pollution control

STABILIZATION OF MILK FAT/CHEESE WHEY EMULSIONS

produces nutritious snack spread, reduces environmental pollution

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Fig. 1—**NUTRITIOUS SNACK SPREAD** *made from cheese whey has a mild, cheesy, slightly sweet, butter-like taste*

□ INABILITY TO FULLY UTILIZE all components of the milk now being produced in the United States is creating serious problems for the dairy industry. The Federal Government buys over 170 million lb of surplus butter annually as part of its milk price support program (Economic Research Service, 1970), and an estimated 14.75 billion lb of fluid cheese whey is being disposed of as waste each year (Anderson, 1970).

WASTE CAUSES POLLUTION

This manner of whey disposal results in large-scale loss of valuable nutrients, overtaxing existing sewage systems and causing direct environmental pollution. Continuation of these operations is undesirable, so better utilization methods are being sought.

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Fig. 2—**FLUID CHEESE WHEY** *is blended with either cream or a mixture of butteroil and nonfat milk, and the blend is then pasteurized, homogenized, and concentrated to produce the spread*

Previous work (Barker, 1968; South Dakota State University, 1968) indicated that low-fat, butter-like products could be made from a properly stabilized and flavored emulsion containing milk solids and a variety of fats and oils. These products, containing about 40% moisture, were made by direct homogenization of concentrated materials. Hull (1955) concentrated a blend of delactosed whey, sugar, and vegetable or animal oil to 75–80% solids content for use in bakery goods and ice cream.

This paper describes the production and properties of food-grade oil-in-water emulsions of milk fat in concentrated sweet Cheddar cheese whey. Cream or butteroil can be used as the source of fat. The emulsions are spreads that are butter-like in appearance and have a unique flavor and plasticity which consumers should find likeable (Fig. 1).

RAW MATERIALS PREPARED

The raw materials were prepared as follows:

- **Sweet Whey.** Sweet wheys were obtained as a by-product from standard Cheddar cheese manufacturing operations. On the average, the various lots of wheys used contained 6.6% total solids, consisting of 5.0% lactose, 0.8% protein, 0.7% ash, and 0.1% fat. The pH varied from 6.1 to 6.3. After fat was removed by centrifugation, the wheys were pasteurized at 165°F for 15 sec.
- **Cream.** Samples of cream containing approximately 45% fat were separated from fresh, raw milk and were pasteurized at 165°F for 30 min.
- **Butteroil.** Cream containing 30% fat was passed twice through a Clarifixator to break the emulsion. Butteroil was then separated from the aqueous phase by centrifugation at 170°F. After being heated to 190°F, the oil was flashed into a vacuum chamber having an internal pressure of 25–28 in Hg to remove water. The final product was 99.5% pure milk lipid.

EQUIPMENT DESIGNED

The equipment used to produce the spreads consisted of a 100-gal mixing tank, a high-pressure pump, a Mallory heater, a homogenizing valve, and an evaporator, all connected in the stated sequence. A gauge mounted on the pump indicated the pressure required to move the product through the tubular heater and the homogenizing valve.

The evaporator was a falling-film evaporator of Wiegand design, custom-built by Arthur Harris & Co. The tube chest of the evaporator was partitioned to allow temperature control of the upper and lower sections of the condensing tubes.

Provisions were made to either draw off the product immediately after condensing, or recycle the concentrate through the heater, homogenizer, and evaporator.

SPREADS PRODUCED

In general, the procedure for producing the spreads was as follows:

Fluid cheese whey was mixed (Fig. 2) with cream or with 9 parts butteroil and 1 part nonfat dry milk. Salt and emulsifier were also added. The mixture was pasteurized at 170°F for 20 sec, homogenized at 2,500–500 psi, and then partially condensed by passing once through the evaporator at the rate of 800 lb/hr. The upper and lower sections of the evaporator tube chest were maintained at 170°F and 150°F, respectively.

Potassium sorbate was added to the collected concentrate at this point, and the mixture was then continuously cycled through the Mallory heater (set to hold at 140°F for 20 sec), the homogenizing valve, and the evaporator. During recycling, the temperatures of the upper and lower sections of the evaporator tube chest were decreased to 160°F and 140°F, respectively.

As water was removed and the material became progressively more viscous, the back pressure on the pump increased. Within a half hour, the combined back pressures in the system reached 5,000 psi. At this point, the homogenizing valve was completely opened. Then the material continued to cycle in the evaporator-heater loop until the total back pressure from the tubular heater reached 5,500 psi. The homogenizer gauge was thus used as a crude viscometer to control the concentration.

The finished thick, viscous concentrate was col-

Fig. 3—**ALPHA LACTOSE HYDRATE CRYSTAL SIZE** *is dependent on fat/solids nonfat ratio. Left to right, at 220x magnification: 0.83, 1.0, and 1.2 ratio spreads*

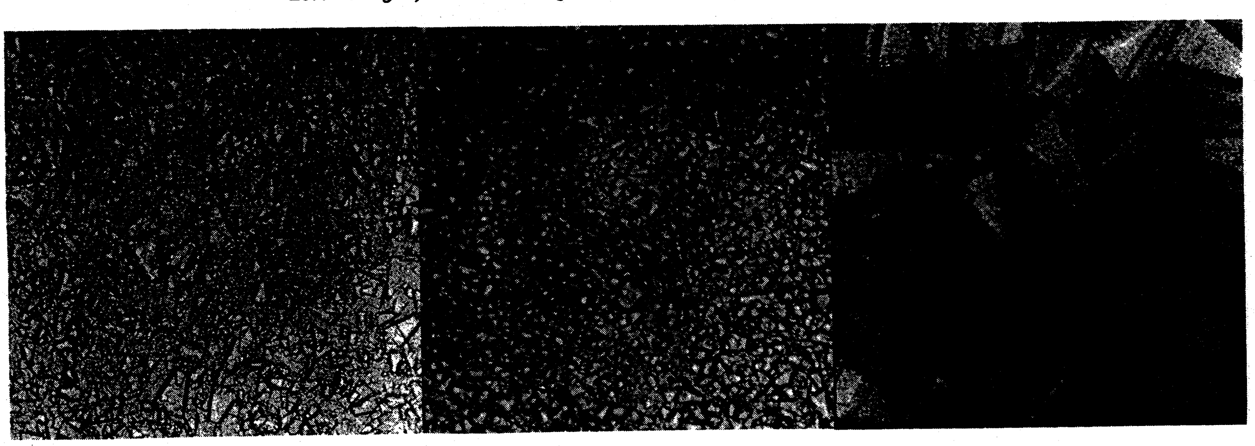

Table 1—EFFECT OF PROCESSING CONDITIONS on stability and on protein adsorption by fat

Sample	Processing conditions[a]	Moisture, %	Protein adsorbed by fat, %	Stability, cc of oil leakage[b] After 2 days	After 7 days
A	CH whey (36% solids) plus cream	26.1	40.2 ± 1.4[c]	2	–
B	CH whey (56% solids) plus cream	22.9	48.3 ± 1.4	3	–
C	SPH[d] whey (6.6% solids) plus cream	24.1	43.5 ± 2.0	5	–
D	CH whey (6.6% solids) plus cream	25.4	53.4 ± 2.0	–	0
E	CH whey (6.6% solids) plus cream[e]	28.0	54.0 ± 2.0	–	0
F	SPH[f] whey (6.6% solids) plus cream	25.0	52.7 ± 2.0	–	0
G	CH whey (6.6% solids) plus butteroil and nonfat milk	28.3	56.0 ± 2.0	–	0

[a] Continuously homogenized (CH) at 2,500–500 psi while condensing except as noted
[b] At room temperature
[c] Standard error of the mean
[d] Single-pass homogenization at 2,500–500 psi
[e] Fat/solids nonfat ratio of 1.2; all other samples had a ratio of 1.0
[f] Single-pass homogenization at 4,500–500 psi

lected in 10-oz plastic containers or in cylindrical polyethylene-lined paperboard containers and stored at 45°F. By 2 days of storage, it had reached its characteristic consistency.

Samples were also prepared by a single-pass homogenization of the fluid whey and fat at both 2,500–500 psi and 4,500–500 psi, followed by condensation to the desired moisture content.

PRODUCTS ANALYZED

A typical finished product contains 34–37% cream fat, 33–36.3% whey solids, 25% moisture, 4% milk or cream nonfat solids, 0.5% mono- and diglycerides (emulsifier), 0.1% potassium sorbate, and 0.1–1.0% total salt (to suit the taste).

Mojonnier total solids as an index of moisture, total fat (Roese Gottlieb), total plate count, and coliform count were determined on spreads by standard methods (Milk Industry Foundation, 1949). A typical analysis of a spread with a 1.0 fat/solids nonfat ratio is as follows: 37.5% fat, 27.8% lactose, 25.0% moisture, 5.6% protein, and 3.6% ash. Products can be produced with zero coliform count and as low as 5,000 total bacteria/g.

PROCESS AFFECTS STABILITY

The effect of various processing conditions on the stability of milk fat-cheese whey emulsions and on the protein adsorption by the fat was studied.

To determine the degree of fat stability of a spread, 170 g of the spread was loosely placed in a 10-oz plastic cup and covered. The amount of oil leaking out of the spread within 2–7 days at room temperature was noted as an indication of instability.

The amount of protein adsorbed by the fat in the spreads was determined by measuring the amount of nitrogen removed with the fat by centrifugation (78,000 × G for 30 min) from a dispersion of the spread in water (Rowland, 1938). Dispersions containing 12.5–13.5% total solids were made in a Waring Blendor set at low speed for 45 sec. Necessary corrections for non-protein nitrogen in the whey and for total fat recovered were made.

Table 1 shows the results of this study. Products A and B were made by first concentrating the whey to 36% and 56% solids, respectively, adding 45% fat-containing cream, then continuously homogenizing the blend and concentrating in vacuo. Product C was homogenized only once (single pass) at 2,500–500 psi before being condensed.

These 3 products received less homogenization than products D and E, which were continuously recycled. The less-homogenized samples were not as stable as the more-homogenized samples and had less than 50% protein adsorbed by the fat.

The higher homogenization pressure used with product F, which was homogenized only once, undoubtedly improved the stability. Sample G, made from butteroil and nonfat milk, had 56% of its protein adsorbed by fat and showed good stability.

PRESSURE AFFECTS PARTICLE SIZE

The effect of homogenization pressure on fat particle size was determined using mixtures of fluid whey and 45% fat-containing cream with a fat/solids nonfat ratio of 1.0. A Manton Gaulin pilot-scale homogenizer was used, and particle size was determined by use of a Coulter Counter (Cornell and Pallansch, 1966).

Table 2 shows that homogenization decreases particle size, up to a point. The effect of very high pres-

Table 2—EFFECT OF HOMOGENIZATION PRESSURE on fat particle size and on protein adsorption by fat[a]

Homogenization pressure, psi	Median particle size, microns	Protein adsorbed by fat, %
None	4.20[b]	29.8 ± 2.0[c]
1500–500	0.97	41.4 ± 2.0
2500–500	0.82	44.5 ± 2.0
3500–500	0.86	44.2 ± 2.0
4500–500	1.02	50.6 ± 2.0

[a] Fat/solids nonfat ratio of 1.0
[b] Source: Cornell and Pallansch (1966)
[c] Standard error of the mean

Table 3—EFFECT of FAT/SOLIDS NONFAT RATIO on various product characteristics

Fat/solids nonfat ratio	Moisture, %	Calculated concentration of lactose, %	Degree of sandiness due to lactose	Protein absorbed by fat, %	Stability, cc of oil leakage in 2 days
0.83	29.1	48.2	none	51.9 ± 2.0[a]	none
1.00	25.4	50.8	none	53.4 ± 2.0	none
1.20	28.0	45.2	excessive	54.0 ± 2.0	none

[a] Standard error of mean

sure on particle size is not well understood. The increase in particle size as homogenization pressure is increased may be due to clumping of particles under high stress.

Protein adsorption by fat was also studied as a function of homogenization pressure (Table 2). The amount of protein adsorbed by fat increases with increasing pressure in the range studied. Significant amounts of protein equivalent to that found in cream are associated with the fat globules in an unhomogenized mixture of cream and whey.

RATIO AFFECTS CRYSTAL GROWTH

The fat/solids nonfat (F/SNF) ratio and the moisture content of the spread affect the size of the lactose crystals, or the degree of graininess. Above 26.5% calculated moisture content, with an F/SNF ratio of 1.2, large lactose crystals form, and the product becomes very sandy to the palate. Its lactose hydrate crystals are also large.

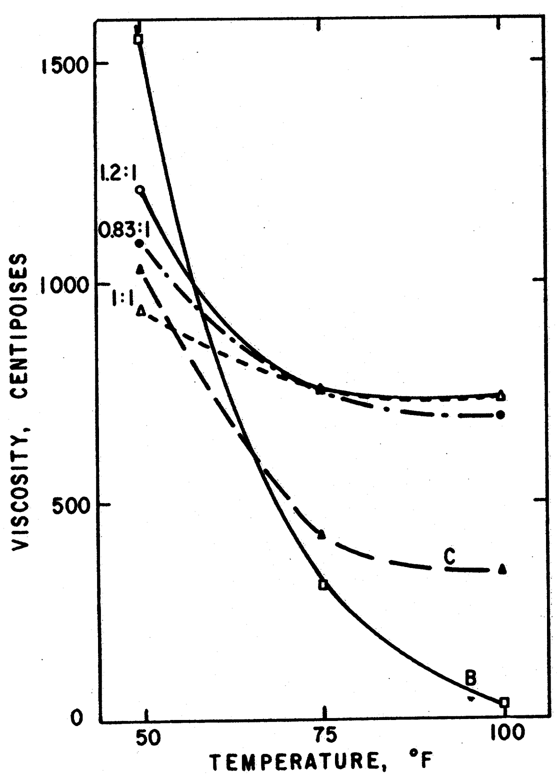

*Fig. 4—**FAT/SOLIDS NONFAT RATIO** has little effect on viscosity of spreads; the spreads are less affected by temperature than are commercial butter (B) and cream cheese (C)*

Only when the moisture level is increased above 28.0–28.5% in a 1.0 F/SNF ratio spread and above 30% in a 0.83 F/SNF ratio spread do the products become excessively sandy. These moisture levels correspond to a 47% level of lactose. Above this concentration, the growth of numerous small lactose crystals undetectable to the palate occurs. Below this concentration the crystals become large.

As the F/SNF ratio increases, less moisture is required to lower the concentration of lactose below 47%. Table 3 shows that, depending upon the moisture level, varying the F/SNF ratio from 0.8 to 1.2 affected only the crystal size. The spreads studied were all stable, and their fat adsorbed much the same amount of protein. Note that with the F/SNF ratio of 1.2, the concentration of lactose was only 45.2%, and consequently the spread had a sandy consistency.

Figure 3 shows the alpha lactose hydrate crystals in the 3 samples from Table 3 at 220x magnification. Note the large size of the crystals, estimated to be 30–50 microns across, in the sample with 1.2 F/SNF ratio. The crystals in the other 2 samples are much smaller, for the most part ranging from 10 to 20 microns across.

LITTLE EFFECT ON VISCOSITY

Viscosities of these 3 formulations were determined using a Haake Rotoviscosimeter equipped with a plate cone device (PK I). Glycerine was used to standardize the instrument, and temperature control was achieved by use of a constant-temperature water bath.

Since the materials studied were non-Newtonian and exhibited decreasing viscosity with increasing shear rate, relative values were obtained by rotating the cone at a constant speed of 81 rpm, producing a shear rate of 2,502 sec^{-1}. Four readings were taken at 15–30 sec after stirring and were averaged.

Figure 4 shows that the 3 formulations, with F/SNF ratios of 0.83, 1.0, and 1.2, are close to one another in viscosity and are affected less by temperature than are commercial butter and cream cheese, especially in the range from 60 to 100°F.

USE OF EMULSIFIER RECOMMENDED

The products listed in Tables 1, 2, and 3 all contained 0.5% added emulsifier (Atmul® 84 mono- and diglycerides) and 0.1% added NaCl. Figure 5 shows the effect that adding emulsifier has on spreads with F/SNF ratios of 0.83 and 1.0. The products with emulsifier were softer and spread more easily than those without emulsifier.

The 1.0 F/SNF ratio spread without emulsifier was viscous enough to cause high back pressure within

Table 4—EFFECT OF EMULSIFIER on various product characteristics

Fat/solids nonfat ratio	Source of fat	Emulsifier[a] added, %	Moisture, %	Texture	Protein adsorbed by fat, %	Stability, cc of oil leakage in 7 days
1.0	Cream	0	29.5	sandy	46.9	trace
1.0	Cream	0.5	30.5	sandy	46.5	trace
0.83	Cream	0	26.2	smooth	49.6	0
0.83	Cream	0.5	26.5	smooth	51.9	0
1.0	Cream	0	28.0	slightly sandy	50.0	1
1.0	Cream	0.5	26.2	smooth	45.0	0
1.0	Butteroil	0	22.5	smooth	20.1	12
1.0	Butteroil	0.5	20.9	smooth	17.4	4

[a] Atmul® 84 mono- and diglycerides

the system, even though the moisture level of the spread was high (29.5%), as shown in Table 4. With emulsifier, lower viscosity was obtained at a comparable moisture level (30.5%). The 0.83 F/SNF ratio spreads with and without emulsifier also had similar moisture levels (26.5% and 26.2%, respectively).

The 1.0 F/SNF ratio spreads had a high enough moisture level to make the texture sandy, but the 0.83 F/SNF ratio spreads were produced with low enough moisture to prevent large lactose crystal growth.

Table 4 summarizes the results of tests on these 4 formulations, as well as 4 other preparations, 2 of which were made with butteroil instead of cream. These last 4 preparations were all collected at the same back pressure in the system (5,500–6,000 psi).

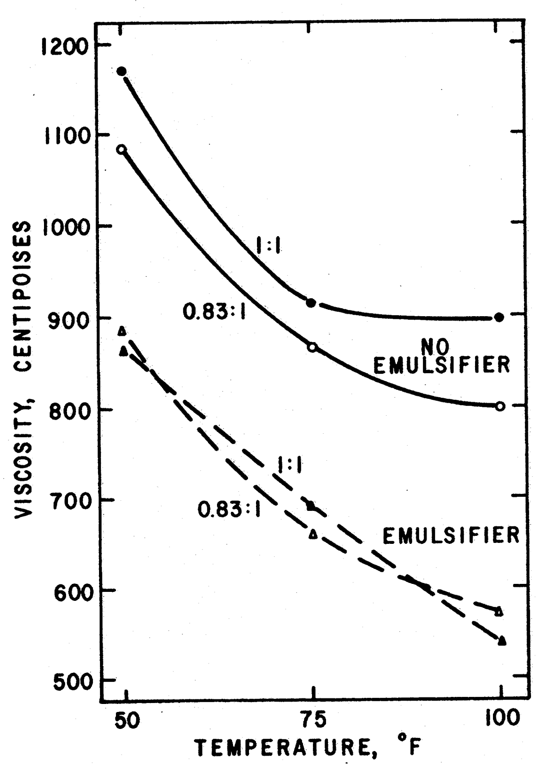

Fig. 5—**ADDITION OF EMULSIFIER** *reduces viscosity of spreads*

The effect of emulsifier on the amount of protein adsorbed by fat is not conclusive. Note that butteroil adsorbs much less protein than does the fat in the cream system.

Since some of the spreads containing emulsifier were slightly more stable and spread more easily than those without, the addition of this material is recommended.

SPREADS EVALUATED ORGANOLEPTICALLY

Spreads were organoleptically judged by 16–20 members of the Dairy Products Laboratory (DPL), using the 9-point hedonic scale (Peryam and Pilgrim, 1957). Fifteen-gram samples were placed in waxed cups and brought to room temperature for half an hour before serving. The panel members spread the products on salted soda crackers for evaluation of both texture and flavor. The samples were randomly presented in the afternoon in the DPL panel room, and the data were treated statistically (Snedecor, 1959).

In these studies, the experimental samples were compared to one brand of commercial cream cheese purchased the day before the evaluation. The cream cheese scores were consistently higher and more uniform than the experimental samples. The cream cheese was softer (as Fig. 4 shows) and had a somewhat pleasing acid taste.

No explanation is readily apparent for some of the experimental samples having lower texture scores than others. Occasional comments were made that the experimental samples were too hard.

The addition of 0.5 or 1.0% salt to the spreads had no significant effect on the panel scores, although the taste of even 0.5% salt was quite pronounced. The salt was blended directly into 4- to 6-lb lots of the freshly processed spread before it cooled and hardened. A level of 0.1% added salt was arbitrarily chosen as being most suitable.

SPREADS ARE STABLE

Results of storage tests show that the spreads can be held at room temperature for over a week with no loss of panel acceptability or change in pH and can be stored up to 4 mo at 45°F with no significant loss of flavor or texture rating. Beyond 4 mo, slight-to-moderately oxidized flavors may develop.

The spreads are not stable if frozen. After 2 wk at 5°F, the spreads become mealy when thawed. Many initially expel water and oil after thawing 1–2 days. They are as physically stable when stored for several days at 70°F as at 98°F. However, the spreads stored at 98°F soon acquire a strong cheese flavor.

Provided the moisture level is in the optimum range, the products have a smooth texture which does not change if they are stored at 45°F in closed containers. On exposure to air, the products case-harden, turn slightly darker on the surface, and lose moisture at room temperature under average humidity conditions. These changes can easily be circumvented by packaging in plastic tubs.

BUTTEROIL MAY BE USEFUL

An equal weight of 9 parts butteroil and 1 part nonfat milk solids can be used in place of 45% fat-containing cream. The spread made with this mixture has satisfactory consistency, stability (Table 1), and panel acceptability.

It is generally more economically advantageous to use cream instead of butteroil. However, milk fat may best be stored as butteroil if it must be held for a considerable length of time before manufacturing the spread.

PRODUCTS SUITABLE AS SNACK SPREADS

The products have a mild, cheesy, slightly sweet, butter-like taste. They do not melt and should not be considered a substitute for butter or oleomargarine. They are most acceptable as a cracker or snack spread. Other uses are also being studied.

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