Physical and Textural Characteristics of Some North American Shortenings

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A number of North American vegetable and animal fat shortenings were evaluated for their melting, crystallization, textural and polymorphic crystal characteristics and solid fat content (SFC). The majority of the dropping points and crystallization temperatures of the fats ranged from 42 to 46°C and from 27 to 31°C, respectively. Softening points of the products were higher than the dropping points of their fats, especially for the vegetable shortenings. Differential scanning calorimetry melting curves of the products were different for the various products. The animal fat shortenings were mainly in the β-polymorphic form, while vegetable shortenings containing palm oil were in the β' form. Textural evaluation was carried out on the products with the cone penetrometer, constant speed penetration and constant speed compression. Constant speed compression supplied a measure of brittleness and a degree of viscosity. Lard and shortenings containing high levels of palm oil were able to withstand large deformations without breakage.

The effect of tempering temperature of the fat in the SFC determination was evaluated and the values obtained were compared with the SFC of the actual product. SFC of fat and product were determined by pulse nuclear magnetic resonance. Correlation of values within textural methods was significant ($P<.01$), but were not significant between texture and SFC of the fat, indicating that the nature of the crystal network also plays a role in texture.

KEY WORDS: **Crystallization, polymorphism, melting behavior, shortening, solid fat, tempering, texture.**

Some shortenings are not suitable for bulk handling because their physical or functional properties are dependent on proper plasticizing, tempering and crystal structure. These shortenings are used in the manufacture of cakes, icings, Danish and puff pastries and also cookies and crackers. Brekke, Chrysam and Weiss have reviewed the various types of shortenings and their uses in bakery products (1–3).

Crystal structure is very important. The β' form is preferred for plastic shortening as the crystals tend to be small and uniform in size. The shortenings then provide good aeration for cakes and icings. Shortenings that have the β-crystalline form aerate poorly but perform well in pie crust applications.

Unemulsified shortenings are especially suitable for cookies, crackers and frying (2). Deodorized and stabilized lard or beef tallow are examples of the lowest cost shortening types for cookies. Lard is commonly used for pie crust. The characteristic flakiness of pie crusts formulated with lard has been attributed to the grainy crystal structure of the fat. An unemulsified, all-vegetable shortening can also be used for pie crust.

For puff pastry, a roll-in fat that is very firm and waxy is used (1). However, a softer fat source can be used if both the dough and the equipment are kept cold by refrigeration. The resulting pastry is less waxy (1). Puff pastry shortening almost always contains an aqueous phase (2).

An unemulsified shortening is a compromise between having the best frying fat and the best pastry and cookie shortening. All-purpose emulsified shortenings represent a compromise between making the best cakes and icings (1).

Tempering generally is limited to plastic shortenings (1). Tempering consists of holding the shortening for 24–72 hr in a room maintained at a constant temperature, usually somewhere between 27 and 32°C (1). Moziar *et al.* (4) studied the effect of tempering on the physical properties of a canola-soybean-palm formulation. Temperature and time both affected the solid content, hardness and firmness of the shortening.

Good plasticity is required for shortenings used in roll-in doughs from which Danish pastries, puff pastries and pie crusts are made (1). In puff pastry the shortening must approximate the consistency of the dough to remain in a continuous, unbroken layer as it stretches and becomes thinner (2).

The ease of handling of shortening in the mixing process is also of importance. The objective of this study was to evaluate a variety of shortenings for their consistency and plasticity. Melting, crystallization characteristics and solid content were also examined.

MATERIALS AND METHODS

Samples 1–7 and 10–16 (Table 1) were purchased from supermarkets in either the U.S. or Canada. Sample 9 was obtained from Malaysia and samples 8 and 17–22 were samples of commercial shortenings which are sold in 20 kg containers. Samples were stored in a 21°C incubator. Samples either had different brand names or were the same brand, but different products.

Softening points and dropping points. Softening points of the product and dropping points of the fats were determined with the Mettler FP 80 Central Processor (Mettler Instruments A.G., Greifensee-Zürich, Switzerland), using a heating rate of 1°C/min. For determination of the softening point, the cup was pushed into the product and excess product carefully removed. For the determination of the dropping point, the fat was melted and solidified in the cups at −10°C for 1 hr (5).

Crystallization, melting characteristics and texture. Differential scanning calorimetry (DSC) was used to determine the melting behavior of the shortenings and the crystallization temperature of the melted fat with a model 900 DuPont Thermal Analyzer (DuPont, Boston, MA). Heating and cooling rates were 5°C/min. The temperature of crystallization was taken as the temperature at the start of the exothermal crystallization deflection of the curve (6). Texture measurements of the products were made after prepared samples were stored in the 20°C incubator for 24 hr.

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TABLE 1

Dropping Points, Softening Points, Crystallization Temperatures of the Shortenings and Polymorphic Form of Crystals in the Solids

Sample	Dropping point of the fat (°C)	Softening point of the product (°C)	Crystallization temp. (°C)	Polymorphic form
Vegetable				
U.S.				
1. Soy-palm	44.3	45.2	28.5	β'
2. Soy-palm	42.2	45.1	28.5	β'
3. Soy-palm	44.8	46.0	29.0	β'
Canada				
4. Soy-canola-palm	44.7	45.8	30.5	β'
5. Soy-canola-palm	45.3	45.7	28.5	β'
6. Canola-palm	45.6	45.7	29.0	$\beta>>\beta'$
7. Soy	46.1	48.6	31.5	β
8. Palm-vegetable	40.4	42.8	27.5	β'
Tropical				
9. Palm-palm kernel	42.4	44.7	27.0	β'
Animal				
10. Lard, U.S.	45.2	44.4	30.5	β
11. Lard, Canada	40.6	41.9	26.5	$\beta>>>\beta'$
12. Lard, Canada	38.2	37.7	23.5	β
13. Tallow-lard, Canada	42.7	42.3	29.0	$\beta>>>>\beta'$
14. Tallow-lard, Canada	42.3	43.7	30.0	β
15. Meat-vegetable, U.S.	44.6	45.8	31.5	$\beta'>>>\beta$
16. Meat-vegetable, U.S.	45.1	46.0	31.0	$\beta'=\beta$
17. Vegetable-tallow, Canada	50.6	50.7	36.5	β
Frying fat (Canada)				
18. Tallow	45.8	46.4	30.0	β'
19. Tallow-vegetable	44.8	44.7	28.0	β'
20. Soy-coconut	41.1	42.1	24.5	β'
21. Corn	44.5	44.3	27.0	β'
22. Canola	42.5	44.6	31.0	β

Constant weight penetration. The cone penetrometer (AOCS Method Ce 16-60) (7) determined the Hardness Index, which was calculated by dividing the mass of the cone assembly (92.5 g) by the depth of penetration in mm (8). Yield value I was calculated according to the formula of Haighton (9) ($Y = K\ W/p^n$) and yield value II according to that of Vasic and deMan (10) [$Y = 10W\ (.5625p^2 + 25.25p + 50.265)$] where Y = yield value, K = 19 for a 20° cone, W = 92.5, p = penetration depth in 0.1 mm and n = 1.6.

Constant speed penetration and compression. A computerized Instron Universal Testing Machine (Instron Canada, Burlington, Ont., Canada) as described by deMan *et al.* (11) was used in the penetration and compression tests. In the penetration tests, samples were contained in small cups and in the compression test cylindrical samples of 2 cm height and 2 cm diameter were compressed to 1 cm. Details of preparation of samples and probe are given by deMan *et al.* (12).

Solid fat content (SFC). The SFC of the shortenings and that of the fat was determined by pNMR (pulse nuclear magnetic resonance) using the Bruker PC/20 Series NMR analyzer (Minispec, Bruker, Milton, Ont., Canada) (11). The direct mode was used, which measures the ratio of the number of hydrogen nuclei in the solids to the total number of hydrogen nuclei in liquid and solids. Samples were run in triplicate with the enhancement setting at 1. The SFC of the fat was determined using the cooling methods of AOCS method Cd-57 (7), which consists of heating the fats at 60°C, solidifying at 0°C for 15 min, tempering at 26.7°C for one-half hour, cooling again at 0°C for 15 min, and then measuring the SFC after conditioning for one-half hour at the appropriate temperatures. Instead of the tempering temperature of 26.7°C, which is based on the Fahrenheit scale of 80°, a temperature of 25°C was used. Other tempering temperatures were also employed.

For measuring the solid content of the actual products, the NMR tubes were filled by means of a sampling device consisting of a stainless steel tube with tight fitting plunger. The solid content in the product was determined after conditioning the samples for one-half hour at temperatures of 20, 30 and 35°C.

Air content. Air content was estimated by the weight of the cylindrical samples (volume 6.283 cm^3) that were used in the constant speed compression measurements, and dividing this by .9 (density of fat). The percent difference between the total volume and that of the fat was taken as the air content.

Fat crystal structure. The polymorphic forms of the fat crystals in the products were established by X-ray diffraction using a 601 Diffractis X-ray generator and a Guiner X-ray diffraction camera, Model FR 552 (Enraf-Nonius, Delft, The Netherlands) which was operated at 21°C. An Enraf-Nonius Guinier viewer was used to measure the distance between diffraction lines on the film and to estimate the relative amounts of β and β′ forms.

Crystal size was visualized by polarized light microscopy using an Olympus model BH polarizing microscope with a PM-6 camera attachment. Fat crystal structure was established within two weeks of purchase of the samples (6).

RESULTS

Dropping points of the fat, softening points of the product, crystallization temperatures of the fat and the polymorphic form of crystals in the shortenings are all displayed in Table 1. The dropping points ranged from 38.2 to 50.6°C, but the majority of the dropping points were in the 42 to 46°C range. The softening points were, on average, 0.9°C higher than the dropping points. The difference between the softening and the dropping points was more pronounced in the vegetable shortenings. Crystallization temperatures ranged from 23.5 to 36.5°C, but the majority fell between 27 to 31°C. There was not much difference between the vegetable and animal fat shortenings as far as melting and crystallization temperature is concerned, but the difference in the polymorphic form of the crystals was distinct. The vegetable shortening were generally in the β′ form, except for sample 7 (Table 1) that consisted of only soybean oil, and samples 6 and 22 that contained canola oil. Canola oil and, to a certain extent soybean oil, are β-tending when hydrogenated (13). For this reason a β′-tending hard fat, such as hydrogenated palm oil, is incorporated (1). The animal fat shortenings were mostly in the β form, except for samples 18 and 19 that contain tallow or tallow with a small amount of vegetable oil.

The DSC melting diagrams of the vegetable shortenings are displayed in Figure 1. The β′ shortenings (curves 1 to 5) showed a sharp melting peak with no major melting peak at the lower temperatures. The shortening containing β crystals showed a broad melting peak (curve 6 and 7). Sample 6 (Table 1) contained solids that melted at lower temperatures (curve 6). The temperatures of the last DSC-melting peak were, on average, 4 to 5°C higher than the softening points (Table 1, samples 1–7), which can be explained by different heating rates used in the two determinations. The heating rate in the DSC was 5°C/min and 1°C/min in the softening point determination. Melting curves for the palm-vegetable and palm-palm kernel samples (Table 1, 8 and 9) are not presented because of their water content (approximate 10%), which interferred during melting.

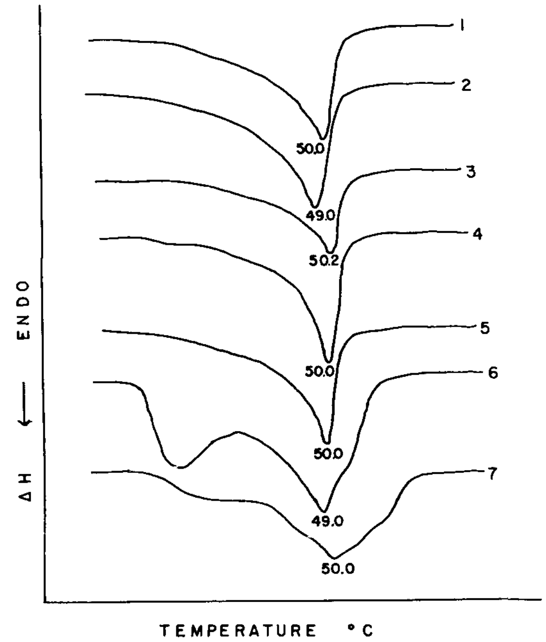

FIG. 1. DSC melting curves of vegetable shortening. Numbers on the curves relate to the same numbers of the shortening in Table 1.

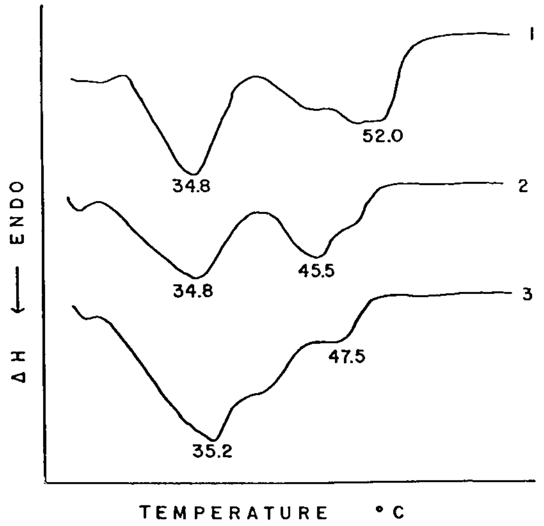

FIG. 2. DSC melting curves of the lard samples 10, 11 and 12 (Table 1), curves 1, 2 and 3, respectively.

The DSC-melting diagrams of the lard samples are shown in Figure 2. Curve 3 in Figure 2 was a pure lard, while those of curves 1 and 2 contained hydrogenated lard. The hydrogenated lard shows up in the last peaks of curves 1 and 2. Obviously the sample of curve 1 contained more hydrogenated lard than that of curve 2 (Table 1, samples 10 and 11, respectively). The addition of hydrogenated lard is also demonstrated in the temperatures of the dropping points (Table 1, samples 10 to 12), which increased with increased addition of hard fat. The DSC-melting diagrams of the tallow-mixtures is displayed in Figure 3. The meat-vegetable shortenings (curves 1 and 2) were quite similar and so were the tallow-lard mixtures (curves 3 and 4). The apparent exothermal peaks in curves 3 and 4 were not due to polymorphic transition because the tallow-lard mixtures were already in the β form. At temperatures of around 25 and 30°C substantional amounts of solids melted in these mixtures. Since DSC melting temperatures are about 5°C higher than dropping points it can be concluded that these solids were present at 20°C. The vegetable-tallow shortening (curve 5), which was in the β form (Table 1, sample 17) showed a single sharp melting peak like the β′ vegetable shortenings (Fig. 1, curves 1 to 5).

The DSC melting diagrams of the frying shortenings are displayed in Figure 4. Curves 1 and 2 are quite similar except that the temperature of the melting peak of curve 2 is slightly lower than that of curve 1. This would indicate that only a small amount of oil was incorporated in the tallow of sample 19 (Table 1). The soy-coconut and the corn samples (Table 1, 20 and 21) that were in the β′ form showed substantial melting in the lower temperature regions. The β-crystal-containing canola sample showed a large wide melting peak.

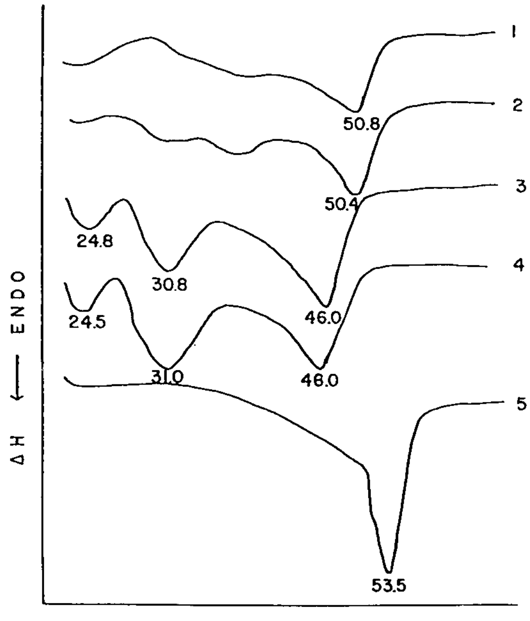

FIG. 3. DSC melting curves of the tallow (meat) mixtures 15, 16, 13, 14, 17 (Table 1), curves 1, 2, 3, 4 and 5, respectively.

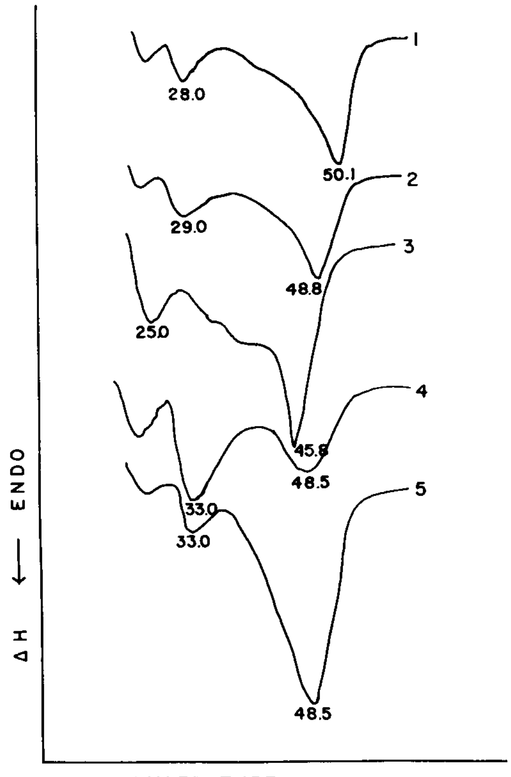

FIG. 4. DSC melting curves of the frying fats 18, 19, 20, 21 and 22 (Table 1), curves 1, 2, 3, 4 and 5, respectively.

As can be seen from the various melting curves polymorphic behavior in shortening, unlike that of pure compounds, cannot be deduced from DSC analysis.

Texture. Some typical curves that were obtained by penetration are displayed in Figure 5. Curve 1 is an example of a soy-palm shortening. Curve 2 was the soy only sample (Table 1, sample 7). This sample was very brittle, which is brought out by the irregularities of the horizontal part of the curve. During penetration with the probe small pieces broke off. The real penetration force would have been greater if the sample had not disintegrated. The tallow-lard and lard sample (curves 3 and 4, respectively) showed a small degree of irregularities, but less than that of curve 2. The palm-vegetable and palm-palm kernel were easy to penetrate without breakage.

Compression of cylindrical samples of shortening produces widely different curves as shown in Figure 6. During compression of samples a diagonal or a V-like crack will appear in the fat cylinder of samples that are soft and pliable. In brittle samples the fat cylinder will disintegrate into small pieces during compression. The initial slope of the curves is a straight line which, according to Dixon (14), represents the elastic non-recoverable deformation. On the curves this is indicated by the letter a. After the initial straight part the curves show a different, more rounded, and less steep slope which, according to Dixon, is an indication of viscous flow. This portion of the curve is indicated by b. Some of the shortening curves do not exhibit this viscous part b during compression (curve 4) or show only a very small portion of b (curve 5). Other samples show a very large b section (curve 6 and 7). The viscous flow will continue until a break appears in the sample, which is indicated by B as the breaking force. The breaking force B can appear early during compression at small deformation (curves 4 and 5) or the sample can tolerate a large deformation before a crack appears as shown in curves 6 and 7, or there can

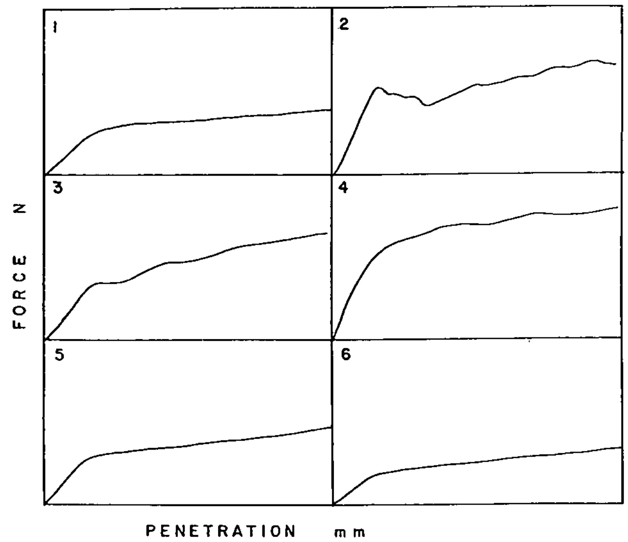

FIG. 5. Examples of penetration curves: 1, Soy-palm; 2, soy only; 3, tallow-lard; 4, lard; 5, palm-vegetable; and 6, palm-palm kernel.

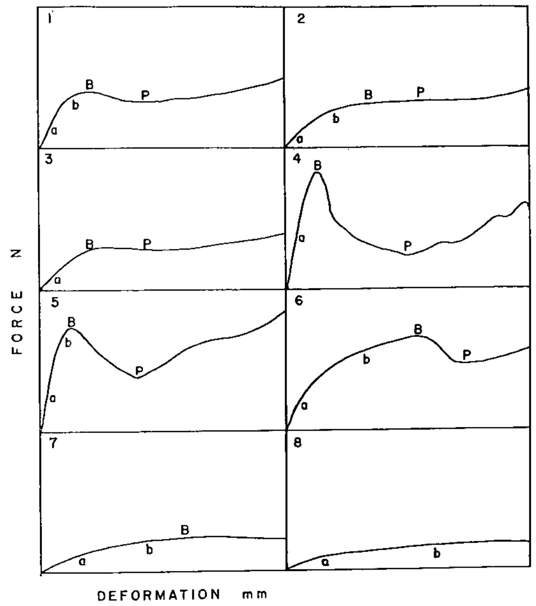

FIG. 6. Examples of compression curves: 1 and 2, soy-palm; 3, soy-canola-palm; 4, soy only; 5, tallow-lard; 6, lard; 7, palm-vegetable, and 8, palm-palm kernel.

be no breaking force at all, as in curve 8. The sample of curve 8 (palm-palm kernel) just bulged on the sides.

After the breaking force, the slope of the curve either reaches a plateau (P) for a while and then increases again (curve 2 and 3) or it dips slightly, as in curve 1. The downward slope can also be very steep (curve 4). The dips in the downward curve before rising again is also called P for plateau force (curve 4).

The breaking force is calculated by dividing force B (Fig. 6) by the surface area of the sample, which is 3.14 cm^2. Brittleness is defined as the difference between the breaking force and the plateau force divided by the breaking force in percentage. Table 2 shows the textural data obtained by the three different methods. The SFC of the fat and that of the product is also included for comparison as well as the estimated air content. The β' vegetable-palm shortenings (sample 1 to 5) are comparable with the meat-vegetable samples 15 and 16 as far as texture is concerned, although the meat-vegetable samples contain higher solids. This may have been caused by the fact that the latter had more air incorporated. Samples 6 and 7 (that contained β crystals) were hard and brittle. The mixtures of tallow and lard were exceptionally hard and the cylindrical sample broke at a small deformation. The lard samples (10 to 12) were able to withstand a much larger

TABLE 2

Textural Characteristics of Shortenings at 20°C by Three Different Methods, SFC of Fat and Product at 20°C and Air Content

	Constant speed				Constant weight cone penetrometer hardness index (g/mm)	SFC at 20°C			
	Penetration	Compression				Fat tempered at			
Sample	Force at 1 cm N/cm^2	Breaking force N/cm^2	Deformation at breaking force (%)	Brittleness (%)		25°C (%)	30°C (%)	Product (%)	Air content (%)
Vegetable									
U.S.									
1. Soy-palm	4.42	.87	8.2	9	5.4	20.4	17.8	15.5	10.1
2. Soy-palm	2.62	.61	11.9	0	4.2	17.4	15.8	12.5	NA
3. Soy-palm	3.55	.73	21.0	0	4.7	19.3	17.3	13.1	11.7
Canada									
4. Soy-canola-palm	3.04	.60	12.8	0	4.3	18.7	16.5	13.5	13.5
5. Soy-canola-palm	3.95	.68	9.2	5	4.4	18.6	16.5	12.2	15.9
6. Canola-palm	6.27	1.80	15.2	19	7.0	23.7	19.9	19.2	12.0
7. Soy	5.36	2.00	6.4	63	7.9	22.6	20.1	13.6	5.9
8. Palm-vegetable	4.94	.61	25.8	0	6.3	32.8	29.4	25.1	13.[a]
Tropical									
9. Palm-palm kernel	2.92	none	none	0	4.6	26.1	22.6	11.4	10.[a]
Animal									
10. Lard, U.S.	3.89	1.06	20.4	19	4.8	28.1	26.9	23.3	2.3
11. Lard, Canada	4.60	1.47	29.0	32	5.1	27.4	26.2	23.0	6.2
12. Lard, Canada	4.00	.54	15.0	4	4.5	26.4	25.3	25.3	10.0
13. Tallow-lard, Canada	12.56	1.93	6.9	40	11.8	28.8	27.0	34.2	8.8
14. Tallow-lard, Canada	13.43	4.28	9.1	55	14.6	28.9	28.7	34.0	9.0
15. Meat-vegetable, U.S.	4.64	.90	12.2	2	5.4	28.3	25.0	21.6	19.5
16. Meat-vegetable, U.S.	4.67	.97	11.6	9	5.9	31.2	26.9	23.3	21.0
17. Vegetable-tallow, Canada	8.82	.89	17.6	10	8.1	28.3	26.6	23.7	4.0
Frying fat (Canada)									
18. Tallow	6.91	1.61	7.4	42	8.9	34.3			
19. Tallow-vegetable	6.61	1.24	11.7	20	6.9	29.1			
20. Soy-coconut	15.60	8.40	6.1	71	19.4	27.2			
21. Corn	10.73	3.74	6.0	53	14.5	27.3			
22. Canola	12.59	5.40	5.0	75	19.6	34.2			

[a] Water content.

deformation before breakage, while the tallow samples (18 and 19) were not as pliable. Mixing of tallow and lard overrides the favorable textural characteristics of the individual lard or tallow. The palm-vegetable (sample 8) was able to withstand a large deformation before breakage. This shortening was recommended for the baking of croissants and Danish pastry. The palm-palm kernel sample was still viscous at 50% deformation indicating that this product would also be suitable for roll-in pastries. The vegetable frying fats were very hard and brittle (samples 20–22, Table 2). The texture of the frying fats were evaluated to obtain a measure of spoonability or ease of handling in restaurants, as these fats are sold in 20 kg containers. The vegetable frying fats, samples 20–22, were harder and more brittle than the tallow samples (18 and 19) in spite of their similar SFCs. Shortenings 18 and 19 are also used in cookie manufacture.

Yield values I and II were calculated according to the formulas suggested by Haighton (9) and Vasic and deMan (10), respectively, from the depth of penetration of the cone penetrometer. The mean of the calculated yield values I was 10.75 and that of yield values II was 1.05 N/cm^2 (sample 9 excluded). The mean of the breaking forces was 1.92 and of the penetration forces 6.82 N/cm^2 (sample 9 excluded). Yield values II ($\bar{x}$ = 1.05) are representative of the breaking forces ($\bar{x}$ = 1.92). The correlation between the two was .95. The penetration forces for the brittle samples were too low as mentioned earlier. When samples that displayed more than 35% brittleness were eliminated from the mean of the penetration forces and yield values I, the new means were 4.48 and 4.61 N/cm^2, respectively. This suggests that yield values I as calculated by the Haighton formula represent the penetration forces (r = .96) or the viscous flow as Haighton suggested. The coefficients of variation (C.V.) of the replicates, of all the samples which were four replicates in constant speed penetration and compression measurements and 10 in the cone penetrometer are displayed in Table 3. The C.V. in the compression test was high for the brittle samples.

The SFC of the fats at 20°C when tempered at 30°C (60 → 0 → 30 → 0 → 20) was lower than when the fats were tempered at 25°C (60 → 0 → 25 → 0 → 20) (Table 2). Brekke (1) stated that in industry, shortenings are tempered between 27 and 32°C for two or more days. The SFC of the products was generally lower than that of their fats when tempered at 30°C. There were two exceptions. The SFC of product sample 9 was much lower than that of the fat tempered at 30°C (11.4 and 22.6% respectively, Table 2). This could be caused by a eutectic formation of the mixture of palm kernel and palm oils as pointed out by Timms (15). The formation of the eutectic can be used to the advantage in the baking industry as this sample was still viscous at 50% deformation. The products of samples 13 and 14 showed a higher solid content than that of the fat tempered at 30°C. According to Chrysam (2) this increase in solid fat content is due to the formation of a crystalline-interaction compound. Several other tempering methods were employed to see if they would agree better with that of the product. Results are shown in Table 4. The fats tempered according to method 2 came closest in solid content to that of the products at all three temperatures of 20, 30 and 35°C (Table 3).

TABLE 3

Coefficients of Variation of Replicates of the Textural Methods—Ranges and Means

Method	Range (%)	Mean (%)
Cone penetrometer	1.9–5.7	4.2
Constant speed penetration	1.3–11.2	4.2
Constant speed compression		
Peak force	1.0–18.0	9.7
Deformation to peak	6.1–21.4	13.7
Plateau	5.8–18.6	11.7

TABLE 4

Mean Values of SFC (%) of 16 Shortening Products and That of Their Fats Cooled and Tempered by Four Different Methods

		Fat method			
Temperature	All products	1	2	3	4
20	20.1	23.0	22.7	25.2	21.5
30	12.6	14.7	13.1	16.3	16.1
35	9.7	10.3	10.0	10.3	10.5

Method 1, 60 → 0 → 30 → 0 → 20 → 30 → 35.
Method 2, 60 → 0 → 35 → 0 → 20 → 30 → 35.
Method 3, 60 → 0 → 25 → 0 → 20 → 30 → 35.
Method 4, 60 → 0 → 30 → 20 → 30 → 35.

TABLE 5

Correlation Coefficients Within Textural Methods and Between Textural Methods and SFC at 20°C

Methods	N	r
Hardness index and penetration	21	.9470[a]
Hardness index and breaking force	21	.9306[a]
Penetration and breaking force	21	.8620[a]
Hardness index and SFC fat tempered at 25°C	21	.6861[b]
Penetration and SFC fat tempered at 25°C	21	.6874[b]
Breaking force and SFC fat tempered at 25°C	21	.7078[b]
Hardness index and SFC-product	17	.7237[b]
Penetration and SFC-product	16	.8000[c]
Breaking force and SFC-product	16	.5807[b]

[a]Significant P<.01.
[b]Not significant.
[c]Significant P < .05.

Table 5 shows the correlation coefficients within the textural methods and between the textural methods and the SFC of the fats tempered at 25°C and that of the products. Correlation within the textural methods was significant (P<.01), while the correlations between the textural methods and the SFC were not significant with one exception, that of penetration and SFC of product (P<.05). The poor correlation between the textural methods and SFC indicates that the crystal network plays an important role in texture.

Fats destined for shortening manufacture are usually specified according to their SFC and melting characteristics. If these parameters fall within the specified range for a certain shortening this will not guarantee a desirable texture. Composition of the fat, manufacturing practice, tempering condition of the shortening and storage temperature will influence the texture of the final product. Cone penetrometry, which is a convenient method in evaluation of texture, contributes in specifying a desired shortening. Unfortunately, cone penetrometry does not estimate brittleness or viscous flow, which is a desirable feature in shortening destined for roll in doughs. Compression tests are useful for shortenings that require a broader specification.

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