A STUDY OF PHYSICAL PROPERTIES OF DAIRY WHIPPED TOPPING MIXTURES

ABSTRACT
The effects of several selected variables on the physical properties of whipped topping containing milk as the major ingredient were investigated. These included: level of stabilizer and emulsifier, type of milk protein fraction, homogenization pressure, and interaction among selected ingredients. Levels of stabilizer and emulsifiers were highly critical factors affecting firmness and overrun of whipped topping. Overrun and firmness were influenced more by type and combination of the emulsifiers than by HLB. Topping mixtures containing sodium caseinate and whey protein lacked firmness and overrun, while those containing skim milk proteins separated by Sephadex gel filtration or precipitated by CMC were rated satisfactory. Overrun and firmness of the product increased as single stage homogenization pressures increased from 0 to 210 kg/cm². With double stage homogenization, firmness attained a maximum at 140 and 35 kg/cm², then tended to remain constant. Overrun, however, continued to increase with pressures up to 210 and 35 kg/cm². Overrun and firmness of the whipped topping decreased when fat globules exceed 2 μm. Factorial experiments involving three levels of fat, Frodex 24, and Dariloid KB indicated that each reacted independently in contributing to overrun and firmness. Decreasing size and increasing number of air cells are associated with increased overrun and firmness.

INTRODUCTION
IN RECENT YEARS there has been a proliferation of products made and sold in semblance of normal dairy products. The most widely accepted of these are nondairy coffee whiteners and whipped toppings. Commercial interest in these products has been stimulated by (a) economic considerations, especially the replacement of milk fat with lower cost vegetable fat, and (b) possibilities of improved physical characteristics such as uniformity and storage stability through the use of additives not generally permitted in the natural products.

Factors influencing the properties of whipping cream have been extensively investigated. However, most investigations (Smellie, 1966; Sommer, 1946) have been limited to products conforming to legal standards of identity, thus restricting their scope. Even though a great deal of research work has been done by commercial research laboratories on nondairy type whipped toppings, information is not generally made available (Knightly, 1968).

The primary objective of this investigation was to study the effect of several selected variables on the physical characteristics of whipped topping mixtures utilizing the constituents of milk as major ingredients. The variables studied include: (1) level of stabilizer and emulsifier; (2) type of milk protein fraction; (3) homogenization pressure; and (4) interaction among the selected ingredients.

MATERIALS & METHODS
FOLLOWING A REVIEW of the literature and preliminary studies on trial formulation, the basic formula was adopted:

- 15.0% milk fat (from 35% cream)
- 5.5% nonfat milk solids (balance from nonfat dry milk)
- 10.0% sucrose (beet sugar)
- 7.0% corn syrup solids (Frodex 24, American Maize Products Co.)
- 0.3% Dariloid KB (Kelco Co.)
- 0.05% carrageenan (Genulacta K-100, Stein Hall & Co.)
- 0.24% Tween 65, 0.16% Tween 60 (ICI, United States)
- 0.20% PGM P-06 (propylene glycol monoester, Distillation Products, Inc.)

For the preparation of whipped topping, the required amounts of Frodex 24, sucrose, nonfat dry milk, Dariloid KB, and carrageenan were thoroughly dry blended. Dry blends were added to warm cream (55°C) with agitation and then about one-half of the total required water was added. The emulsifiers and the PGM P-06 were melted in a hot water bath (71–81°C) and added to the warm (55°C) mixes. The balance of the required water was added to standardize mixes. The mixtures were pasteurized at 71°C for 30 min or equivalent and homogenized at the same temperature with a 125-F Manton Gaulin homogenizer at a pressure of 140 + 35 kg/cm² (2 stage). The homogenized sample was cooled to 5°C or below and aged 24 hr at 2°C prior to whipping. The mixtures were whipped for 2 min with a Hamilton Beach Kitchen-type electric mixer (Model 8FM-127A) at full speed at 21°C.

The overrun was determined by the following formula:

\[ \% \text{overrun} = \frac{W_2 - W_1}{W_1} \times 100 \]

where \( W_1 \) = weight of a given volume of whipping mixture and \( W_2 \) = weight of the same volume after whipping.

Firmness of the product was measured by the Brookfield Synchro-Lectric model HBT viscometer mounted on a Helipath stand. The force required to drive a 4.8 cm T-bar spindle at 50 rpm while descending through the whipped product at a constant rate was measured just after whipping in a temperature controlled room maintained at 21°C. Duplicate readings were made. Firmness was judged to be satisfactory by a panel of five judges who were familiar with whipped toppings when viscometer readings were above 18. Microscopic evaluation of the foam structure followed the method of Berry et al. (1965).

RESULTS & DISCUSSION
THE SELECTION of Dariloid KB as the stabilizer for this investigation does not imply that certain other commercial blends of stabilizers may not have been equally satisfactory. In order to determine the optimum level of Dariloid KB, whipped topping mixtures were prepared in which the level was varied from 0.1–0.5% in increments of 0.1%. Stabilizer level markedly affected overrun and firmness (Fig. 1). Levels of stabilizer below 0.3% resulted in very unsatisfactory whipped products. Overrun reached a maximum at a stabilizer level of 0.3%. In some instances there was a tendency toward slight whey separation, but it was found that this could be eliminated by adding as little as 0.04% carrageenan to the topping mixture.
ICI (1971) introduced a systematic method of classifying emulsifiers according to their hydrophilic and lipophilic balance (HLB). In an attempt to determine the effect of the HLB of emulsifiers on whipping properties, combinations of selected "polysorbate" type emulsifiers were utilized in securing a range of HLB numbers.

With the total concentration of Tween 60 (polyoxyethylene sorbitan monostearate) (HLB 14.8) plus Tween 65 (polyoxyethylene sorbitan tristearate) (HLB 10.5) held constant at 0.4%, ratios of the two were calculated to yield HLB numbers of 10.5, 12.0, 13.5 and 14.8. Similarly, combinations of Tween 65 and Tween 80 (polyoxyethylene sorbitan monooleate) (HLB 15.0) were determined which yielded HLB numbers of 10.5, 12.0, 13.5 and 15.0.

Experimental results shown in Figure 2 indicated that overrun and firmness of the whipped topping were influenced more by type and combination of the emulsifiers than by HLB. Tween 65 and Tween 80, either alone or combined, yielded lower overrun and firmness values than did a combination of Tween 60 and Tween 65 which yielded HLB numbers between 12.0 and 13.5.

Flavor evaluation of whipped topping containing 0.4% each of Tween 60, Tween 65, and Tween 80 revealed that the products containing Tween 60 and Tween 80 were bitter. However, no bitterness was detected in whipped toppings containing 0.4% of Tween 65, which either alone or combined with Tween 60 or Tween 80 yielded HLB values up to 12.0. Above an HLB of 12.0, the degree of bitterness increased with the higher proportion of Tween 60 in the blend.

The effect of concentration of emulsifiers on whipping characteristics is shown in Figure 3. The ratio of Tween 60 to Tween 65 was held constant at 2:3 to yield an HLB number of
The results show that overrun and firmness increased rapidly as concentration was increased from 0.2 to 0.4% and tended to level off at a concentration of 0.5%. A concentration of 0.4% is not only the legal limit but also appears to yield nearly optimal results.

The effect of emulsifier concentration on size and appearance of air cells of whipped product is shown in Figure 4. It is evident that air cell size decreased and air cells became more numerous as emulsifier concentration increased from 0.2 to 0.4%. Increasing the concentration from 0.4 to 0.6% caused little apparent change in air cell structure. A relationship between air cell structure, overrun and firmness is evident; that is, decreasing size and increasing number of air cells of whipped products are associated with increased overrun and firmness.

The protein in whipped topping is believed to act as a film-forming agent that affects the strength and resiliency of the film that surrounds the entrapped air. The protein also helps stabilize the fat against churning and thereby aids in providing strength to the film that surrounds the entrapped air (Knightly, 1968). The effect of different milk protein fractions was investigated. Those selected were skim milk colloid and whey proteins separated by Sephadex gel filtration (Morr et al., 1967), CMC precipitated milk protein (Cluskey et al., 1969), sodium caseinate and nonfat dry milk.

The data in Table 1 reveal marked differences in the effect of the various proteins on overrun and firmness. The products containing sodium caseinate and whey protein were judged as unsatisfactory with respect to overrun and firmness.

It was postulated that the state of dispersion of the proteins from various sources may account for variations in their performance in whipped toppings. Undoubtedly, casein in the form of sodium caseinate would exist in the whipped topping mixture as smaller particles than the calcium caseinate micelles from natural milk sources (Morr, 1969). The process used in the manufacture of sodium caseinate results in nearly complete removal of all the native Ca++ present in milk. Therefore, the effect of Ca++ in whipped toppings containing the different sources of added milk proteins was investigated. Ca++ was increased by adding CaCl₂ solution (50 mg Ca++/ml) prior to whipping. The results indicated that additions of 50 and 100 mg Ca++/100g of whipped topping containing sodium caseinate caused increases in overrun and firmness of the whip. However, these increases did not result in the magnitude of overrun and firmness attained when utilizing either skim milk colloid protein or CMC milk protein complexes. The addition of 150 mg Ca++/100g of topping mixture caused a marked increase in overrun, although the firmness of the whipped product was slightly greater than that of the control. Addition of calcium to topping mixtures containing all of the other sources of

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**Table 1—The effect of different milk protein fractions on the overrun and firmness of whipped topping**

<table>
<thead>
<tr>
<th>Source of protein</th>
<th>Added protein (%)</th>
<th>Overrun (%)</th>
<th>Firmness (viscometer reading)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium caseinate protein</td>
<td>1.5</td>
<td>116</td>
<td>10.0</td>
</tr>
<tr>
<td>Whey protein</td>
<td>1.5</td>
<td>124</td>
<td>15.0</td>
</tr>
<tr>
<td>Nonfat dry milk (low heat)</td>
<td>1.5</td>
<td>193</td>
<td>23.5</td>
</tr>
<tr>
<td>Skim milk colloid protein</td>
<td>1.5</td>
<td>181</td>
<td>24.5</td>
</tr>
<tr>
<td>CMC milk protein complex</td>
<td>1.5</td>
<td>184</td>
<td>24.5</td>
</tr>
</tbody>
</table>

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Fig. 4—The effect of emulsifier concentration upon the air cell structure in whipped topping. (A) 0.2%; (B) 0.3%; (C) 0.4%; (D) 0.5%; (E) 0.6%. Scale: 100µL.
added milk proteins resulted in decreased overrun and firmness of the whip in every instance.

It is pertinent to note that the casein separated from skim milk by either Sephadex gel filtration or CMC precipitation is in the form of calcium caseinate micelles similar to those in the original milk system. Since the results of the above experiments show these sources of milk protein to be superior to sodium caseinate for use in the whipped topping mixtures of the type employed in this study, a potential practical use for the former is suggested, should they become commercially available.

The effect of various single and double stage homogenization pressures on overrun and firmness of a topping formulation is shown in Figure 5. With single stage homogenization, both the overrun and firmness of the whip increased with increasing pressure. At the pressure of 175 kg/cm², overrun has approached maximum but firmness was still increasing although at a decreasing rate. When double stage homogenization was employed, firmness attained a maximum at 140 and 35 kg/cm², but then tended to remain constant. Overrun, however, continued to increase with pressures up to 210 kg/cm² and 35 kg/cm².

Measurements of fat globule size indicated that at pressures of 140 kg/cm² or higher, practically all globules were below 2 μm in diameter. It appears that fat globule diameters in excess of 2 μm tend to reduce overrun and firmness. Presumably, the larger fat globules constitute points of weakness in the films surrounding the air cells.

Three levels of milk fat, Frodex 24, and stabilizer were selected for factorial experimental design. Since the Food and Drug Administration does not permit more than 0.4% "poly- sorbate" emulsifier in whipped topping, the emulsifier was eliminated from the factorial design as a variable factor. The selected levels of milk fat were 15%, 18% and 21%; Frodex 24, 7%, 10% and 13%; and stabilizer, 0.3%, 0.5% and 0.7%. The entire experiment was replicated.

An analysis of variance indicates that all three components (Table 2) were significant at the 99% level in their effect on the firmness of the whipped topping, but Frodex 24 and stabilizer (Table 3) were significant at the 99% level, and fat was significant at the 95% level on the overrun of whipped topping.

Neither the first order interactions (fat and Frodex 24, fat and stabilizer, stabilizer and Frodex 24) nor second order interactions (fat and Frodex 24 and stabilizer) were significant at the 95% level on overrun and firmness. Therefore, it is concluded that fat, stabilizer and Frodex 24 act independently of each other in contributing to overrun and firmness of a whipped topping.

REFERENCES


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