inversely with the holding time used in forewarming. The foam-drying process was successfully extended to a lactose-enriched whole milk, an acid-modified whole milk, and a chocolate-flavored whole milk. Products of enhanced dispersibilty were prepared by this method when compared to commercially available materials of similar types.

The dispersibility of nonfat milk powders has not yet been matched commercially with dry whole milk. The fat content of whole milk, amounting to a minimum of 26% by weight of the dry product, poses many problems not found with dry nonfat milk. A foam-dried whole milk *(3)* possessing excellent dispersibility in ice water with spoon stirring has been produced successfully on a pilot plant scale in the Philadelphia Laboratory of the Eastern Utilization Research and Development Division of the Agricultural Research Service. The current paper discusses the effect of storage on the dispersibility of the foam-dried product made from flash-pasteurized whole milk, with and without additional heat treatment of the whole milk. The value of foam drying as a means for improving the dispersibility of other dry fat-containing milks is discussed.

RETENTION OF DISPERSIBILITY ON STORAGE

Storage tests were made on foam-dried whole milk containing 29.5% fat and 2½% moisture, crushed to pass through a 20-mesh screen, and packaged in cans under an atmosphere containing 98.5% N_2 and 1.5% O_2. The cans were stored at 38, 73, and 100° F. and evaluated for dispersibility after storage periods of 2 wk. and 1, 2, 4, 6, and 12 mo. Dispersibility rate curves *(3)* were used to evaluate the effect of storage on the dispersing property. The tests showed that the dispersibility of foam-dried flash-pasteurized whole milk remains unimpaired for at least 1 yr. at room temperature (see Table 1).

The reasons for this good dispersibility and its permanence are not fully understood. However, some of the contributing factors are as follows:

1. *Avoidance of protein alteration during processing.* That the proteins are not denatured is evidenced by ultracentrifugal tests [described in *(3)*] which show the whey proteins to have the same sedimentation pattern as those in fresh pasteurized milk (see Figure 1). As might be expected, the

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TABLE 1
Effect of storage at 73° F. for one year on dispersibility rate of foam-dried whole milk

Stirring time	Dispersibility rates	
	Fresh	Stored
(sec.)		
20	70.2	76.4
40	87.8	84.3
60	93.7	93.6
80	95.3	94.5
100	95.3	96.8
120	97.8	98.1
Mean dispersibilities	90.0	90.6

product contains only trace amounts of undispersed material by the ADMI solubility index test.

2. *Dispersion of the fat globules which remain discrete throughout processing and storage.* Microscopic examination of the fat in the concentrate before drying, and in the milk reconstituted from the dried stored product, shows no evidence of coalescing or clustering. The fat globules remain discrete and are of the same size as immediately after homogenization. They appear to be "bound," perhaps by physical-chemical means, within a matrix of readily dispersible material.
3. *The distinctive shape of the particles.* Unlike spray-dried particles, particles of crushed foam-dried milk are irregular in shape, have one very small dimension, are not powdery; hence, have little tendency to cake or ball-up in contact with water.

Storage at 100° F. impaired the dispersibility (as shown in Figure 2). After 1 mo. of storage there was a loss of about 5% in dispersibility with 2 min. of

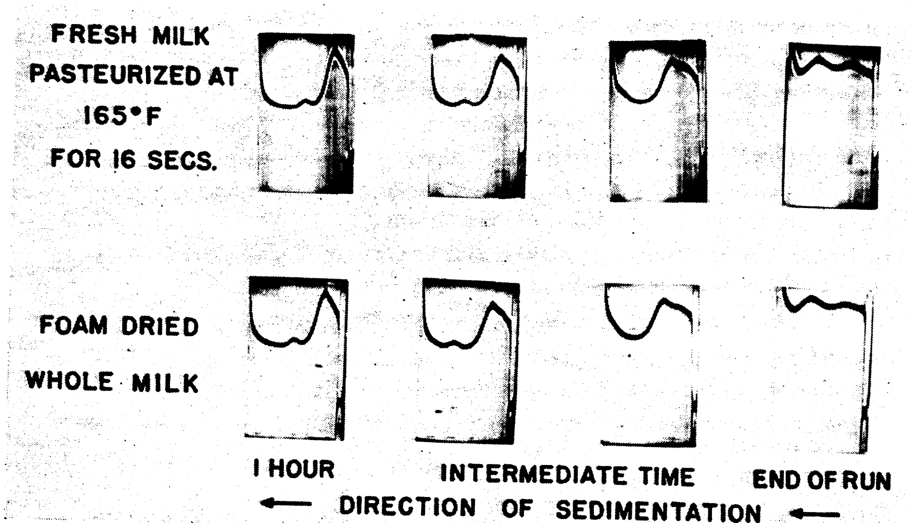

FIG. 1. Ultracentrifugal patterns of whey protein concentrates *(4)*.

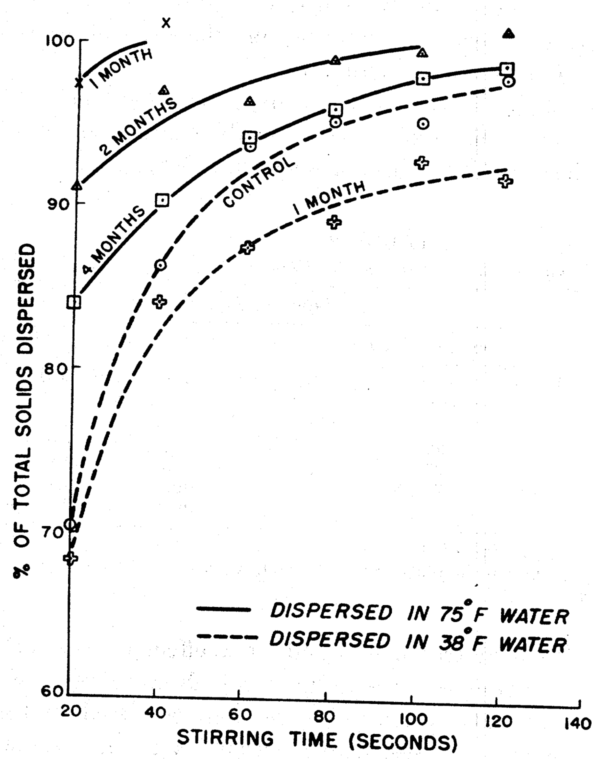

FIG. 2. Dispersibility rate changes with storage at 100° F.

stirring in 38° F. water. However, when 75° F. water was employed, which is the temperature normally used in dispersibility tests, complete dispersibility resulted after only 35 sec. of stirring. Even after 4 mo. of storage at 100° F., dispersibility in 75° F. water was excellent.

Microscopic examinations of the fresh and stored samples showed in both cases that the fat globules were imbedded in a milk solids-not-fat matrix. The only apparent change resulting from the storage was in this matrix. In the case of the stored sample, it disintegrated slowly in water. There was no evidence, however, of "fat migration," to which the well-known loss of dispersibility in some dry whole milks has been attributed. It appears probable that the loss in dispersibility is a consequence of protein insolubilization resulting from high-temperature storage.

EFFECT OF FOREWARMING

To determine the effect on dispersibility, heat treatments were given flash-pasteurized whole milk of 3.2% butterfat, using conditions favoring the development of sulfhydryl groups *(2)*. The milk, after deaeration, was quickly heated to 190° F. in a Votator[2] and held at that temperature for approximately 2, 5,

[2] Mention of companies and commercial products anywhere in this paper does not imply that they are endorsed or recommended by the Department of Agriculture over others of a similar nature not mentioned.

and 8.5 min., respectively, then quickly cooled to below 100° F. These three batches, and a control given no heat treatment beyond that of flash pasteurization, were foam-dried by the published procedure *(3)*.

These were nitrogen-packed in cans with an oxygen content below 1.5% and stored at 100° F. for 1 mo. Dispersibilities were determined in 38° F. water with 60- and 100-sec. stirring. The results are shown (Table 2).

TABLE 2

Effect of forewarming of whole milk on its dispersibility after foam-drying[a]

Heat treatment		Dispersibility (%)[b]					
		60 sec. stirring			100 sec. stirring		
Time	Temp.	Fresh	Stored[c]	Loss	Fresh	Stored[c]	Loss
(min.)	*(°F.)*			*(%)*			*(%)*
0	......	95.1	92.4	2.7	97.1	94.0	3.1
2.1	191	95.7	85.0	10.7	98.3	87.8	10.5
5.1	190	92.6	74.2	18.4	96.5	78.7	17.8
8.6	189	93.0	75.7	17.3	96.5	78.3	18.2

[a] All products contained 26% fat (MFB).
[b] Averages of data from four pilot-plant runs at each set of conditions.
[c] One month at 100° F.

It is apparent that the heat treatments had little effect on the dispersibility before storage. However, changes were induced which were responsible for a more rapid loss in dispersibility during storage than occurred in the product which had no heat treatment. The loss also increased with time of holding the heated milk. The losses in dispersibility were accompanied by a slight increase in insolubles suggesting that, as previously observed in the case of the unheated product stored at 100° F. (see Figure 2), loss in dispersibility was a consequence of protein insolubilization. It is important to avoid damage to the proteins if a dry *whole* milk of good dispersibility in ice water is to be produced. Damage may occur either during processing or on high-temperature storage of the dry product.

The importance of forewarming in improving the flavor stability of spray-dried whole milk is well known. The need of forewarming to protect against atmospheric oxidation during processing of foam-dried whole milk is unnecessary, because dehydration is carried out under high vacuum and low temperature, in contrast to the high-temperature oxidative conditions typically used in spray-drying. The latter conditions, coupled with the tenacious retention of entrapped oxygen within the spray-dried particle, create a different storage problem than is encountered with the foam-dried material. Moreover, preliminary tests using the forewarming conditions of Table 2 showed no improvement in the flavor stability of gas-packed, foam-dried material. The effects of forewarming and other factors on the flavor stability of the foam-dried product are currently under investigation.

The elimination of heat treatment (typically 180° F. for 30 min.) can pose a problem in controlling bacterial growth during operations. This can be overcome by the sound practice of using milk of low bacterial count and by processing rapidly with only short-time holdup at points where temperature favors bacterial growth. For example, in the foam-drying process it was proposed to concentrate the milk at 90° F. *(3)*. If this were done in a conventional recirculation type evaporator, the relatively long time required to concentrate the milk would favor the growth of bacteria. Thus, this operation could better be carried out in a single-pass evaporator, wherein concentration is accomplished in a matter of seconds. This has the added advantage of permitting higher evaporation temperatures without protein denaturation. Evaporators of this type are characterized by the mechanical agitation of the heat-sensitive film on the heated surface. They are manufactured domestically by at least two companies. Another single-pass evaporator of possible use here is one developed at the Eastern Utilization Research and Development Division for fruit juices *(1)*.

Thus, the foam-drying process would be carried out somewhat as shown in Figure 3.

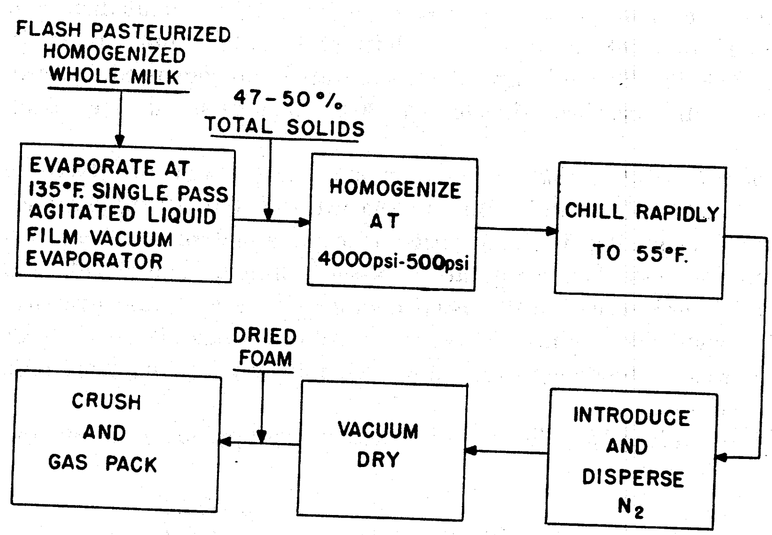

FIG. 3. Process for preparing foam-dried whole milk.

We have observed in the course of some 300 pilot-plant runs, drying whole milk, that when on rare occasions the solubility index was above about 0.1 cc., the otherwise excellent dispersibility of the dry whole milk was impaired. In contrast, it is well known that spray-dried *nonfat* milks of excellent dispersibility may contain 0.4 cc. insolubles or more. Similarly, in foam-dried nonfat milk, a higher level of insolubles can be tolerated without impairment of dispersibility than with dry whole milk. Therefore, the high-temperature processes commercially feasible with nonfat milk are at a disadvantage with whole milk.

Foam-drying of other fat-containing milks. Adaptation of the foam-drying process to fat-containing milks other than whole milk was shown to enhance the dispersibility of these products. They include a chocolate-flavored whole milk and infant foods such as lactose-enriched whole milk and an acid-modified whole milk. Table 3 gives pertinent drying data on these products. Evaporation temperature and the temperature and pressures of homogenization were, in all cases, the same as in the standard process for whole milk.

TABLE 3

Conditions used in foam-drying fat-containing milk products

Material whole milk	Total solids in concentrate	Drying			Product moisture
		Time	Max. temp.	Volume increase	
	(%)	*(min.)*	*(°F.)*	*(fold)*	*(%)*
Chocolate-flavored whole milk	50.70	207	107	32	1.33
Lactose-enriched whole milk	55.38	161	106	24	1.80
Acid-modified whole milk	40.85	118	114	10	1.03

1. *Chocolate-flavored whole milk.* A commercially available chocolate-flavoring powder composed of Dutch-processed cocoa, sugar, salt, an emulsifier, and flavorings was added to whole milk of 4.1% butterfat, 12.9% total solids, in the ratio of 1 to 25.8 lb. The mixture was evaporated, homogenized, gassed, chilled, foam-dried, and crushed through a 20-mesh screen in the usual manner *(3)*.

2. *Lactose-enriched whole milk.* Lactose monohydrate was dissolved in whole milk of 4.1% fat, 12.9% total solids, in the ratio of 1 to 19 lb. This resulted in a dry product similar in composition to commercial products of this type. The formulation was then evaporated, gassed, chilled, foam-dried, and crushed through a 20-mesh screen in the usual manner *(3)*, except that evaporation was carried beyond 50% solids. This was possible because at 50% solids the concentrate showed no tendency to gel and was more fluid than whole milk at the same solids content.

3. *Acid-modified whole milk.* The dry product was prepared from the following recipe:

	(lb.)
Whole milk (4.1% fat, 13.0% solids)	41.24
Dextrins-maltose	1.21
Sucrose	1.21
Corn starch	0.83
Lactic Acid (85% soln.)	0.24

The resulting dried product was similar in composition to commercial products of this type. The milk was warmed to 90° F. and the ingredients added with stirring. Curdling occurred just before all of the acid had been added. In spite of this, the formula was processed in the usual manner *(3)*, except that evaporation was carried only to about 41% solids, due to the high viscosity of the concentrate at that point. A subsequent experiment showed that a solids content of about 38% yields a foam of more desirable physical form than was obtained in the present instance.

Dispersibility of the dry materials. Figure 4 contains dispersibility rate curves for the three foam-dried products and, in the cases of the infant foods,

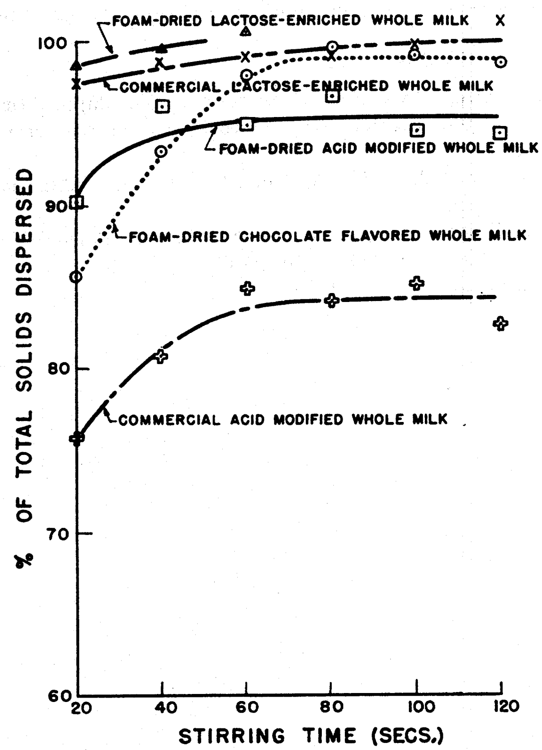

FIG. 4. Dispersibility rates of dry fat-containing milk products.

for commercially available products of similar compositions. These curves were obtained by use of the dispersibility rate test as previously published *(3)*, with the following exceptions:

1. The weight of the dry chocolate-flavored whole milk was increased from 15 to 17.4 g. per 90 cc. of water. This was done so that its dispersibility curve would be based on the solids content of a typical chocolate-flavored whole milk.
2. The infant foods were dispersed in water at 100° F. instead of the usual 38° F., because in household practice water at or above the former temperature would normally be used for reconstituting products of these types.

The curves show that foam-drying can be advantageously applied to these materials. The curves show that a dry chocolate-flavored whole milk of excellent dispersibility may be prepared by foam-drying. The results suggest the application of foam-drying to whole milk flavored with fruit juice concentrates, essences, honey, or other natural flavors. The authors are currently investigating this.

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