Chemical Composition and Physical Properties of Soft (tub) Margarines Sold in Malaysia

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ABSTRACT: Seven samples of domestic and imported Malaysian tub margarines were analyzed for their fatty acid and triglyceride (carbon number) composition, solid fat content, dropping and softening points, crystallization temperature, polymorphic form, color, and textural attributes. Domestic margarines were formulated from palm oil or palm olein and palm kernel oil with a liquid oil but no hydrogenated oils. Two imported products contained hydrogenated palm oil product, which resulted in a high level of β′ crystals, whereas the domestic nonhydrogenated products contained more β than β′ crystals. Crystal habit was related to the fatty acid and triglyceride composition of the high-melting glycerides. Domestic products were firmer in texture, probably because they were formulated to be sold in a tropical climate.
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Soft or tub margarine is mainly used as a spread for toast and sandwiches. Soft margarines have to be stored under refrigeration and should be spreadable when taken from the refrigerator. Preferably, there should be no oil separation when the product is left for a short time at a room temperature of 21°C.

Soft margarines are often formulated from one or more hard stocks and a liquid oil. The hard stock can be prepared from hydrogenated oils, a mixture of natural solid fats, or interesterified fats. The liquid oil can be sunflower, canola, soybean, or even olive oil. Because the margarines are stored under refrigeration, oxidation of the liquid oils is kept to a minimum, and the choice of oil depends on what is thought to be nutritionally desirable or on the price of the oil.

Enig (1) estimated United States fat consumption to contain from 2 to 11.1% of *trans* 18:1 isomers. Chen *et al.* (2) estimated the mean intake of *trans* fatty acids of lactating Canadian women to be 10.6 g/person/d by analyses of their breast milk. Soft or tub margarines contain 14–18% *trans* fatty acids (3). At present, *trans* fatty acids are viewed as being detrimental to health (4–6). For this reason, companies are trying to formulate margarines from nonhydrogenated fats.

The hardstock or solid fat consists of fat crystals that incorporate the liquid oil. The fat crystals should preferably exist in the β′ polymorphic form. This type of crystal is small, and contributes to a shiny surface area, and if the β′ crystals are stable, they will lead to a good unaltered consistency upon storage. Melting points of soft margarines should be below body temperature and not leave a waxy aftertaste in the mouth. The chemical composition and physical properties of North American soft margarines and their fats have been reported by deMan *et al.* (7,8) and D'Souza *et al.* (9). Physical properties are dictated by the solid fat content and particularly by composition of the high-melting triglycerides (HMG) because these triglycerides are thought to set the trend in the polymorphic crystal behavior (9,10). Fatty acid composition of the HMG and solids should be diverse in chainlength. Palmitic acid should preferably be located in the 1 and/or 3 position of the triglyceride (TG) molecule (11,12).

Palm oil is a natural solid fat at room temperature (mean m.p. of 36.7°C). Palm kernel oil (PKO) (m.p. 26.0°C) and palm olein (mean m.p. 21.5°C) (13), which are solid at lower temperatures, are readily available in Malaysia and are used in margarines. Malaysia also imports other margarines. This study evaluates the chemical composition and physical characteristics of Malaysian domestic and imported soft margarines.

MATERIALS AND METHODS

Samples were bought in the supermarket and transported to the laboratory where they were stored in a 5°C cold room. All samples were analyzed in duplicate.

Texture was evaluated by means of a penetrometer at 5 and 10°C. The cone of the penetrometer had an angle of 40°, and the weight of the cone assembly was 79.03 g. The yield value was calculated according to the formula of Haighton (14).

The margarines were melted in an oven at 60°C to obtain the fat. The water layer was syphoned off, and the remaining fat was filtered in the oven through Whatman #1 filter paper that contained some anhydrous sodium sulfate. The fat-soluble ingredients remained in the fat.

The HMG were obtained as follows: The filtered fat was melted in the oven and was dissolved in acetone at a ratio of one part fat to twenty parts solvent (wt/vol). The solution was left in a 10°C cold room overnight to crystallize. The crystal-

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lized fat was filtered under vacuum through a 0.45 μm nylon filter paper, which was supported on a fritted glass vacuum holder (10).

The separated fat and the HMG were analyzed for fatty acid composition and triglyceride by carbon number as follows.

Fatty acid composition. The filtered oil (50 mg) was weighed in a 2-mL screw-capped vial. Hexane (1 mL) and sodium methoxide solution (0.05 mL) were added to the oil. The mixture was shaken with a vortex mixer and left to stand for 5 min (15). One μL of the upper clear ester layer was injected into a Hewlett-Packard 5890 II gas chromatograph, fitted with a polar SP-2340 (Supelco, Bellefonte, PA) capillary column (0.25 mm i.d. × 60 m × 0.2 μm). Gas chromatograph conditions were injector temperature, 240°C; flame-ionization detector (FID), 240°C; oven temperature programming: 120–185°C at 4°C/min (16).

Triglyceride (TG) composition by carbon number. A sample of the filtered fat was dissolved in chloroform to give a 2% solution. The solution (1 μL) was injected into the Hewlett-Packard 5890 II chromatograph, equipped with a 0.53-mm i.d. column × 12 m × 0.15 μm, coated with 5% siloxane-carborane copolymer. Gas chromatograph conditions were injection temperature, 380°C; FID temperature, 380°C; oven temperature programming: 280–340°C at 4.5°C/min. Quantitation was carried out by calibration with a pure TG mixture of known composition (17).

Solid fat content (SFC) was determined with a Bruker Minispec pNMR Analyzer Model no. 120 (Rheinstetten, Germany) according to AOCS method Cd 16-81 (18) and IUPAC method 11.B.6 (19).

X-ray diffraction analysis was used to determine the polymorphic forms of fat crystals in the margarines. The camera was an Enraf Nonius Model FR592 (Delft, The Netherlands). The instrument was fitted with a fine-focus copper X-ray tube. The sample holders were flat stainless-steel plates with a rectangular hole. Samples were prepared at 10°C. Short spacings on the X-ray film were measured with a Guiner viewer (Enraf Nonius). Detailed outlines of the method of X-ray diffraction spectroscopy and short spacings of β and β' crystals have been provided by deMan (20) and D'Souza *et al.* (21).

Dropping points and softening points were determined with the Mettler dropping point apparatus model FP5 (Zurich, Switzerland). In the dropping point determination, the fat in the cups was left for one hour in the freezer compartment of a refrigerator; in the softening point determination, a sample was taken directly from the margarine and transferred to the apparatus (22).

Crystallization temperatures were established by differential scanning calorimetry (DSC). The model was a Perkin-Elmer DSC-7 (Norwalk, CT). The fat was melted at 60°C in the DSC pan and left for 5 min before cooling to −10°C at a rate of 5°C/min. The start of the exothermal peak was taken as the crystallization temperature.

Color of the margarines was determined on the intact products by using a Minolta chroma meter model CR-300 (Osaka, Japan), equipped with a data processor (DP-30). Measurements were taken in terms of "L," "a," and "b" values.

RESULTS AND DISCUSSION

The various oils used to formulate the margarines are listed in Table 1. All margarines contained a fat phase of 80%. The Malaysian products contained either palm oil or palm olein. Two of the products, as stated on the label, also contained palm kernel oil (Table 1, C and D). The label on product G also indicated that it contained palm oil.

Chemical composition. The fatty acid (FA) compositions of the products are shown in Table 2. Judging from the 18:1*t* content, only the Malaysian products C, D, and F did not contain hydrogenated fats. All of the other margarines contained some hydrogenated fats. Products E and G did not indicate this on their labels. TG composition of the original fats is displayed in Table 3. The FA and TG composition of the HMG are displayed in Tables 4 and 5, respectively. The 18:1*t* FA content was much higher in the HMG (Table 4) for all non-Malaysian samples than in the original samples (Table 2). *Trans* FA have much higher melting points than their *cis* counterparts and end up in the solids, especially the HMG. The unidentified isomers (i) were included in the *cis* (c) fatty acid. These isomers include fatty acids with *cis* and *trans* double bonds. Hydrogenation results in double bonds with positional *cis* and geometrical *trans* isomers and combinations of both. Identification of these isomers is difficult and beyond the scope of this investigation.

Judging from the 16:0 content of the HMG (Table 4), product E also contained a palm oil product, likely in a slightly hydrogenated form. The level of 16:0 in palm oil is 44%. Judging from the 18:3 content (Table 2), the liquid oil in product D was a small amount of soybean oil; in E it was most likely soybean oil; and in F and G, the liquid oils were as shown on the labels. Soybean oil contains high levels of 18:2 (54%) and intermediate levels of 18:3 (7%). Sunflower oil also contains high levels of 18:2 (76%), and canola oil has high levels of 18:1 (59%) and 18:3 (11%). Judging from the medium-chain FA levels in Tables 2 and 4, products C, D, and E also contained palm kernel oil.

Palm oil and palm olein are characterized as containing relatively high levels of C_{50} and low levels of C_{54} TG compared to other vegetable oils, in which the opposite is true (12,23). The high level of C_{50} TG in Table 3 confirmed that

TABLE 1
Composition of the Fat as Stated on Labels

Country	Product	Composition
United Kingdom	A	Corn oil, hydrogenated corn oil
United Kingdom	B	Sunflower oil, hydrogenated vegetable oil
Malaysia	C	Palm olein, sunflower oil, palm kernel oil
Malaysia	D	Palm oil, palm kernel oil, soybean oil
Australia	E	Vegetable oil
Malaysia	F	Palm olein, sunflower oil, canola oil
Japan	G	Soybean oil, rapeseed oil, palm oil

TABLE 2
Fatty Acid Composition of the Separated Fats (wt%)[a]

Fatty acid	Product						
	A	B	C	D	E	F	G
8:0	—	—	0.1	0.5	0.4	—	—
10:0	—	—	0.9	0.4	0.3	—	—
12:0	0.2	—	13.2	6.0	5.0	0.2	—
14:0	0.1	0.2	5.1	2.6	2.2	0.5	0.1
16:0	9.8	11.0	24.7	33.7	24.5	23.1	9.6
16:1	0.1	0.1	0.2	0.1	0.1	0.1	0.1
18:0	5.4	5.5	3.8	4.1	4.7	3.7	7.5
18:1*t*	9.9	6.0	0.3	0.1	4.1	0.1	7.3
18:1*c*,i	27.1	23.2	29.2	33.0	26.8	54.3	27.4
18:2*tt*,*ct*	0.3	0.3	0.9	0.8	0.5	0.7	0.5
18:2*cc*	45.5	51.8	19.6	16.0	25.7	12.5	39.9
18:3	0.8	0.7	0.2	1.2	4.1	3.1	6.3
20:0	0.4	0.3	0.3	0.3	0.3	0.4	0.4
Others	0.4	0.9	0.5	1.2	1.3	1.3	0.9

[a] *t* = *trans*, *c* = *cis*, i = positional and geometrical isomers not identified.

TABLE 3
Triglyceride Composition by Carbon Numbers of the Separated Fats (wt%)

Carbon no.	Product						
	A	B	C	D	E	F	G
30	—	—	0.3	0.1	0.1	—	—
32	—	—	1.4	0.2	0.7	—	—
34	—	—	2.0	0.4	1.0	—	—
36	—	—	4.8	0.9	2.3	0.1	—
38	—	—	4.1	0.9	2.0	0.2	—
40	—	—	2.7	1.4	1.1	—	—
42	—	—	3.4	2.5	1.1	0.1	—
44	0.5	0.3	3.6	3.7	0.9	0.3	0.1
46	1.4	0.2	5.3	7.3	0.9	1.3	0.9
48	5.2	2.2	8.9	11.4	4.1	6.3	2.5
50	7.1	9.7	15.3	24.7	21.1	17.0	7.5
52	35.5	24.9	21.6	27.6	29.8	23.9	30.0
54	49.5	61.4	26.1	18.6	34.5	49.0	58.0
56	0.7	0.4	0.4	0.3	0.2	1.2	0.5
58	0.1	0.9	0.1	—	0.1	0.6	0.5

TABLE 4
Fatty Acid Composition (and yield) of the High-Melting Point Triglycerides of the Fats[a]

Fatty acid	Product						
	A	B	C	D	E	F	G
12:0	—	—	4.3	2.7	0.8	—	—
14:0	—	0.5	4.5	3.0	1.5	1.1	0.1
16:0	16.1	44.4	65.7	73.3	59.1	73.5	14.7
16:1	—	—	—	0.2	—	—	0.2
18:0	33.6	20.7	10.9	8.7	10.5	9.3	42.4
18:1*t*	30.4	19.5	0.9	0.2	12.7	—	24.6
18:1*c*,i	16.3	10.3	9.3	8.8	12.1	14.0	14.5
18:2*tt*,*ct*	—	—	—	—	—	—	0.6
18:2*cc*	2.6	4.0	3.3	2.4	3.1	2.0	2.0
20:0	0.8	0.6	0.8	0.7	—	—	0.6
Yield (%)	5.8	5.6	5.7	7.2	9.8	9.0	6.2

[a] *t* = *trans*, *c* = *cis*, i = positional and geometrical isomers not identified.

TABLE 5
Triglyceride Composition of the High-Melting Point Triglycerides of the Fats

Carbon	Product						
no.	A	B	C	D	E	F	G
34	—	—	0.2	—	0.1	—	—
36	—	—	0.4	0.1	0.2	—	—
38	—	—	0.7	0.1	0.2	—	—
40	—	—	1.3	0.4	0.3	—	—
42	—	—	1.9	0.8	0.7	—	—
44	0.6	0.4	6.3	6.6	1.3	0.7	0.1
46	1.1	0.9	8.3	8.4	3.5	4.3	0.1
48	2.2	11.2	36.2	43.1	22.2	43.2	0.7
50	9.6	42.5	30.4	31.4	47.2	39.5	7.6
52	35.4	30.7	10.5	7.3	19.3	9.6	37.1
54	49.3	13.2	3.5	1.5	4.5	2.5	52.9
56	1.0	1.0	0.3	0.3	0.3	0.2	1.0

products C, D, E, and F contained palm oil or palm olein. In addition, the FA and the TG composition of the HMG (Tables 4 and 5) suggested that the hydrogenated vegetable oil in product B and F was a hydrogenated palm oil or olein. FA and TG compositions by carbon number of common vegetable oils have been reported by deMan and deMan (12).

Polymorphic crystal structure. The polymorphic crystal behavior of the products is displayed in Table 6. Products E and G were in the β' form. Product B showed a high level of β' crystals, and in product A, the β' form predominated, but to a lesser extent than in product B. In the remainder of the samples, the β form predominated. The short spacings of the β' form are at 4.2 and 3.8 Å, and that of the β form is at 4.6 Å (20,21). Levels of β' and β crystals in mixtures are estimated by the relative intensity of the short spacings at 4.2 and 4.6 Å.

If the solid fat of margarines, especially the HMG of margarines, consists of high levels (>50%) of C_{54} TG or C_{48} TG, the products are usually in the β form (9,10). C_{54} TG in vegetable oils consist mainly of 3 × 18-carbon FA, and the C_{48} TG of 3 × 16-carbon fatty acids (except in lauric oils). In the HMG of margarines, formulated with hydrogenated oil, the 18-carbon FA consists mainly of 18:0 and 18:1 *trans* FA (9,10). This is confirmed in Table 4 for products A, B, E, and G. Therefore, C_{54} TG in the HMG of the hydrogenated products (Table 5) consisted mainly of 18:0 and 18:1 *trans* FA (18:1*t*). 18:1*t* FA in the TG molecule behave polymorphically similar to 18:0 FA. Tristearin, trielaidin, and TG of mixtures 18:0 and 18:1*t* are very β-tending; the total level of these TG should be low (<50%) in the HMG (10) if a β' product is desirable. Similarly, the C_{48} TG, consisting mainly of tripalmitin, should be kept low in the HMG. The level of C_{48} in HMG of the Malaysian products ranged from 36.2–43.2% (Table 5). The C_{50} TG of the HMG of these products ranged from 30.4–39.5%. The C_{50} TG of the unhydrogenated Malaysian products can be assumed to consist mainly of POP (palmitic–oleic–palmitic FA). POP is also a β-tending TG (11). Palm oil, unlike other vegetable oils, contains a high level of C_{50} TG (12). The mean level of C_{50} TG of palm oil in a large survey (n = 244) was 39.9% (23). The relatively high level of C_{48} and C_{50} TG in the HMG of products C, D, and F could explain their tendency to β crystallinity.

Almost all TG can exist in a β' and β form. There is one exception, the TG PSP (palmitic–stearic–palmitic). This TG is extremely stable in the β' form, and the β form is difficult to obtain. It has been shown that PEP (E is any *trans* form of oleic acid) has the same polymorphic trend as PSP (11). High levels of PSP and PEP can be obtained by hydrogenation of palm oil or palm olein because of their high content of POP. Deffense (24) has analyzed the individual TG of palm oil and fractionated palm products. His reported POP contents for palm oil, palm super olein, and palm midfraction were 30.9, 24.8, and 55.1%, respectively (24). Products B and E, which contained hydrogenated oils, likely hydrogenated palm oil, showed high levels of C_{50} in the HMG, 42.5 and 47.2%, respectively (Table 5). Product B showed a high level of β' crystals, while E was exclusively in the β' form.

Corn oil margarines are either in the β' form or contain high levels of β' crystals (7–10). The likely reason is that the C_{50} TG in the HMG of hydrogenated corn oil consist of PSP or PEP, and the C_{52} TG consist of the asymmetrical TG PSS or PEE or combinations of the two TG, which are less β-tending than the C_{54} TG.

Incorporation of PKO diversified the fatty acid chainlength in the HMG of C, D, and E (Table 4) only to a small extent. Only 4.3% 12:0 ended up in the HMG of product C, the product that contained the highest level of PKO as judged by the 12:0 level in the original product (Table 2). Diversification of FA chainlength in the solids and HMG promotes β' stability. The level of PKO in product C was insufficient to make this a β' stable product. It is difficult to explain why product G was in the β' form. The label of this product indicated incorporation of palm oil (Table 1). Perhaps a small amount of hydrogenated palm oil or hydrogenated palm midfraction was incorporated at a level sufficient to keep product G in the β' form. It is also possible that a compound was added that stabilized the β' crystal structure.

SFC. The SFC of the margarine fats is shown in Table 6 as determined according to the AOCS and IUPAC methods. SFC, on the American continent, is measured according to AOCS method Cd 18-81. In this method, the fat is tempered at 26.7°C after it has been crystallized at 0°C. The fat is then cooled again at 0°C. The remainder of the AOCS method is similar to the IUPAC method, which is used in Europe and Malaysia. In IUPAC method 11.B.6, where temperature treatment of samples is similar to that of ISO method 8292:1991(E) (25), the fat is cooled at 0°C for 1.5 h, but it is not tempered as in the AOCS method. The AOCS method better reflects the actual solid content in margarines and shortenings than the IUPAC method (7,22). The mean values (Table 6) demonstrate that the IUPAC values were much higher, especially at 10°C, than those of the AOCS method. The SFC at 10°C of the products (Table 7, mean 18.0%) were close to those of the AOCS method of the fat (Table 6, mean 20.7%).

At 10°C, the SFC was high for products C, D, and E (Table 6), but at 20°C, only sample D was high. This sample contained palm oil instead of palm olein (Table 1).

A survey of North American soft margarines (n = 27) has shown that the SFC at 10°C (AOCS method) ranged from 7.1–18.8% with a mean of 13.7% (12). The SFC at 10°C of the Malaysian products C and D was 27.2 and 31.9%, respectively, and that of Australian product E was 22.3. All were higher than the SFC of North American soft margarines that were surveyed in a previous study (12).

Texture. Products C and D were very hard at 5°C as shown by their yield values (Table 7). These values decreased to a great extent at 10°C. Samples B and G were very soft, too soft for use in tropical countries because they tended to oil off when left at room temperature for a short period. Haighton (14) indicated that margarines with yield values from 8–10 N are hard but spreadable. Those with values above 10 N are too hard. This would indicate that products C and D are only spreadable at 10°C but not at 5°C. The relationship between SFC and yield values as determined in Equation 1 is graphically displayed in Figure 1. The linear correlation coefficient (r) was 0.9404 ($P < 0.01$):

$$\text{yield value} = 0.58475 \times \text{SFC} - 4.42434 \qquad [1]$$

From this equation for a calculated yield value of 0, we derived an SFC of 7.6%. In other words, a minimum of 7.6% of solids was required in the margarines to form a texture or a crystal structure.

Melting and crystallization characteristics. Softening and dropping points are displayed in Table 7. Softening points as determined for the products show high values for products D and F (39.2 and 40.9°C, respectively). These temperatures are above body temperature. A sensory panel judged products D and F as slow melting in the mouth. Product C was judged as having good melting properties, whereas the others were judged as quick melting and oily. The good melting characteristics of product C were probably due to the steep melting curve of the fat (the SFC was high at 10°C and low at 30°C). A survey of North American soft margarines (n = 27) showed dropping

TABLE 6
Polymorphic Form and Solid Fat Content of Soft (tub) Margarines Sold in Malaysia

		10°C		20°C		30°C		35°C	
Product	Polymorphic form	AOCS[a]	IUPAC[b]	AOCS	IUPAC	AOCS	IUPAC	AOCS	IUPAC
A	β′ > β	16.5	19.9	9.1	11.1	2.2	3.5	1.2	0.5
B	β′ > > β	12.8	17.1	8.3	10.3	3.1	3.8	1.9	1.6
C	β > β′	27.2	35.0	8.6	11.9	1.5	3.4	0.8	0.5
D	β > > > β′	31.9	41.4	13.5	19.7	5.1	6.7	3.5	3.3
E	β′	22.3	30.7	11.7	16.0	4.1	6.3	2.8	1.9
F	β > > β′	18.5	25.2	9.6	14.2	6.0	7.2	4.8	4.8
G	β′	15.9	21.1	10.1	13.0	3.6	5.9	2.9	2.3
Mean		20.7	27.2	10.1	13.7	3.7	5.3	2.6	2.1

[a] Reference 18.
[b] Reference 19.

TABLE 7
Texture by Penetrometer as Expressed in Yield Value and Solid Fat Content (SFC) of the Product as Measured by Proton Nuclear Magnetic Resonance at 5 and 10°C, Softening Points of Products, Dropping Points, and Crystallization Temperatures of Fats

	Yield value (N/cm^2)		SFC (%)		Melting characteristics		
Product	5°C	10°C	5°C	10°C	Softening point (°C)	Dropping point (°C)	Crystallization by DSC[a] (°C)
A	4.0	2.7	15.0	13.3	34.4	31.0	14.9
B	3.5	1.6	12.1	10.4	34.9	34.6	20.0
C	15.5	7.7	30.5	24.5	32.6	32.7	14.9
D	16.1	9.8	33.7	28.9	39.2	36.4	18.5
E	9.4	8.3	25.9	19.2	35.9	32.9	16.9
F	9.5	7.5	19.9	17.0	40.9	36.6	21.4
G	2.5	1.6	13.6	12.6	35.4	34.2	18.9

[a] DSC, differential scanning calorimetry.

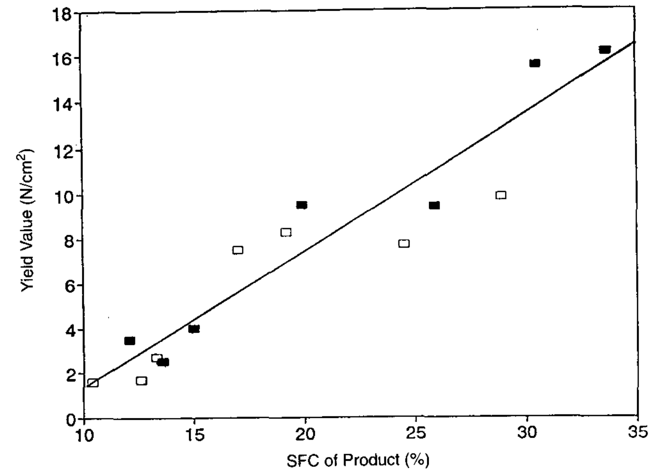

FIG. 1. Relationship (r = 0.9404) between texture [expressed as yield value (N/cm^2)] and solid fat content (SFC) of product at 5°C (■) and SFC of product at 10°C (□). The line in the graph was determined with the regression equation: yield value (N/cm^2) = % SFC × 0.58475 − 4.42434.

points to range from 27.3–34.2°C with a mean of 31.3°C (12). The dropping points of products D and F are outside this range.

Softening points are usually higher than dropping points, especially when the fat crystals in the margarine are in the β polymorphic form. The reason is that melting points of TG in the β form are higher than those in the β′ form.

Knowing the crystallization temperature is helpful to determine the temperature conditions for scraped surface heat exchangers in the manufacture of margarine. Obviously, temperature conditions ought to be different for fats that start crystallizing at 21.4°C (product F, Table 7) than for fats that crystallize only at around 14°C (products A and C).

Color. Table 8 shows the "L," "a," and "b" values of the soft margarines. The "L" value indicates lightness (whiteness). Positive "a" (+a) value indicates redness, while negative "a" (−a) value indicates greenness. Positive "b" (+b) value indicates yellowness. Product A was moderately yellow with an "L" value of 79.4 and a "b" value of 37.0. Products B and G were light yellow with "L" values of 80.5 and 81.9 and "b" values of 35.5 and 34.3, respectively. On the other hand, products D and F were of strong yellow color with high "b" values of 55.3 and 51.6, respectively. Products C and E with "a" values of −1.8 and −.05 and "b" values of 39.4 and 36.2 were orange-yellow in color. As shown in Table 8, margarine colors varied widely, especially in "b" values. More research is required on the visual color preference of the consumer.

Formulations and properties. This survey of soft margarines sold in Malaysia showed that product characteristics varied widely. Of the products that contained nonhydrogenated fats (C, D, and F), product C showed the best physical characteristics and the highest level of 18:2 FA (Table 2). The fat crystals of product C were about 40% in the β′ form. To improve the β′ stability of this product, the addition of a small amount of hydrogenated palm midfraction is advisable.

TABLE 8
Color Measurements in Terms of "L," "a," and "b" Values of Soft Margarines[a]

Sample	"L"	"a"	"b"
A	79.4	−2.2	37.0
B	80.5	−2.8	35.5
C	82.3	−1.8	39.4
D	81.9	−1.4	55.3
E	84.0	−0.5	36.2
F	79.5	−3.2	51.6
G	80.1	−3.9	34.3

[a] "L" = lightness, "+a" = redness, "−a" = greenness, "+b" = yellowness.

As mentioned earlier, hydrogenated palm midfraction will contain high levels of PSP or PEP, which are β′-stable TG. At a level of less than 3% hydrogenated palm midfraction in a formulation of nonhydrogenated oils, as shown in product C, the level of *trans* FA in the product would be less than 1%, which in many countries does not require declaration on the label.

Soft margarines are also formulated from a hard stock of interestified palm stearin and PKO (26). Such products are not β′-stable. It is difficult to manufacture a β′-stable soft margarine from nonhydrogenated oils, especially when high levels (>80%) of liquid oil are incorporated (27). Usually, a β′-stabilizing compound has to be included. Low *trans* (7%) β′-stable soft margarines with at least 80% liquid oil can be manufactured from hydrogenated palm olein as a hard stock (28).

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