Destabilization and Fat Crystallization of Whippable Emulsions (Toppings) Studied by Pulsed NMR

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The role of lipid surfactants in toppings has been investigated. Based on low-resolution pNMR analysis it seems that part of the fat phase in toppings is present in a supercooled state induced by lipid-protein interactions. Upon reconstitution in cold water, protein is desorbed from the fat globule surface and dissolves into the water, thereby eliminating the protein-induced supercooling of the fat. Subsequently, spontaneous fat crystallization takes place which can be followed by pNMR measurements. These phenomena result in an increase in the viscosity of the reconstituted emulsion. The surfactants usually used in toppings (e.g. propylene glycol monostearate) act as destabilizing factors in the reconstituted topping emulsion, accelerating (i) protein desorption from the fat globule surface, and (ii) the crystallization rate of coalesced fat. The fat crystallization process seems to be important for the texture and foam stability of whipped toppings.

Spray-dried, vegetable fat-based whippable emulsions, so-called toppings which are used as imitations for whipped dairy cream, have been known for several years and offer advantages in cost, transportation and long-term storage.

The physical changes during whipping of reconstituted toppings previously have been thought to be similar to those in whipped dairy cream. In whipped dairy cream the air bubbles in the foam are stabilized by an adsorbed layer of fat globules (1). The fat globules have lost part of their protective membrane layer, and liquid fat is present between the globules. In whipped toppings a much higher degree of emulsion destabilization is observed.

By transmission electron microscopy (TEM) it has been shown that only a few intact fat globules are present in reconstituted, whipped toppings, and that the fat phase in whipped toppings consists of crystalline platelets absorbed at the air/serum interface (2). In contrast to this, a whipped dairy cream is stabilized by genuine spherical fat globules. It was the aim of this work to study the mechanisms of destabilization of model whipped topping foams by analyzing the the desorption of protein from the fat phase of centrifuged emulsions, and by determining the crystallization behavior of reconstituted emulsions by a pNMR technique. The model toppings were designed with different concentrations of both protein and surfactant. For comparison, toppings with poor whippability were made by using a different surfactant or by omitting the surfactant.

EXPERIMENTAL PROCEDURES

Preparation of topping powders. The topping powders were made by spray-drying an emulsion containing 25–30% (weight percent) hydrogenated coconut oil with a final melting point (m.p.) of 31 C, 0–5% surfactant, 15–19% maltodextrin, 1–5% sodium caseinate and 50% water. In topping powders with varying amounts of surfactants the total percent of surfactant plus triglyceride was kept constant. Correspondingly, in topping powders with varying amounts of protein the total percent of protein plus maltodextrin was kept constant. Thus, the relative amounts of lipids and water soluble material (protein plus maltodextrin) were kept constant. The total composition of all investigated topping powders is shown in Table 1.

The emulsions were prepared by melting coconut fat and surfactant together at 80 C and separately dissolving the caseinate and maltodextrin in the water phase at 90 C. The two phases were mixed together and homogenized on a one-stage high pressure piston homogenizer with a Ranne liquid whirling type valve at a pressure of 100 kg/cm^2 at 80 C. The emulsions were then spray-dried, using a rotating atomizer (16,000 rpm) with an air inlet temperature of 150 C and an outlet temperature of 90 C. The spray-dried topping powders were cooled to 5 C for one hr and then stored at 20 C or a lower temperature. The lipid surfactants used were: Promodan SP, distilled propylene glycol monostearate (PGMS), and Dimodan PV, distilled monoglycerides based on fully hydrogenated soybean oil (GMS). The surfactants contained min. 90% mono-esters and are commercial products manufactured by Grindsted Products A/S, Denmark.

Viscosity measurements. The topping powders were reconstituted in water at 15 C by mixing one part powder with three parts water. The emulsion was then transferred to the cup of a Haake Rotovisco Viscometer with sensor system MVII. The temperature in the sensor cup was thermostatically controlled at 15 C. The viscosity of the emulsion was measured continuously at a shear rate of 1.76 sec^{-1} as a function of time.

Whipping test and foam texture measurements. One part of the topping powders was reconstituted in three parts of water at 10 C and whipped with a Kenwood Chief Mixer at maximum speed for 2 or 3 min depending on the type of surfactant used. The foam firmness of the whipped cream was then tested with a Voland Stevens Texture Analyzer using a cylindrical probe (TA 5) 12.7 mm in diameter, adjusted to a penetration depth of 100 mm at a speed of 2 mm sec^{-1} and using a load range position 100 g.

Emulsion fractionation. Topping was reconstituted in water (1:2) at 22 C, degassed, and 60 ml of the emulsion was transferred to 100-ml centrifugal tubes which were placed 60 min at 5 and 30 C. The emulsions were then centrifuged 60 min at 15,000 rpm using a Measuring & Scientific Equipment Ltd. high speed centrifuge equipped with a 6- × 100-ml fixed angle rotor.

The amount of protein was determined as total nitrogen using the Kjeldahl method. One g freeze-dried fat phase obtained by centrifugation was extracted

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TABLE 1

Total Composition of Topping Powders Investigated

No.	1	2	3	4	5	6	7	8	9
Series A									
Hardened coconut oil, m.p. 31 C	50	50	52	54	56	60	52	52	52
PGMS (Promodan SP)	—	10	8	6	4	0	8	8	8
GMS (Dimodan PV)	10	—	—	—	—	—	—	—	—
Sodium caseinate	8	8	8	8	8	8	6	4	2
Maltodextrin	32	32	32	32	32	32	34	36	38
Series B									
Hardened coconut oil, m.p. 31 C	50	53	56	60	50	50	50		
PGMS (Promodan SP)	10	7	4	0	10	10	10		
Sodium caseinate	10	10	10	10	7	4	2		
Maltodextrin	30	30	30	30	33	36	38		

with 25 ml of $CHCl_3$ at 45 to 50 C. After dissolution, the sample was filtered on a Millipore filter holder using Whatman GF/A glass filters. After flushing with additional $CHCl_3$, the amount of $CHCl_3$-soluble material was determined by weighing after evaporation of the combined filtrates. The amount of $CHCl_3$-insoluble material was determined by weighing the dried filters with retentate and subjecting to Kjeldahl protein analysis.

PULSED NMR MEASURING CONDITIONS

The measurements were done on a pulsed low-resolution NMR spectrometer (model Minispec PC/20B from Bruker Spectrospin, West Germany) operating at 20 MHz for protons. The sample probe temperature was 40 C. A 90° pulse, with a pulse width of 0.8 μsec and diode detection mode was used. The signal heights measured 11 and 70 μsec after the end of the radio frequency pulse are proportional to the total number of protons in solid(s) plus liquid (l) phase, respectively (3). To compensate for the dead time of the receiver circuit a correction factor (f) is used to obtain the initial solid signal level s = fs′. The f factor (in range of 1.3 to 1.4) was estimated from standards having predetermined solids content. These standards consisted of a rod of celeron plastic immersed in paraffin oil. The samples were pulsed four times each with a repetition of two seconds. This short measuring time avoided the necessity of thermostating the sample holder.

Calculations based on pNMR analysis. The percent solid phase (%S) was calculated automatically by the built-in spectrometer computer:

$$\%S = s/s + 1 = fs'/(fs' + 1) \quad [1]$$

The signal amplitude after 11 μsec representing s + 1 and after 70 μsec, representing 1, may be read out separately from the data registers of the spectrometer (dREG01 and dREG02, respectively). To convert the relative measurements (% S) to absolute FID signals in some experiments the signal value was corrected for density (d) because the magnitude of the magnetization depends on the proton density of the sample. The normalized absolute liquid and solid FID signals were obtained from:

$$dREG01/d = s' + 1 \text{ and } DREG02/d = 1 \quad [2]$$

From this, the normalized absolute liquid signal was easily calculated. Since s = fs′ the normalized absolute solid signal is

$$s = (dREG01/d - dREG02/d)f \quad [3]$$

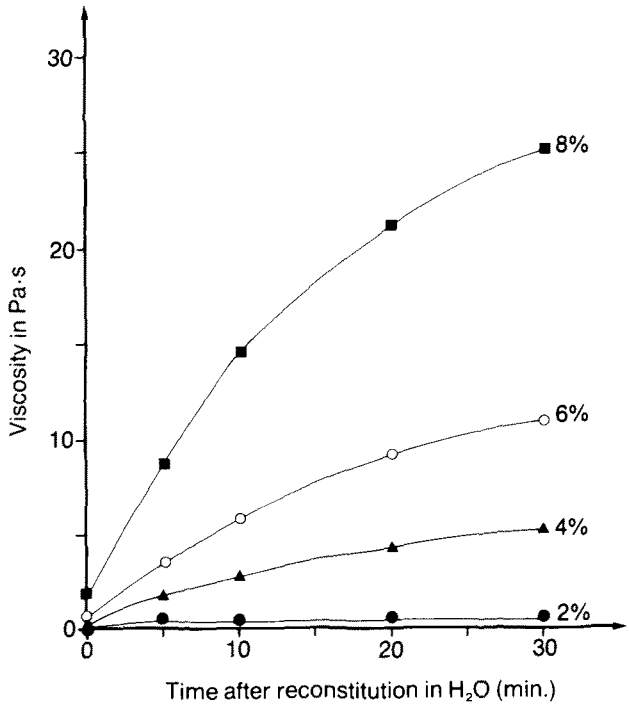

FIG. 1. Viscosity increase in reconstituted topping emulsions at 15 C in water (1:3) containing 2, 4, 6 and 8% sodium caseinate on dry weight basis (Samples no. A9, A8, A7 and A3 in Table 1).

PULSED NMR OF DRY POWDERS

The percent solids of topping powder and of simple dry mixtures were analyzed at various temperatures between 5 and 25 C.

The fat phase in the mixtures was finely ground before mixing with powdered maltodextrin and sodium caseinate, and the dry matter content was exactly the same as in the corresponding topping powder. However, the dry mixture was not subjected to the homogenization and emulsification process in contrast to the topping powders. The samples were stored at 5 C overnight before analyses and equilibrated one hr at each temperature (starting from 5 C) before pNMR analysis.

Pulsed NMR in D_2O. For each experiment topping powder and D_2O were equilibrated overnight at the same temperature (either 5, 15, 25 or 35 C) before pNMR analysis. In these time-dependent analyses the powders and D_2O were mixed for two min before the first analysis. Between analyses the samples were stored at the temperature used for equilibration.

RESULTS AND DISCUSSION

Viscosity measurements. When a topping powder is reconstituted in water and the emulsion is kept below room temperature (e.g. 15 C), an increase in viscosity will occur (2). With decreasing temperature (down to 5 C) the viscosity will increase, but at 20 C or higher temperatures the increase in viscosity is negligible. The viscosity increase depends also on the type of surfactant used. Using GMS instead of PGMS or omitting surfactants results in no viscosity increase as shown previously (2).

Figures 1 and 2 show the effect of varying the protein and surfactant concentrations on the time dependent viscosity increase in reconstituted topping emulsions at 15 C. (The total composition of these toppings is shown in Table 1). It is seen that adequate amounts of both protein and surfactant are needed to obtain a rapid increase in viscosity which is a manifestation of a destabilization process. With a low concentration of surfactant, or protein, in the toppings, no increase in viscosity occurs and the emulsion remains fluid.

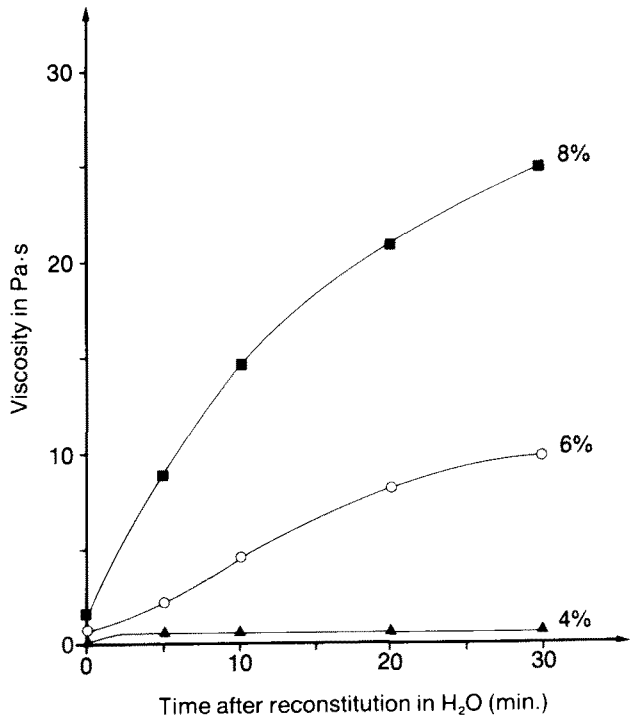

FIG. 2. Viscosity increase in reconstituted topping emulsions at 15 C in water (1:3) containing 4, 6 and 8% surfactant on dry weight basis (Samples no. A5, A4 and A3 in Table 1).

Whipping tests. The whippability and foam characteristics of the topping powders with varying contents of surfactants (PGMS) and sodium caseinate together with toppings containing GMS or no surfactant are shown in Table 2. The total composition of the topping powders is shown in Table 1. Decreasing the PGMS content, or the protein content, results in lower overrun and a softer, less stable foam. The best whipping results are obtained with 7-10% protein and 10% PGMS. Topping with GMS as surfactant gives poor whippability and no foam stiffness. The effect of surfactant concentration on topping functionality also has been shown by Min et al., who reported similar results (4).

TABLE 2

Effect of Protein and Surfactant Content in Dry Powder on Whippability and Foam Texture

Sample no.	Protein %	Surfactant %	Foam Texture Index (g)	Overrun[a] %
B7	2	10 (PGMS)	9	6
B6	4	10 (PGMS)	14	218
B5	7	10 (PGMS)	51	382
B1	10	10 (PGMS)	67	368
B4	10	0 (PGMS)	<1	5
B3	10	4 (PGMS)	25	168
B2	10	7 (PGMS)	38	261
A1	8	10 (GMS)	4	51

[a]Overrun, (ml foam/g foam)100 −100.

TABLE 3

Distribution of Protein Between the Fat Cream Phase and the Water Phase of Centrifuged Topping Emulsions

		After 1 hr at 5 C[a]		After 1 hr at 30 C[a]	
Sample no.	Surfactant	% Protein in fat phase[b]	% Protein in water phase[b]	% Protein in fat phase[b]	% Protein in water phase[b]
A2	10% PGMS	1.3	98.7	33.7	66.3
A1	10% GMS	7.7	92.3	12.3	87.7
A6	None	24.0	76.0	41.7	58.3

[a]The toppings were reconstituted at 22 C and tempered for 1 hr at 5 C or 30 C before centrifugation.
[b]Fraction of total protein in fat and in water phase.

Protein distribution in topping emulsions. The increase in viscosity is closely related to a destabilization of the topping emulsion as studied by light microscopy or transmission electron microscopy (2). The role of lipid-protein interactions in the destabilization of reconstituted topping emulsions (1:3) was studied by high speed centrifugation tests of topping with an effective (PGMS), an ineffective (GMS), and without surfactant (A2, A1 and A6 in Table 1).

After centrifugation of topping emulsions, reconstituted and kept at 5 C for one hr, a fractionation of the topping ingredients took place following two characteristic distribution patterns: Topping emulsions with GMS and without surfactant separated into an upper cream layer and a lower water phase. The cream layer could be resuspended into an emulsion. The emulsion with 10% PGMS had totally destabilized with pure liquid oil as the upper phase, a small interphase with partially intact fat globules and a lower water phase. The separation of a liquid oil phase in the destabilized emulsions was due to a rise in temperature during centrifugation to between 35 and 38 C. Use of a temperature controlled centrifuge at 5 C was not suitable because no fractionation of coalesced fat would be obtained after centrifugation due to the presence of much crystalline fat. Thus, the destabilized topping

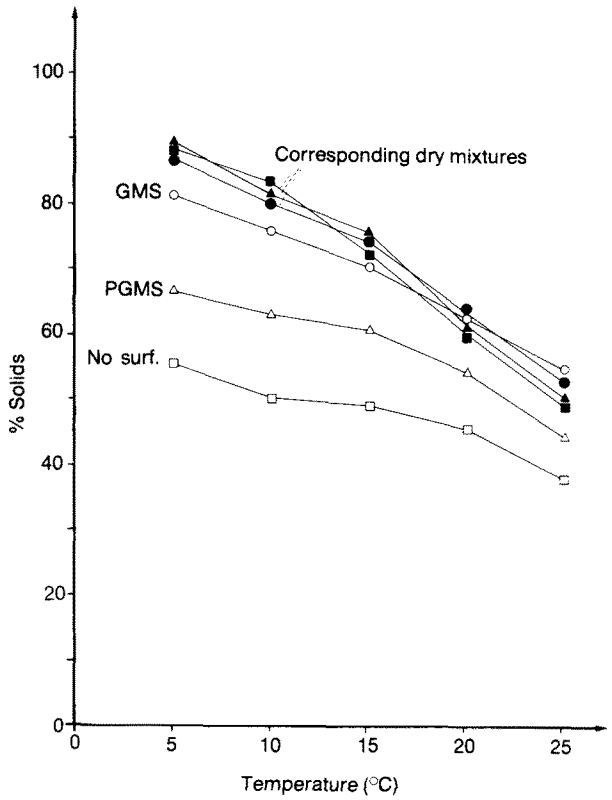

FIG. 3. Percent solids of topping powders and corresponding dry mixtures measured by pNMR at temperatures from 5 to 25 C. The toppings were composed of 50% hardened coconut oil m.p. 31 C, 10% surfactant (GMS or PGMS), 8% sodium caseinate and 32% maltodextrin. The topping without surfactant contained 60% coconut oil. (Samples no. A1, A2 and A6 in Table 1).

TABLE 4

A. Normalized Absolute Liquid (l) and Solid (s) FID Signals of Topping Powders and Corresponding Dry Mixtures

Sample no.	Surfactant	Solids %	l (mV)	s (mV)
Topping powders:				
A2	10% PGMS	60.0	2.73	2.02
A1	10% GMS	70.7	2.22	2.37
A6	None	49.1	2.92	1.63
Dry mixtures:				
A2	10%PGMS	76.5	1.88	2.65
A1	10% GMS	74.0	1.72	2.52
A6	None	72.8	2.09	2.41

B. Percent Interaction and Increase (+) or Decrease (−) of FID Signals of Topping Powders in Relation to Dry Mixtures

Sample no.	Surfactant	Interaction %	l[a] %	s[b] %
A2	10% PGMS	16.5	+45	−28
A1	10% GMS	3.3	+29	− 6
A6	None	23.7	+40	−32

$^{a}\%l = (l_{dry\ mix.} - l_{topping}/l_{dry\ mix.}) \times 100.$
$^{b}\%s = (s_{dry\ mix.} - s_{topping}/s_{dry\ mix.}) \times 100.$

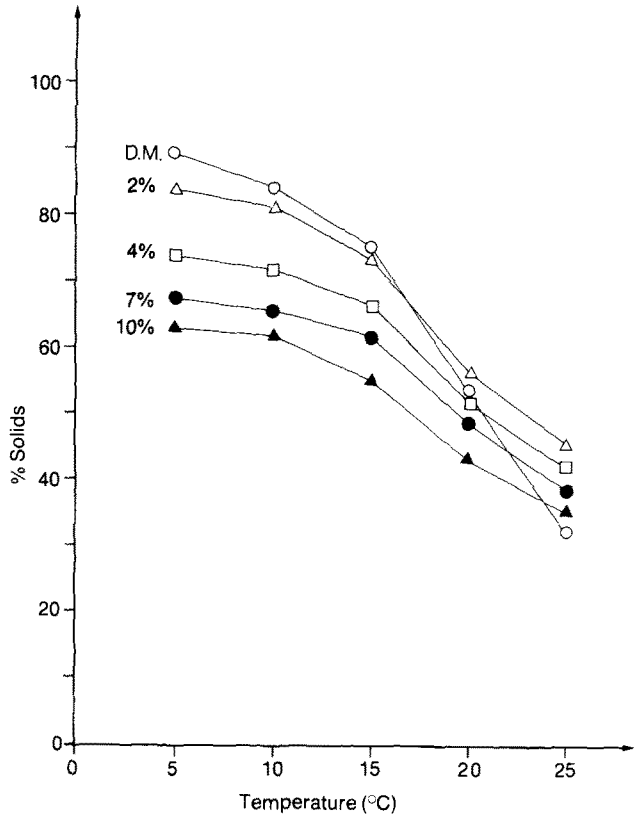

FIG. 4. Effect of protein content (2, 4, 7 and 10%) on percentage solids in topping powders with 10% surfactant (PGMS). (Samples no. B7, B6, B5 and B1 in Table 1) D.M. = Dry mixture of topping ingredients.

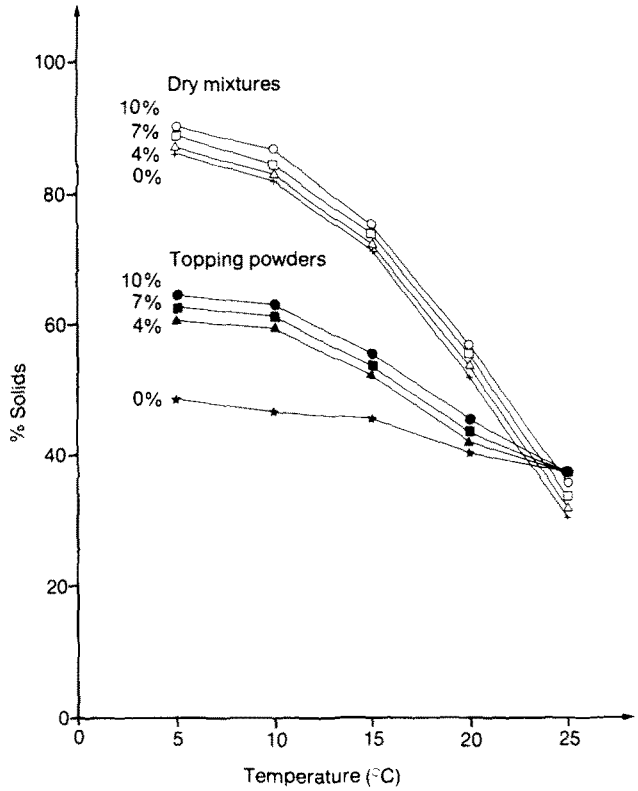

FIG. 5. Percent solids in topping powders and dry mixtures with varying surfactant content (0, 4, 7 and 10%). Black symbols: Topping powders. Open symbols: Dry mixtures. (Samples no. B4, B3, B2 and B1 in Table 1).

emulsion required heating to above the melting point (31 C) of the fat phase to obtain fractionation of the coalesced fat.

In contrast to emulsions cooled to 5 C, no difference was found between the topping emulsion kept at 30 C one hr before centrifugation. Here, all emulsions separated into a cream layer on top of the water phase after centrifugation.

The amount of protein in the fat and the water phase was analyzed by the Kjeldahl method. In Table 3 it is seen that the association of protein with the fat phase generally is high at 30 C in all three emulsions and considerably lower at 5 C. However, at 5 C there are very marked quantitative differences: in the highly destabilized emulsion of PGMS at 5 C only a very small fraction of the protein remains associated with fat, whereas in the more stable emulsions with GMS and without surfactant more than half of the total protein present remains associated (adsorbed) with the fat phase.

Pulse NMR of dry topping powders. The percent of solids (%S) in the topping powders as shown in Figure 3 is lower than in the corresponding dry mixtures. This difference is largest at low temperature and decreases as room temperature is approached. The difference between powder and dry mixture is most pronounced in the topping without surfactant or with PGMS, whereas the topping with GMS shows only a very small difference from its dry mixture. We consider the difference between %S in topping powder and dry mix as an expression of the interaction of topping ingredients. Thus, we define:

$$\text{Percent interaction} = \%S \text{ of dry mix} - \%S \text{ of topping powder.}$$

The physical meaning of this difference may be elucidated by reading out and calculating on the normalized absolute liquid and solid signals from the SFC program as described under experimental procedures. The experimental data are shown in Table 4A. Table 4B shows that the liquid signal is increased most in toppings with PGMS (45%) and without surfactant (40%) and less in GMS topping (29%). This increase probably is caused by solubilization of solid protein protons into the fat phase during the emulsification, according to Trumbetas et al. 1979 (5). The increase in the liquid signal is accompanied by a similar decrease of about 30% in the solid signal of toppings with PGMS and no surfactant. However, in GMS topping there is only a very small effect on the solid signal (decrease of about 6%). Because the amount of sodium caseinate (8%) and maltodextrin (32%) is the same in the three toppings, the differences observed may be due to alterations in the physical state of the fat phases after emulsification and spray-drying.

From these results we suggest that a high percentage interaction means first, a larger increase in the liquid signal, probably due to solubilization of protein in fat, and second, a large decrease of the solid signal

due to inhibition of fat crystallization. With a low percentage interaction (GMS topping) we observe a lower increase in liquid signal due to less protein solubilization (in accordance with the direct analysis of fatbound protein described in Table 3) and only a very weak reduction of the solid signal.

A tentative conclusion could be that high lipid-protein interactions induce a supercooling of the topping fat phase. Thus, percentage interaction can be redefined as percentage supercooling.

The supercooled state of the topping fat may be stabilized by the emulsified system because it is known that the nucleation rate of fat is strongly reduced if it is present in a large number of non-communicating droplets with a small particle size (6).

Figure 4 shows %S measured by pNMR in a series of toppings with different protein contents and a constant PGMS content (10%). It is seen that the protein content in the topping formulations influences the %S of topping powders in such a way that a high protein content gives a lower content of %S. The %S of all the corresponding dry mixtures containing the same amounts of ingredients as the spray-dried powders (curve D.M) were identical. Because a decrease in %S is defined as a supercooling of the fat phase, it seems that the degree of supercooling is determined by the protein content.

The influence of the surfactant concentration on the supercooling of the fat is shown in Figure 5, where toppings with varying concentrations of PGMS and constant protein content (10%) have been analyzed by pNMR. Compared to a topping without surfactants (0% curve) the addition of 4-10% PGMS decreases the degree of supercooling of the fat phase. Within the toppings containing 4 to 10% PGMS there are, however, only small differences.

Pulsed NMR measurements of toppings in D_2O. The effect of emulsion destabilization on the state of supercooled fat was investigated by reconstituting topping in deuterated water, D_2O, and measuring the %S in the emulsion under isothermal conditions. As the

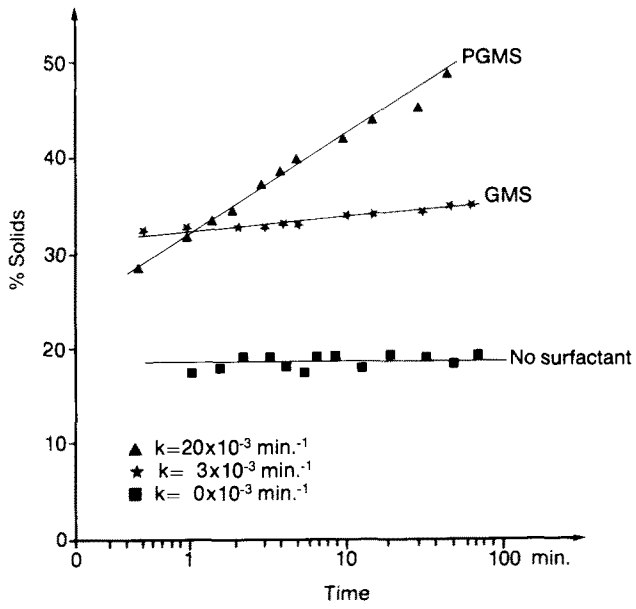

FIG. 7. Crystallization of supercooled fat measured by pNMR (% solids) in toppings with 10% PGMS or GMS or without surfactants (Samples no. A2, A1 and A6 in Table 1) reconstituted isothermally in D_2O (1:3) at 15 C, shown as first order rate kinetics plots. K = rate constant of crystallization.

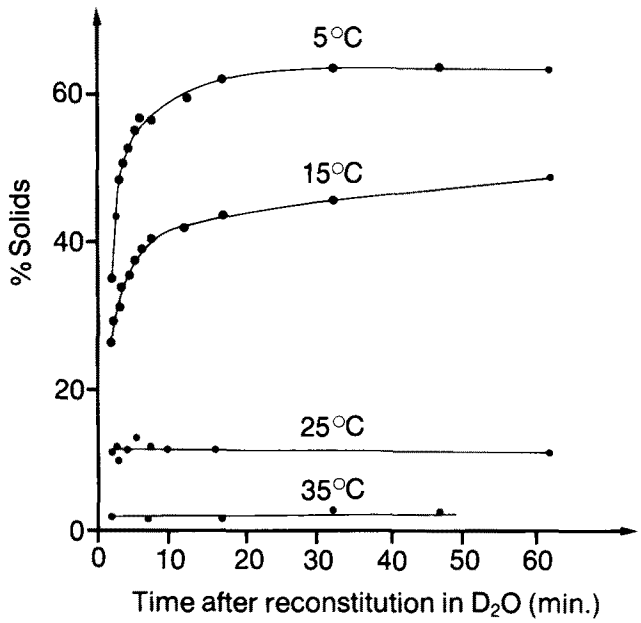

FIG. 6. Crystallization of supercooled fat measured by pNMR (% Solids) in topping with 10% PGMS (Sample no. A2 in Table 1) reconstituted isothermally in D_2O (1:3) at 5, 15, 25 or 35 C.

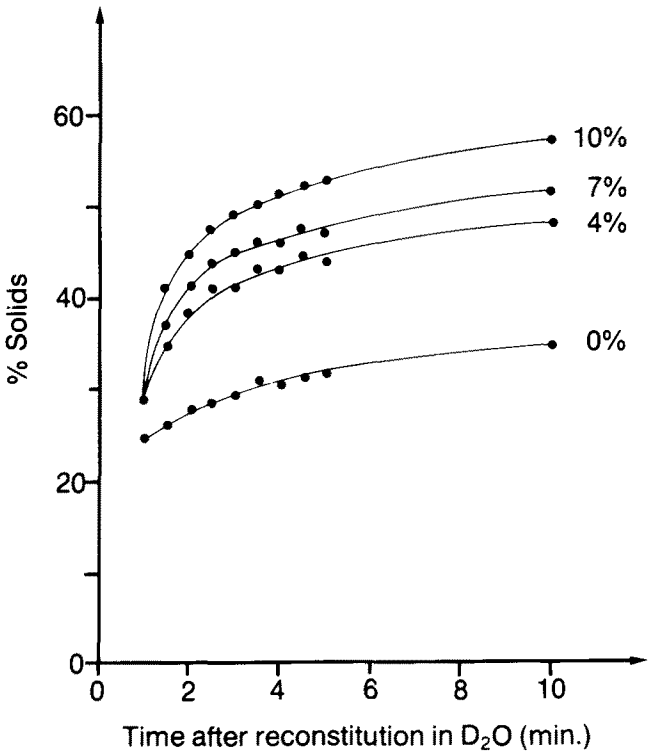

FIG. 8. Effect of surfactant content (0, 4, 7 and 10%) on fat crystallization of toppings with 10% protein reconstituted in D_2O (1:3) under isothermal conditions at 5 C. (Samples no. B4, B3, B2 and B1 in Table 1).

maltodextrin and sodium caseinate dissolve in D_2O, the signal from protons in the solid state can only come from the crystallized fraction of the fat phase. From Figure 6 it appears that at 35 and 25 C there is no change in %S with time, whereas at 15 C and even more at 5 C the %S increases, indicating that a crystallization process is taking place in the emulsion immediately after reconstitution.

The influence of various surfactants on the crystallization process below room temperature is shown in Figure 7. The results are shown as first order kinetics plots of %S versus a logarithmic time scale. From these plots a rate constant of crystallization is calculated for each experiment as shown in the figure. The PGMS (8%) topping shows an increase in %S at 15 C, illustrating a pronounced fat crystallization in contrast to toppings with GMS (8%) or without surfactant which gives no or very little crystallization.

Because first order kinetics often is encountered in coalescence studies (7), the rate-limiting step in the topping emulsion destabilization follows a first order reaction rate kinetics.

Thus, the toppings with good functionality show an increase in fat crystallization after reconstitution in cold water. It has been reported that "the stability of an emulsion against coalescence is adversely affected by the formation of crystals in the oil droplets" (6). Thus, the fat crystallization observed in topping emulsions below room temperature is probably an important destabilizing factor.

The effect of surfactant concentration on the crystallization of supercooled fat in reconstituted emulsions under isothermal conditions at 5 C is shown in Figure 8. It can be seen that the crystallization of the fat phase increases with increasing PGMS content. Thus, the surfactant content in topping is an important factor in the destabilization process.

Because the protein content of toppings is determining the degree of supercooling of the fat phase (Fig. 4), it can be assumed that a decrease in protein content will limit the crystallization in reconstituted emulsions. Therefore this was investigated and the results shown in Figure 9 confirm the anticipated behavior.

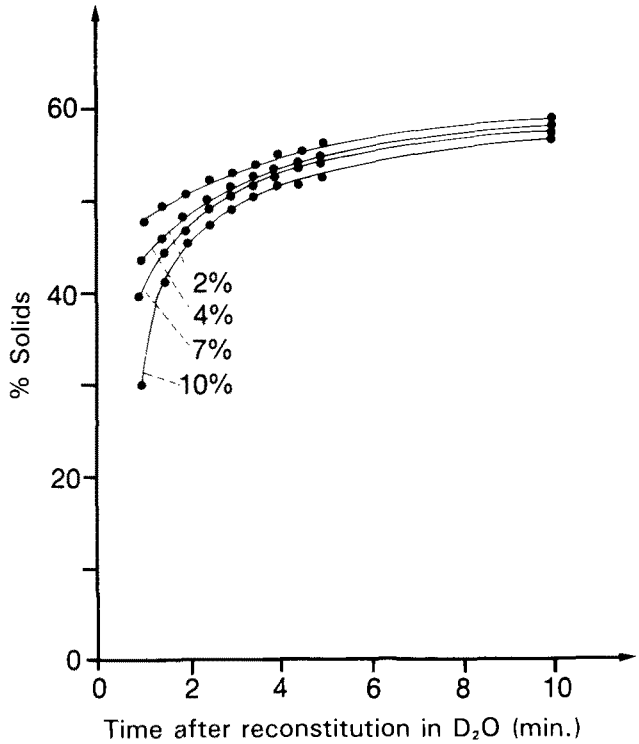

FIG. 9. Effect of protein content (2, 4, 7 and 10%) on fat crystallization of toppings with 10% PGMS reconstituted in D_2O (1:3) under isothermal conditions at 5 C. (Samples no. B7, B6, B5 and B1 in Table 1).

The relationship between supercooling in dry powders and crystallization tendency after isothermal reconstitution in water at 5 C is shown in Table 5. The rate constants for the crystallization process of the various toppings are calculated from first order kinetics plots. As shown by the results, the protein component in topping seems to determine the degree of supercooling in the fat phase and thus the potential for crystal formation, whereas the surfactant seems to determine how quickly the fat crystallization will occur after reconstitution in cold water.

TABLE 5

Supercooling in Dry Topping Powder at 5 C and Corresponding Crystallization after Reconstitution in Water at 5 C

Sample no.	Protein %	Surfactant %		Supercooling %	Crystallization[a] %	Crystallization rate[b] (10^{-3k} min^{-1})
B7	2	PGMS	10	6	10	24
B6	4	—	10	15	15	32
B5	7	—	10	21	18	40
B1	10	—	10	27	28	54
B4	10	—	0	37	5	16
B3	10	—	4	25	15	29
B2	10	—	7	26	21	41
A1	8	GMS	10	5	4	3

[a]Percent crystallization = $\%S_{t10} - \%S_{t1}$.

[b]Crystallization rate (k) obtained from 1. Order Kinetics plots: $k = \ln (100 - \%S_{t1}/100 - \%S_{t10})/10-1$.

If we combine the above observations with the observations of crystalline platelets in reconstituted emulsions by TEM as described earlier (2), we can interpret these phenomena in the following way: In dry topping powders with good functionality (PGMS topping) a large part of the protein is adsorbed strongly to the surface of the oil droplets during the manufacturing process, and the crystallization of the fat phase in the spray-dried powder is strongly inhibited (e.g. super-cooled fat phase). When reconstituted in cold water the protein is desorbed and effectively transferred to the water phase due to the presence of surfactant, resulting in coalescence of the unprotected fat globules with subsequent spontaneous crystallization of supercooled fat taking place. Thus, active topping surfactants behave as destabilizing agents or deemulsifiers in the reconstituted topping emulsion below room temperature. The milk protein desorption induced by surfactants has also been observed in dairy emulsions systems by Walstra and coworkers using surface rheological analysis (8).

In the non-whippable topping powder without lipid surfactant there is also much protein-adsorption to the oil droplets and great supercooling of the fat phase. However, when reconstituted in cold water the protein transfer from the fat globule surface to the water phase is much more restricted, resulting in negligible emulsion destabilization and very little crystallization.

In the GMS topping powder which has poor functionality only a small amount of protein is bound to the fat phase and a very small degree of supercooling of the fat phase is observed. When reconstituted in cold water some of the protein is solubilized, however, without any visible destabilization of the emulsion. Since there is very little supercooling of the fat phase in dry powder, only a slight spontaneous fat crystallization is observed after reconstitution.

The direct relationship between the whippability and foam texture and the physical properties of the toppings can be seen by comparing the data in Table 5 with those in Table 2.

The degree of supercooling is essential to obtain good whippability, and is related to the protein content as shown in Figure 4. It is unknown, however, how the amount of protein influences the degree of supercooling of the fat globules. A high protein content may give a smaller particle size resulting in higher supercooling and vice versa, but a direct protein-fat interaction by hydrophobic protein segments' penetration into the surface of the fat globules is another hypothesis. The destabilization of the reconstituted topping emulsions and subsequently the fat crystallization which is related to the surfactant type and concentration is likewise very important in order to obtain the crystal network structure in the whipped topping giving the desired foam texture.

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