Physical and Textural Evaluation of Some Shortenings and Margarines

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Solid fat content of shortening and margarine was estimated by pulsed NMR. These values were compared with those of the melted fats using different cooling methods. Solid fat content of shortenings measured at 10 and 20 C followed the same trend as those measured on the melted fat tempered at 30 C. Solid fat content of margarines followed the same trend as those measured on the nontempered fats. Softening points of the products were similar to the dropping points of the fats, as were the temperatures of the DSC major melting peaks. Compression tests of cylindrical samples provided more information about textural characteristics of the products than one penetration tests.

At present, different cooling and tempering methods are used to estimate the solid content in fats [AOCS method Cd 10-57, AOCS recommended practice Cd 16-81 (1); IUPAC 2.141 (2)]. It is not known how well these solid fat index (SFI) values correlate with the solid content in final products such as shortening and margarine. Pulsed nuclear magnetic resonance (NMR) for the determination of solid fat is based on the measurement of the ratio of the number of hydrogen nuclei in the solids to the total number of hydrogen nuclei in the sample (solid and liquid). The fast and slow decaying signals arising from the hydrogen nuclei in the solid and liquid phases respectively, are converted into the percentage of solids which is displayed and is reported as NMR solids percent (3). Because pulsed NMR measures the ratio of the number of hydrogen nuclei in the solids to the total number of hydrogen nuclei, it was thought that pulsed NMR would be suitable for measuring the solids present in shortening itself even when a certain amount of air is incorporated. Pulsed NMR records zero solids for water or skim milk. Margarines contain 80% fat, with the remainder consisting of water, skim milk powder and salt. For this reason, margarines were also tested for their solid-liquid ratio.

In the manufacture of shortening and margarine, the melted fat is processed in a scraped surface heat exchanger which must cool the fat quickly in order to form as many crystal nuclei as possible. After passing through the crystallizing A-unit(s), followed by working or static B-unit(s), margarines are stored at refrigeration temperatures; shortenings, after tempering, are stored at room temperature (4,5). These storage conditions also affect their physical properties. At no time during the crystallization process is the fat cooled to O C. Solid fat determinations, however, always involve a cooling step at 0 C. For this reason the effect of different temperature treatments on the SFC as determined by pulsed NMR was studied. Solid fat content (SFC) values thus obtained were compared with the SFC values of the shortening and margarine.

Texture evaluation of shortening and margarine usually consists of a cone penetration method. The amount of air incorporated plays an important role in the results of this test. Smoothness and brittleness depend on the crystal network and are not measured with the cone penetrometer. For this reason, a compression test was used to obtain additional information. The products were also analyzed for fatty acid composition, polymorphic crystal structure, crystallization and melting behavior, in order to explain some of the physical properties.

MATERIALS AND METHODS

The shortenings were obtained from a local manufacturer and were labelled as follows: 1) blended pastry shortening; 2 and 3) all vegetable emulsified shortening, and 4) all purpose vegetable shortening. The margarines were stick margarines from western Canada.

Margarine fat was obtained by melting the margarine, followed by centrifugation and filtration of the fat layer. Fats were transesterified with Na- methoxide, and the methyl esters were analyzed by GLC on a 2m column packed with 10% SP2330. The liquid oil from the products was obtained by placing Whatman chromatography paper #1 strips of medium flow rate 1.5 cm into the products and letting the oil rise about 5 cm. The oil was extracted from the paper and analyzed as above. A Bruker PC/20 series NMR analyzer (Minispec) was used for all solid fat content measurements. For measuring the solid fat content of the actual products, the NMR tubes were filled by means of a trier

TABLE 1

Fatty Acid Composition of Shortenings and Margarines

	Fatty acid wt %							
Product	14:0	16:0	16:1	18:0	18:1	18:2	18:3 + 20:0	20:1
Shortening 1	1.5	18.3	1.0	19.8	26.6	28.5	4.3	—
Shortening 2	0.2	15.2	—	11.0	62.3	11.1	0.2	—
Shortening 3	0.4	15.0	—	12.8	57.5	13.4	0.5	0.4
Shortening 4	0.3	10.8	—	12.2	73.8	2.0	0.4	0.5
Margarine 1	0.1	7.9	—	9.1	80.3	1.2	0.5	0.9
Margarine 2	0.1	8.3	—	7.4	79.8	2.7	0.9	0.9

consisting of a stainless steel tube with tight fitting plunger. Crystal form of the fat was established by X-ray diffraction using a 601 Diffractis X-ray generator and a Guinier camera model FR 552 (Enraf Nonius, Delft, The Netherlands) (6). Dropping points of the fats were determined by the Mettler dropping point method (7) using the cup with the small opening. The cup with the wider opening determined the softening point of the products.

DSC analyses were carried out with a model 900 du Pont Thermal Analyzer. Heating and cooling rates were 5 C/min. Temperature of crystallization was taken as the temperature at the start of the exothermic deflection of the curve.

Textural properties were measured in two ways: (i) By cone penetrometer (AOCS method Cc 16-60). Hardness was calculated by dividing the mass of the cone assembly (92.5 g) by depth of penetration in mm. (ii) By compression of cylindrical samples of 2.0 cm height and 2.0 cm diameter at a speed of one cm/min to 50% compression. A 4.5kg load cell was hooked up to a signal conditioner, A-D converter and Apple IIe computer (8).

RESULTS AND DISCUSSION

Fatty acid composition of the four shortenings are displayed in Table 1. Shortening 1 apparently contained liquid oil, judging from the 18:2 and 18:3 content. It also contained animal fat which is reflected in the 16:1, 14:0 and high 16:0 content. Shortenings 2 and 3 were similar in composition. Judging from the 18:2 content, both shortenings contained either liquid oil or lightly hydrogenated oil in addition to partially hydrogenated oil. The 16:0 content of shortenings 2 and 3 was high, indicating that hydrogenated palm oil was incorporated. Shortening 4 was a partially hydrogenated oil and also contained hydrogenated palm oil. Judging from the fatty acid composition of the liquid oil (Table 2), shortening 4 contained canola oil. The margarines consisted of hydrogenated canola oil and palm oil. X-ray analysis revealed that only shortening 1 was in the β-form; all others were in the β' form. Photomicrographs, however, showed fine crystal structure for all products. SFC values using various cooling and tempering procedures are presented in Figures 1 to 6. These figures also contain the SFC values for the shortenings and margarines. SFC values for temperatures above 30 C are not reported, as these values were similar for almost all treatments and coincided with those of the actual shortening or margarine. There was

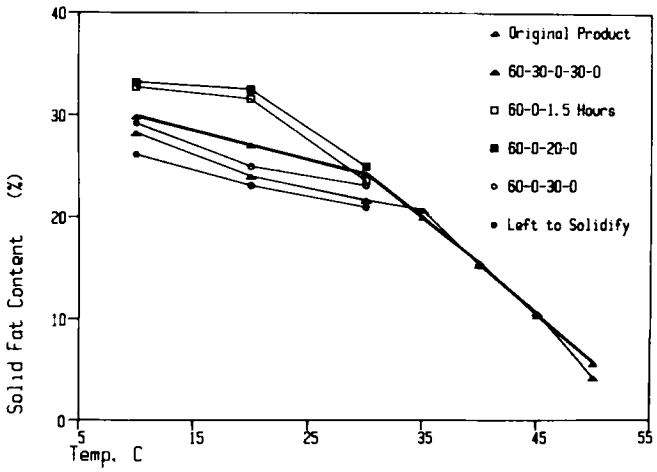

FIG. 1. Solid fat content of shortening 1.

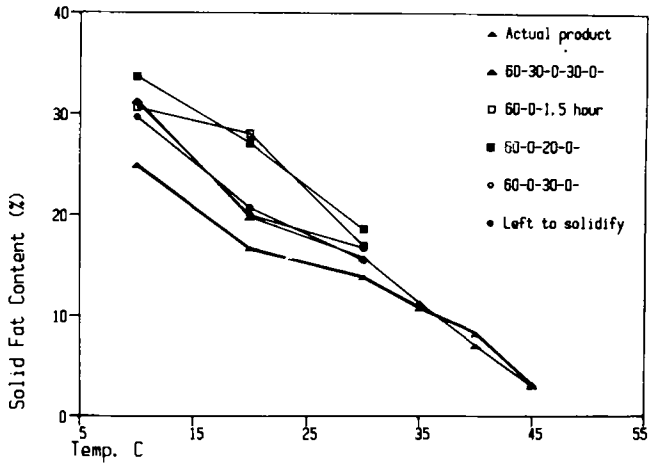

FIG. 2. Solid fat content of shortening 2.

little difference between the softening point of the shortening and the dropping point of the fat (Table 3). The temperatures of the last melting peak of the DSC diagrams of the products were similar to those of the solidified fat (Table 4). The temperatures of the last melting peaks were in all cases about 4 C higher than the temperatures of the softening and dropping points. The temperature of the last DSC melting peak signifies the complete melting of the fat, whereas in the dropping point determination, the fat has not yet completely melted and, therefore, is lower. Also, the rate

TABLE 2

Fatty Acid Composition of Oil Base of Shortenings and Margarines

	Fatty acid wt %							
Product	14:0	16:0	16:1	18:0	18:1	18:2	18:3 + 20:0	20:1
Shortening 1	0.6	14.1	0.4	5.7	33.6	39.9	5.5	—
Shortening 2	0.1	9.6	—	4.3	71.6	14.1	0.2	0.1
Shortening 3	0.5	8.9	—	4.5	66.4	18.3	0.7	0.7
Shortening 4	0.1	5.7	—	4.6	85.9	2.5	0.3	0.9
Margarine 1	—	6.6	—	5.0	85.0	1.3	0.5	1.5
Margarine 2	—	6.3	—	3.6	84.8	3.2	0.9	1.2

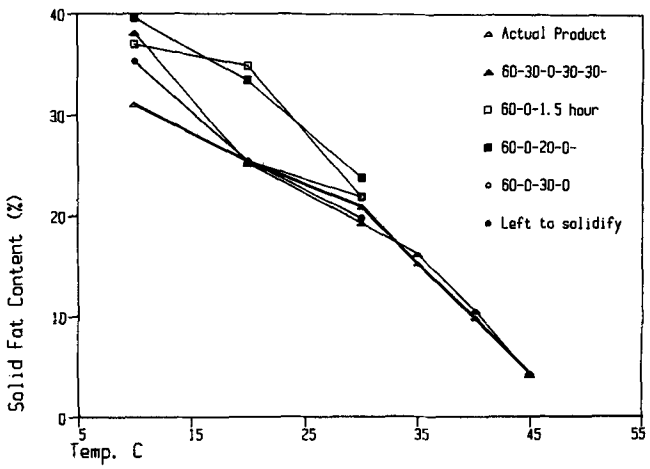

FIG. 3. Solid fat content of shortening 3.

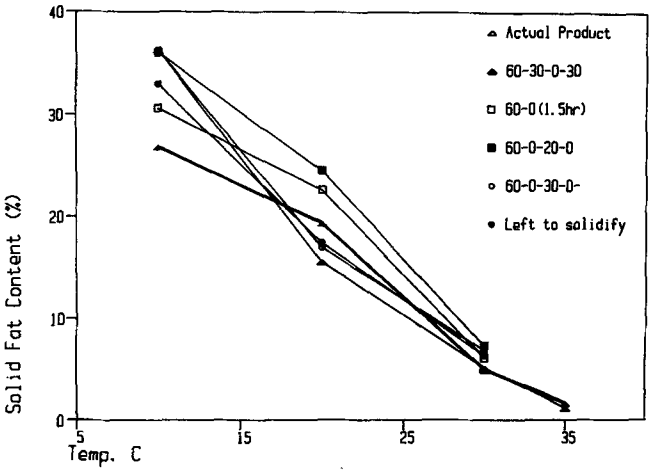

FIG. 5. Solid fat content of margarine 1.

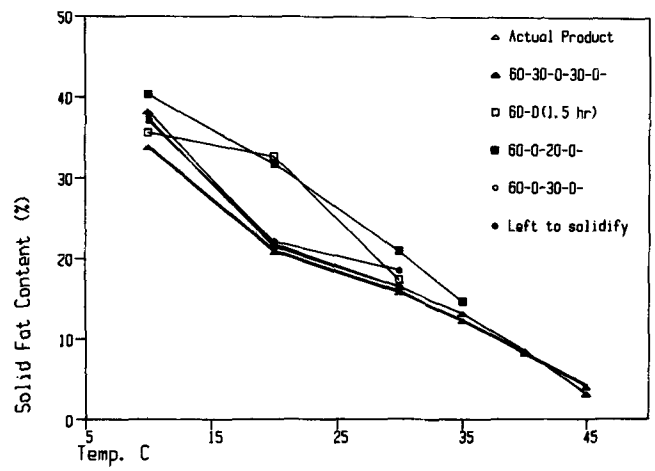

FIG. 4. Solid fat content of shortening 4.

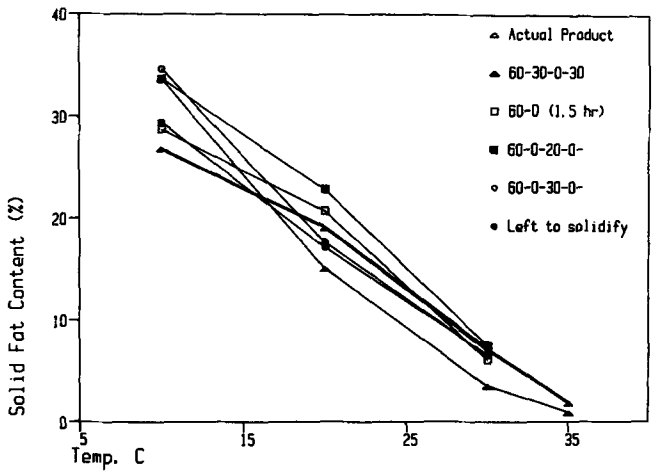

FIG. 6. Solid fat content of margarine 2.

of heating in the DSC is higher (5 C/min) than the rate of heating in the dropping point determination (1 C/min). The major difference of the various temperature treatments of the fats as compared to the actual product is, therefore, reflected in the SFC values at 10, 20 and 30 C.

Generally, when the fats were melted at 60 C and left to solidify at 20 C, the SFC values were low at all temperatures (Figs. 1-6). SFC values were high at all temperatures when the fats were cooled from 60 to 0 C and then either left for 1.5 hr at 0 (IUPAC method) or were tempered at 20 C and then cooled again to 0 C. Tempering the fats at 30 C resulted in low SFC values at 20 C. Precooling at 30 C before freezing at 0 C and then tempering at 30 C resulted in almost the same SFC values as without the precooling. Quick chilling instantaneously forms mixed crystals composed of high and low melting triglycerides. Upon tempering, some of the mixed crystals will melt into the liquid phase. Cooling after the tempering will resolidify only the higher melting triglycerides (4). The SFC values for the actual shortenings (Figs. 1-4) except for shortening 1 tended to be lower at all temperatures than the SFC values of the fats. The SFC content of shortening 2 (actual product) was exceptionally low.

Margarine fats exhibit steeper SFC curves and contain lower solids at 30 and 35 C than those of shortening fats. Tempering at 30 C is almost like remelting the fat. The trend of the SFC curves using the IUPAC method is similar, although it is higher than those of the actual margarines (Figs. 5,6). Tempering at 30 C of margarine fats results in quite different curves from those of the actual product. This is in contrast with shortening fats, where tempering at 30 C results in similar curves with somewhat higher values than those of the actual product.

It should be pointed out that although the fats of shortenings 2 and 3 were similar in fatty acid composition (Tables 1, 2), they had different SFC values.

The accuracy of the determination of the SFC of the actual product was good. The coefficient of variance of a shortening containing 13% air and 13.3% solids at 20 C was 5.4% (N = 10), and that of another shortening containing 4% air and 29% solids at 20 C was 1.3% (N = 10).

Crystallization behavior of the fats is displayed in

Table 5. Crystallization temperature of shortening 1 was the highest. This may be the reason that the fat in this product crystallized more completely than the fat in the other shortening products. The SFC of the product (Fig. 1) was between those of the tempered and nontempered fats. This fat contained high levels of 18:0 and 16:0 (Table 1) and a low level of 18:0 in the oil base, indicating that the solids contained large amounts of 18:0 with the possible presence of trisaturates. Trisaturates are high melting triglycerides which are β-tending. Crystallization temperatures for margarines are considerably lower than those of the shortening. The amount of fat crystallized after 15 min at 20 C is reflected in the ΔH of melting. ΔH of shortening 2 was the lowest. This shortening also contained low solids in the product (Fig. 2).

Textural properties are presented in Table 6. Shortening 2, containing the lowest percent solids, also shows the lowest hardness and the lowest firmness as measured by penetrometer and Instron, respectively, indicating that this shortening is the softest. Shortening 1, with the highest solids content, was judged the firmest by Instron but not by the penetration method. Shortening 4 also was firm, probably because no liquid oil was incorporated in this shortening (Tables 1 and 2). Shortening 3, which was prepared on a drum, showed the highest hardness value but was not judged the firmest by Instron although the plateau force was the highest. The margarines, although similar in solid fat content, exhibited different textural properties. Hardness values showed the same trend as Instron results. Correlation between hardness and plateau force for all samples was 0.956. The reason hardness values do not correlate with solid contents in the product is that the fat crystal network plays an important role in the rheological properties of the product (9). Plastic fats contain a three-dimensional network of fat crystals held together by primary (nonreversible) and secondary (reversible bonds).

The advantage of the compression test is that peak force is shown. When the peak force was at the beginning of the compression, many vertical cracks appeared in the sample, which is an indication of brittleness. Only shortening 2 and margarine 2 showed a gradual increase in force with no break in force during the test, indicating no brittleness.

These experiments have shown that different cooling and tempering treatments of fats result in different SFC values. Tempering treatment at 30 C will reflect the solid content in the final product as far as shortening is concerned, but they do not reflect the solid content in margarines. Fats destined for margarine manufacture should, therefore, not be tempered at 30 C if an estimation of the solids content in the final product is desirable.

TABLE 3

Melting points of shortenings and margarines

Product	Softening point[a] (°C)	Dropping point[b] (°C)
Shortening 1	51.5	51.8
Shortening 2	45.5	45.1
Shortening 3	47.0	47.4
Shortening 4	46.5	47.0
Margarine 1	34.2	33.7
Margarine 2	35.2	34.6

[a]Determined on the product.
[b]Determined on the fat separated from the product.

TABLE 4

Major Melting Peaks on the DSC Diagrams of Shortenings and Margarines and the Fats Separated From Them

Sample	Product peak (°C)	Fat peak (°C)
Shortening 1	55	54[a]
Shortening 2	49	51[a]
Shortening 3	51	51[a]
Shortening 4	50	50[a]
Margarine 1	37	33[b]
Margarine 2	38	38[b]

[a]Melted at 60 C, cooled in ice for 3 min, left at 20 C.
[b]Melted at 60 C, cooled in ice for 3 min, left at 7 C.

TABLE 5

Crystallization Temperature and ΔH of Melting of Fats Cooled at 20 C for 15 min

Sample	Crystallization temp (°C)	ΔH Cal/g
Shortening 1	36	8.95
Shortening 2	32.5	6.73
Shortening 3	31	8.64
Shortening 4	31	8.39
Margarine 1	21	5.67
Margarine 2	24	5.20

TABLE 6

Textural Properties, Solid Fat Content and Air Content of Shortenings and Margarines at 20 C

	Instron measurements			Penetrometer		Air
Product	Peak force N	Plateau force N	Firmness N/mm	hardness (g/mm)	SFC %	content %
Shortening 1	11.0[a]	5.1	18.7	8.0	27.1	5.6
Shortening 2	2.1[b]	1.6	1.3	3.3	16.6	10.9
Shortening 3	9.5[a]	5.8	11.2	10.8	25.3	0.
Shortening 4	6.8[a]	3.2	10.7	7.2	20.9	13.0
Margarine 1	4.0[a]	2.6	7.8	5.4	19.2	—
Margarine 2	2.3[b]	1.8	4.1	4.7	19.0	—

[a]At beginning of compression.
[b]At end of compression.

Solids content in the final product is not an indication of its hardness. Although the cone penetrometer reflects the hardness or softness of a product, this instrument cannot evaluate the brittleness. Compression tests are better suited to evaluate this parameter.

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