Butter Texture: The Prevalent Triglycerides

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The effect of composition on butter texture usually has been treated *via* the iodine value or the fatty acid content. The development of a new analytical technique allowed accurate determination of triglyceride composition of five different types of butters collected in winter and summer periods. The firmness of these samples has been measured in parallel, by using an Instron® universal testing machine and a cone penetrometer. As expected, a regional and seasonal variation of butter firmness was found. The correlation between firmness at 15°C and triglyceride composition allows the selection of four triglyceride fractions (TG1, TG2, TG3 and TG4) mainly represented by: TG1, POO; TG2, MyOO; TG3, CLaO + CyMyO + CoPO + BuSO and TG4, BuPO + CoMyO + CoPL (P, palmitic acid; O, oleic acid; My, myristic acid; C, capric acid; La, lauric acid; Cy, caprylic acid; Co, caproic acid; Bu, butryic acid; S, stearic acid; L, linoleic acid). The proportions of TG1 and TG2 are negatively correlated with firmness (r = 0.89 and r = 0.95, respectively). The level of the two other groups runs parallel to firmness (r = 0.95 and r = 0.91, respectively). The high correlation coefficients of these prevalent triglyceride fractions could be a better representative indication than iodine value or fatty acid content on the variation of this physical property of butter.

KEY WORDS: Butterfat, fatty acids, firmness, penetrometry, texture, triglycerides.

Texture has been recognized as an important parameter of the total organoleptic properties of food (1,2). However, texture awareness often stands at a subconscious level: "If the texture of the food is as people have learned to expect it to be, it may go unnoticed; but if it is not, it becomes a focal point of criticism, and rejection may ensue" (3). In the case of butter, the most important textural property is spreadability (4,5). In this regard, penetrometry is a widely used method found to correlate well with consumer assessment of spreadability and, hence, has been adopted by the International Dairy Federation (6), as well as the American Oil Chemists' Society, as an official method to measure butter firmness. Another advantage of this method is that the required apparatus is easy to use and relatively cheap. Commercial models of standard design (7) are readily available.

Many factors may influence butter firmness, including the nature of the cream (8,9), the thermal and mechanical treatments of cream (10,11), the manufacturing techniques, such as conventional churning or continuous manufacturing methods (12), and the post-manufacturing handling and storage (13,14,15). This subject has been examined in comprehensive literature and has been reviewed by Mulder and Walstra (12). It is well known that the composition of butterfat partially determines its consistency. Dolby (16) attributed roughly 80% of the variation in butter firmness to changes in butterfat composition. However, the variation of the composition is often indicated by the iodine value (17) or the fatty acid content (18). Few papers in the literature deal with triglyceride (TG) composition.

TG composition of winter and summer butterfat from five different French areas were analyzed previously (19). The aim of the present study is to determine the textural properties of these samples and to try to obtain information on the nature of the correlations arising from TG composition and textural properties. This investigation was undertaken to select the TG components that could influence butter firmness.

MATERIALS AND METHODS

Materials. Creams from five different, specific areas in France were collected in January (winter) and in July (summer). They were assumed to be representative of the major dairy regions in France.

Buttermaking method. To avoid the effect of manufacturing on the consistency of butter, laboratory conditions (according to the following procedures) were used (Fig. 1).

Dry matter was determined according to the standard method of the Association of Official Analytical Chemists (20). The results were in line with the recommended water content of 16%. The fresh butter was stored in 6 cuvettes (diameter, 5 cm, height, 3 cm) at 4°C for 20 h, then it was compressed and finally stored at 15°C for 2.5 h prior to analysis.

Constant weight penetration. The instrument used was the AP 411 penetrometer (Veb Feinmess, Dresden, Germany). The penetration time was 5 s (21,22). The cone was a commercial model according to the Amerian Society for Testing and Materials (7) standard.

Three cuvettes were submitted to six penetrations each. Tests were performed at 15°C in a temperature-controlled laboratory room. The cone penetration gave the firmness index, which is the ratio of the mass of the cone assembly (w = 150 g) over the penetration depth (P is expressed as tenths mm). Yield value was calculated according to the formula of Haigton (23):

$$Y = K\ W\ /\ P^{1.6} \qquad [1]$$

where K is a constant depending on the cone angle.

Constant speed penetration. A computerized Instron® universal testing machine (model 1122; Instron, Buc, France) was used at a constant temperature (15°C). Three penetration tests were done in each of the remaining three cuvettes. The force (N) required to drive a 28-mm^2 stainless-steel cylinder to a depth of 3 mm into the sample at a speed of 5 mm/min was measured by a load cell.

Statistical tests. Statistical analyses were performed with STATITCF software (ITCF, Boigneville, France).

RESULTS AND DISCUSSION

Each type of cream was manufactured in duplicate, according to the method previously described. Therefore, each value of firmness is an average of thirty-six measurements, including a coefficient of variation lower than 7%.

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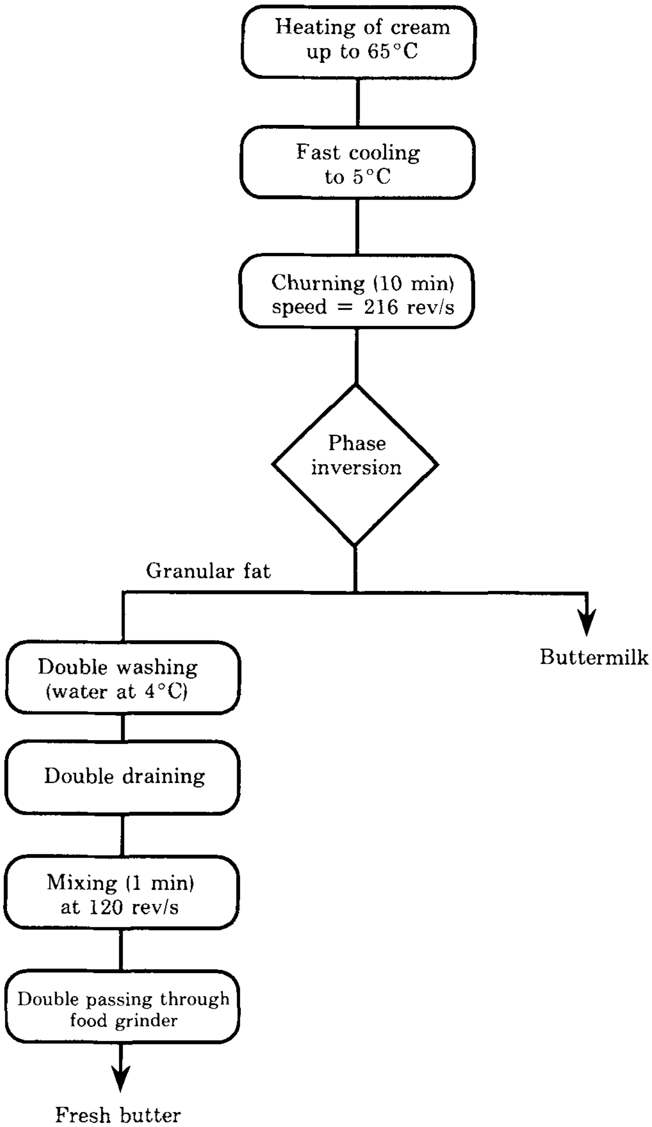

FIG. 1. Buttermaking method.

From these results it appears that the accuracy of the physical methods used is satisfactory.

Figures 2 and 3 show the mean firmness value of the five types of butter obtained from winter and summer periods. As observed by several authors (18,24,25),

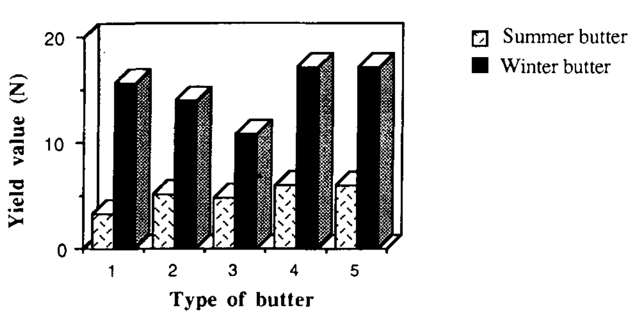

FIG. 2. Yield value of the five types of winter and summer butter.

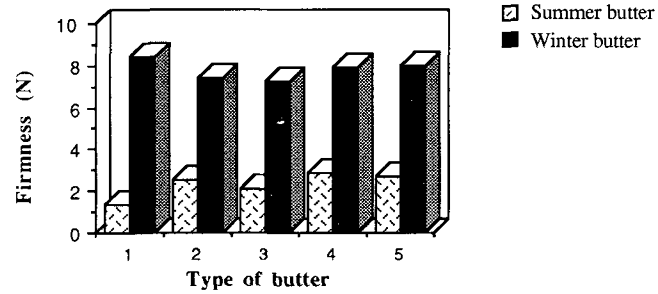

FIG. 3. Firmness of the five types of winter and summer butter.

seasonal and regional variations affect the physical properties of the butter.

Firmness and fatty acids. As shown in a previous paper (19), the major fatty acids contributing to seasonal and regional variations are myristic acid, palmitic acid and oleic acid. The contribution of each fatty acid to variation is expressed by the ratio V_i/V_t, so that:

$$V_i = [(AG_{is} - AG_{iw})^2/100] \times [(AG_{is} + AG_{iw})/2] \quad [2]$$

$$V_t = \Sigma V_i$$

AG_{is} is the fatty acid "i" content of summer butterfat; and AG_{iw} is the fatty acid "i" content of winter butterfat.

Many authors (24,26,27) explain the seasonal variation of butter firmness by variation in oleic acid and palmitic acid only. However, from the analysis of the correlation coefficient between firmness and content of these fatty acids, it appears obvious that myristic acid is an important firmness indicator, along with oleic and palmitic acids (Table 1).

Nevertheless, the determination of firmness based only on fatty acids remains insufficient, because fat is merely made of TG's molecules and crystals. In such a situation, considering the relationship between firmness and TG composition is more realistic than fatty acid content.

Firmness and triglycerides. Among the several fractions of TGs displayed in the chromatograms, some of them seem to provide the most important contribution to seasonal and regional variation. They are gathered in four groups, as follows (19): TG1, mainly represented by POO; TG2, mainly represented by MyOO; TG3, mainly represented by ClaO + CyMyO + CoPO + BuSO; TG4, mainly represented by BuPO + CoMyO + CoPL (P, palmitic acid; O, oleic acid; My, myristic acid; C, capric acid; La, lauric acid; Cy, caprylic acid; Co, caproic acid; Bu, butryic acid; S, stearic acid; L, linoleic acid).

As mentioned in a previous paper, identification is based on theoretical carbon numbers and quantitation on

TABLE 1

Correlation Coefficients Between Firmness (or yield value) and the Percentage of the Most Important Fatty Acids in Butter

	C14	C16	C18:1
Yield value (N)	0.95	0.96	0.95
Firmness (N)	0.96	0.94	0.97

random distribution. In view of the complexity of the system, these hypotheses are presented, not to calculate the exact proportions of TGs present in butter, but only to determine the possible major TGs in this product.

As illustrated in Figures 4, 5, 6 and 7, the evidence of a significant interacting phenomenon is clearly established between the relative proportion of these four peak areas (%TG1, %TG2, %TG3 and %TG4) and butter firmness, which is proportional to the percentage of TG3 and TG4 and varies conversely with TG1 and TG2. The correlation coefficients between yield value and the percentage of these four TG fractions, firmness and the proportion of the same TG fractions are given in Table 2. However, Cullinane *et al.* (24), who characterized each TG solely by its carbon number (CN), found that a large proportion of solid-fat content and butter firmness variations are not explained by the modification of the TG composition of milkfat. The discrepancy between the results of the present paper and those of the abovementioned authors could be due to the accuracy of the present analysis: Cullinane *et al.* (24) were unable to separate TG with different molecular structures (unsaturation degree, for example), but with the same CN. Such an incapability suggests that these investigators dealt with the same group TGs, which has very different behaviors. Conversely, the present study (using theoretical CN) takes into account structural parameters (19). Consequently, TGs are better separated and their behaviors are better discriminated.

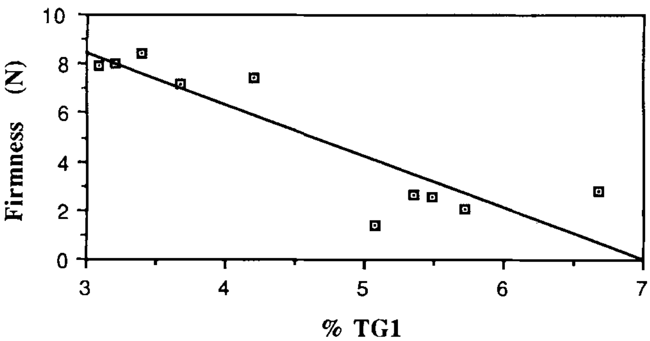

FIG. 4. The relationship between firmness and the percentage of triglyceride fraction (TG1).

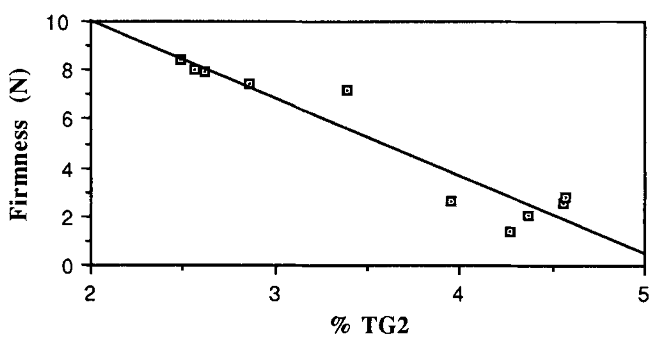

FIG. 5. The relationship between firmness and the percentage of triglyceride fraction (TG2).

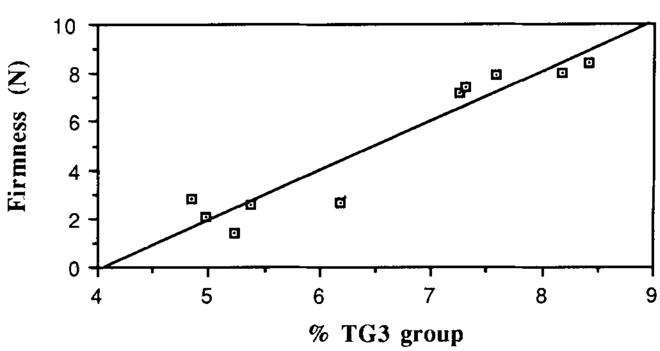

FIG. 6. The relationship between firmness and the percentage of triglyceride fraction (TG3).

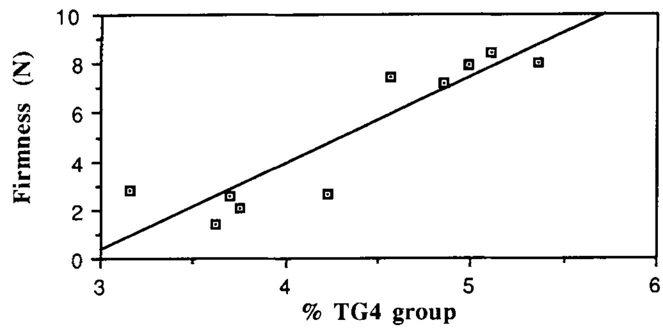

FIG. 7. The relationship between firmness and the percentage of triglyceride fraction (TG4).

TABLE 2

Correlation Coefficients Between Firmness (or yield value) and the Percentage of the Prevalent Triglycerides in Butter[a]

	POO	MyOO	TG3 group	TG4 group
Yield value (N)	0.88	0.96	0.94	0.90
Firmness (N)	0.89	0.95	0.95	0.91

[a]P, palmitic acid; O, oleic acid; My, myristic acid; TG, triglyceride.

In view of the need for quantitation of different molecular TG species in butterfat, Maniongui *et al.* (28) fractionated total TGs by reversed-phase liquid chromatography (RPLC) and analyzed the fatty acids and TGs of each fraction. With LichroCART columns (Merck, Darmstadt, Germany) packed with Lichrospher 100 RP-18 (Merck), they stressed the complexity of the high-performance liquid chromatography peaks (*e.g.*, when TGs contained butyric residue in combination with two longer-chain fatty acid chains, the retention time was lengthened by a time equivalent to one or two more RPLC peaks, so that 4:0 16:0 16:0 is eluted later than 12:0 12:0 12:0). Considering these observations, our identification may not be sufficiently precise, and more accurate correlations might be obtained if the molecular species of TGs were more precisely identified and measured.

As found by Daubert *et al.* (29,30), the melting points of POO and MyOO, corresponding to α, β' and β forms, are presented in Table 3. Therefore, at 15°C MyOO is liquid, whatever its crystalline form. This may explain the negative effect of this TG on firmness at 15°C. At the same temperature, POO can be in the liquid state, too, if it is in the α or β' form. However, the melting point of POO in the β form is 19°C, which is above the present

TABLE 3

Melting Point of POO and MyOO (Refs. 29 and 30)[a]

	α	β'	β
MyOO	−21.8	−4.2	13.5
POO	−13.2	2.5	19.0

[a]Abbreviations as in Table 2.

measuring temperature. Two hypotheses can be assumed. First, the melting point given by Daubert *et al.* (29,30) corresponds to the pure component. So, in a complex mixture, the POO pattern may be different (31). The second hypothesis is that POO mainly exists in the α and β' forms in the sample under analysis. This probability is high because of the short time of butter storage (32). Triglycerides forming groups 3 and 4 are heterogeneous, and their thermal data are not available in the literature. Therefore, it is more difficult to understand the effect of these triglyceride fractions on firmness at 15°C.

By means of computer evaluation (regression analysis), the following equations for yield value (HI), measured by cone penetrometer, *vs.* TG proportion (Eq. 2), and for firmness, expressed in Newtons (I) and measured by the Instron® universal testing machine, *vs.* TG proportion (Eq. 3), were obtained:

$$HI = -5.79\ (\%TG2) + 37.04 \quad r = 0.99$$

$$I = -2.02\ (\%TG2) + 11.85 \quad r = 0.91 \qquad [3]$$

These equations imply that butter firmness is strongly affected by the content of TG2 (MyOO). However, analysis of the correlation coefficient between the different statistical parameters shows that fractions 2, 3 and 4 are highly correlated with each other (Table 4). Consequently, it seems that one of these groups acts as if it masks the other, and, therefore, the result of this test is inconclusive.

The results discussed in this paper clearly demonstrate the prevalence of some specific TG fractions to explain the butter firmness. However, the question is: To control butter firmness, how can cream be enriched or thinned by these selected TG fractions?

Several methods are available. Selection of cream could be one of them. Different creams must be systematically analyzed and, before churning, mixtures should be made depending on the final desired butter texture. This technique already has been used empirically in the butterfat industry.

The second possibility is fractionation. This method is already used in the fat industry to separate high-melting fractions from low-melting fractions (33,34). In this regard, more work is needed to achieve the appropriate thermal diagram. Last but not least, directed interesterification is possible. This method, set up in a monitored way, could be expected to favor the appearance of specific products, such as POO and MyOO, for example. This chemical modification has been studied widely elsewhere (35,36). But the chemical reaction has to be optimized in a selected way, which is not easy, considering present knowledge on these systems.

Furthermore, it should be taken into account that, according to Borwankar (37), there is no direct relationship between molecules and texture. However, rheology, in association with molecular composition and structure of the product, is a powerful means for texture determination of foodstuffs. Further study for a better understanding of butter texture is needed. For instance, monitoring the TG crystallization under x-ray diffraction should give more information on fat properties (38). Such an approach is presently underway at our laboratory.

Finally, according to several authors (39,40,41), distribution and arrangement of fatty acids in TGs seem to influence the physical characteristics of fats. Indeed, interesterification to modify physical properties of fats soon led to several publications and patents (42,43,44). However, it would be of interest to know how interesterification, *i.e.*, randomization, changes the physical characteristics of fats.

TABLE 4

Correlation Coefficients Between the Four Prevalent Triglyceride (TG) Groups in Butter

	TG1	TG2	TG3	TG4
TG1	1			
TG2	0.76	1		
TG3	−0.74	−0.98	1	
TG4	−0.83	−0.94	0.97	1

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