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Evaluation of Shortenings Based on Various Palm Oil Products

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ABSTRACT

Several formulations based on blends of hydrogenated palm oil (MP 41.5°C) and palm stearin (IV 44) with other liquid oils, on direct blends of palm stearin with other liquid oils, and on 100% inter-esterified palm olein, were used as feedstocks in shortening production. The shortenings were stored at 20°C over a period of one month. Physicochemical characteristics, creaming properties and baking performance of the shortenings were evaluated and compared with the best shortening on the market. Slip melting point of the shortenings ranged from 41.5 to 46.4°C. Palm-cottonseed oil shortenings had higher solid fat contents at all temperatures than palm-soya bean or palm-low erucic acid rapeseed oil shortenings. The shortenings were rich in C₅₀, C₅₂ and C₅₄ glycerides. Creaming power after 12 min of beating ranged from 1.55 to 1.77 cm³ g⁻¹. Palm stearin-cottonseed (3:2) oil shortening showed the best creaming performance. The specific volume of cakes ranged, for the experimental shortening, from 90% to 101% from the control, with low erucic acid-palm blends showing the best performance. In applications for both aerated cream and cakes, inter-esterified palm olein was excellent.

Key words: Shortenings, hydrogenated palm oil, palm stearin, inter-esterified palm olein, physicochemical characteristics, creaming performance, baking performance.

1 INTRODUCTION

Palm oil has become one of the leading vegetable oils for edible applications because of its good quality and properties. Its versatility is well known (Chapman 1981). Examples demonstrating the width of its applications are as shortenings,

margarines, vanaspati, cocoa butter substitutes and in deep fat frying. The latest applications are in whipped creams and humanised milk. Shortenings are used in the preparation of many foods such as cream fillings, icings, cakes, cookies, pastry and bread and as a frying fat. They aid in lubrication of ingredients, give structure to the products, help in air incorporation and provide a moisture barrier as well as contributing to the eating quality of the products.

Modification processes such as fractionation, hydrogenation and inter-esterification are commonly applied to oils and fats for specific uses. Another important process is blending. Fractionation separates an oil into a solid and a liquid fraction. Palm oil can be separated into palm stearin (solid fraction) and palm olein (liquid fraction).

The hydrogenation process introduced in the early 1900s has enabled manufacturers to produce plastic shortenings entirely from vegetable oils (Anon 1982). It permits tailor-made fats to be produced and allows almost limitless variations of the basic raw materials (Gander 1976). The inter-esterification process was developed later than the hydrogenation process, and today it has enabled production of shortening with improved performance capabilities (Gander 1976).

The objective of this work was to evaluate the physicochemical characteristics, creaming properties and baking performance of shortenings based on blends of hydrogenated palm oil and palm stearin with other liquid oils, direct blends of palm stearin with other liquid oils, and a 100% inter-esterified palm olein.

2 EXPERIMENTAL

The shortening formulations were based on:

- (1) three blends of hydrogenated palm oil (HPO) and palm stearin (POs) with other liquid oils;
- (2) direct blends of 50% palm stearin with 50% other liquid oils;
- (3) direct blends of 60% palm stearin with 40% other liquid oils;
- (4) inter-esterified palm olein (IE POo).

The formulations are as shown in Table 1.

2.1 Feedstock preparation

Palm oil, palm stearin (IV 44), palm olein and soya bean oils (SBO) were obtained from a local refinery. Palm oil was hydrogenated to a melting point of 41.5°C at the Palm Oil Research Institute of Malaysia (PORIM) pilot plant using hydrogenation conditions as follows: temperature, 200°C ; hydrogen pressure, 50 psi; catalyst, supplied by Indian vanaspati manufacturer (amount 0.05% nickel); time, 15 min; stirrer speed, $10\,000\text{ r min}^{-1}$.

Cottonseed oil (CSO) and low erucic acid rapeseed (LEAR) oil were commercially refined oils obtained from Australia. Inter-esterified palm olein was prepared using the following conditions: temperature, 110°C ; catalyst, 0.2% sodium methoxide; time, 30 min; stirrer speed, maximum.

The oils and fats were used in the preparation of feedstocks for shortening

TABLE 1
Shortening formulations

<i>Code</i>	<i>Formulation</i>
<i>Group 1</i>	
1A	{ 18% Hydrogenated palm oil (MP 41.5°C) 42% Palm stearin (IV 44) 40% Soya bean oil
1B	{ 18% Hydrogenated palm oil (MP 41.5°C) 42% Palm stearin (IV 44) 40% Cottonseed oil
1C	{ 18% Hydrogenated palm oil (MP 41.5°C) 42% Palm stearin (IV 44) 40% Low erucic acid rapeseed (LEAR) oil
<i>Group 2</i>	
2A	{ 50% Palm stearin (IV 44) 50% Soya bean oil
2B	{ 50% Palm stearin (IV 44) 50% Cottonseed oil
2C	{ 50% Palm stearin (IV 44) 50% Low erucic acid rapeseed (LEAR) oil
<i>Group 3</i>	
3A	{ 60% Palm stearin (IV 44) 40% Soya bean oil
3B	{ 60% Palm stearin (IV 44) 40% Cottonseed oil
3C	{ 60% Palm stearin (IV 44) 40% Low erucic acid rapeseed (LEAR) oil
<i>Group 4</i>	
4A	100% Inter-esterified palm olein

production, which was conducted at the PORIM pilot plant. The blends were prepared by mixing relevant components at appropriate proportions in a stainless steel vessel of 100 kg capacity to give a total of 40 kg of each blend.

2.2 Shortening production

The feedstocks were melted to a temperature of 48–55°C and processed on a pilot plant scale on the Schroeder Kombinator type VUK B 01/60-400 (Lubeck, FRG). The products were run at a standard pump speed (250 r min⁻¹) and a standard back pressure (2.5 kg cm⁻²), and refrigeration was adjusted to obtain a standard filling temperature (20°C). The shortenings were stored in temperature-controlled cabinets at 20°C over a period of one month during which evaluations were conducted.

2.3 Evaluations

One day prior to evaluations, samples were stabilised at room temperature (23–24°C).

2.3.1 Slip melting point

Slip melting point was measured according to the official AOCS open capillary method No Cc-3-25 (AOCS 1984).

2.3.2 Solid fat content

A Newport Analyzer MK II wideline NMR (Newport Pagnell, UK) with temperature controller was used. The sample in the NMR tube (1.5 g) was first melted at 70°C for 30 min and then chilled at 0°C for 90 min. The tube was held at each measuring temperature for 30 min prior to measurements (Oh and Berger 1980).

2.3.3 Fatty acid composition

Fatty acid composition was analysed as methyl esters on a glass column (1.8 m × 3 mm id) of 10% SP 2330 on 100–120 Supelcoport (from SUPELCO, Bellefonte, PA, USA) at 200°C with 40 cm³ N₂ min⁻¹. Data were processed using a Perkin Elmer Sigma 10.

2.3.4 Triglyceride composition

Triglyceride composition was analysed according to carbon number using a glass column (46 cm × 25 mm id) of 1% Dexil 300 on 100–129 mesh Supelcoport on a Pye 104 gas chromatograph.

2.3.5 Consistency

Consistency was measured after storage at 20°C for a period of up to 30 days, and was determined by a cone penetrometric method (Haighton 1976). The cone angle used was 40° and the penetration time was 5 s. Measurements were made after stabilisation at ambient temperature (23°C) for 24 h.

2.3.6 Creaming test

A Kenwood Junior mixer was used with a K beater and a static scraper blade shaped to fit the contour of the bowl (Meara *et al* 1974). Icing sugar (260 g) and shortening (170 g) were mixed sufficiently using a palette knife to avoid sugar being thrown out of the bowl when the Kenwood was started. The two were then mixed using a K beater for 30 s at speed 1, adding water (14 g) during that time. Mixing was continued for 2 min at speed 4. The aerated cream was filled into stainless steel cups of known volume in duplicate, avoiding the inclusion of void spaces during filling. The weight of the cup with cream was taken. This process was repeated at 2-min intervals until creaming time reached 12–14 min. Creaming power was calculated in terms of specific volume of cream (cm³ g⁻¹).

TABLE 2
Madeira cake formulation

<i>Ingredient</i>	<i>Content</i>
Flour	475 g
Shortening	169 g
Sugar	460 g
Egg	236 g
Water	230 g
Skimmed milk powder	11 g
Salt	8.4 g
Baking powder	11 g
Colouring	1 ml
Flavouring	1 ml

2.3.7 Baking test

The shortenings were evaluated for their performance in cakes using a Madeira cake formulation (Table 2). This particular formulation was chosen because it is rather low in fat content and therefore particularly sensitive to the properties of the fat. The procedures were as follows.

A syrup was made by heating sugar with water until the sugar dissolved. The solution was then cooled. Part of the flour (333 g), salt, baking powder and skimmed milk powder were mixed to obtain a homogeneous dispersion of ingredients. Shortening was mixed with the remaining flour using a Hobart mixer model N50 (Hobart Manufacturing Co, London, UK) at speed 1 for 30 s. After scraping the sides, mixing was continued for further 2 min at speed 3, scraping the sides again after each minute of mixing. Mixing was continued for 3 min at speed 3. Eggs were beaten and added to the cooled syrup together with colouring and flavouring. The mixture was then added to the aerated mix of shortening and flour over 30 s while mixing at speed 1. The blend of the dry ingredients was then added to the batter over 1 min 30 s while mixing at speed 2. The sides of the bowls were scraped and the mixing was continued for 1 min 30 s at speed 2. The batter was placed into four round cake baking tins, 154 mm id, lined with greaseproof paper. Each baking tin contained 375 g batter. The cakes were baked at 180°C in a Rotary Simon oven for 1 h 15 min. When the cakes had cooled, their weights and volume were measured, volume by rapeseed displacement. The specific volume of cake ($\text{cm}^3 \text{g}^{-1}$) was then calculated. The performance of the experimental shortening was compared with that of a standard shortening which was an international brand available in the supermarket and selected for its superior performance. The standard cakes were always prepared using the same ingredients (except the fat) and baked at the same time, side by side with the experimental cake.

3 RESULTS AND DISCUSSION

3.1 Physicochemical characteristics

Table 3 shows the physicochemical characteristics of the experimental and the

TABLE 3
Slip melting point, fatty acid composition and triglyceride composition of shortenings

Shortening code:	Group 1			Group 2			Group 3			Group 4	
	1A	1B	1C	2A	2B	2C	3A	3B	3C	4A	Standard
Slip melting point (°C):	44.5	45.0	44.0	44.6	45.2	43.9	42.2	46.4	42.3	41.5	42.4
Fatty acid composition (%)											
12:0	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2
14:0	0.8	1.0	0.7	0.6	1.0	0.7	0.5	1.0	0.5	1.1	0.7
16:0	34.9	27.6	31.4	30.2	38.6	27.7	26.6	41.0	23.1	39.9	22.8
16:1	0.1	0.3	0.1	—	—	—	—	—	—	0.1	0.3
18:0	9.5	3.9	3.8	4.3	3.8	3.0	4.3	4.0	2.9	4.1	9.8
18:1	30.7	28.3	44.7	29.4	25.8	43.7	28.2	27.5	46.1	43.3	47.2
18:2	25.0	27.8	13.3	31.8	30.4	16.8	36.3	26.4	18.4	11.0	16.9
18:3	2.4	0.2	3.8	3.5	0.2	5.6	4.1	0.3	5.9	—	1.7
20:0	0.6	0.3	0.4	—	—	—	—	—	—	—	0.4
20:1	—	—	0.4	—	—	1.2	—	—	1.4	—	—
22:0	—	—	—	—	—	0.1	—	—	0.2	—	—
22:1	—	—	—	—	—	—	—	—	—	—	—
24:0	—	—	0.3	—	—	1.1	—	—	1.4	—	—
Triglyceride composition (%)											
42	—	—	—	—	—	—	—	—	—	—	—
44	—	—	—	—	—	—	—	—	—	—	—
46	0.6	0.8	0.6	0.1	0.9	1.0	0.1	0.1	0.1	0.6	—
48	8.3	8.5	7.9	8.1	8.8	6.3	6.8	10.2	6.4	1.5	—
50	27.2	29.4	24.9	21.6	28.4	16.0	18.4	30.7	16.9	8.9	2.2
52	33.0	38.8	27.2	29.7	37.4	19.8	29.2	36.4	20.4	30.1	9.8
54	29.9	22.0	35.8	38.9	23.8	46.7	43.8	21.1	45.5	39.6	26.9
56	0.6	0.3	2.1	0.4	0.4	4.8	0.5	0.3	4.5	18.8	60.2
58	0.2	—	0.4	0.3	0.1	3.0	0.4	0.1	3.0	0.1	0.8
60	—	—	—	—	—	0.4	—	—	6.4	—	—

standard shortening. All of the samples had slip melting points $>40^{\circ}\text{C}$. The slip melting points of shortenings based on palm blends with cottonseed oil (1B, 2B and 3B) were slightly higher than those of the other blends whereas shortenings 3A and 3C were similar to the standard shortenings in this respect. On the other hand, inter-esterified palm olein had a slightly lower slip melting point than the standard. According to Berger (1985) the slip melting point of cake shortenings should be about 40°C . During baking the shortening should not melt too quickly, otherwise the body-forming properties of the egg protein and starch will not have reached the point at which they can retain the air. Since the slip melting points of all of the experimental shortenings were above 40°C , they would aid in the structure formation of the cake.

Triglyceride composition showed that the shortenings were rich in C_{50} , C_{52} and C_{54} glycerides. Among the experimental shortenings, the contents of C_{50} and C_{52} were high in 1B, 2B and 3B which were palm blends with cottonseed oil, and also 4A which was inter-esterified palm olein. Palm blends with LEAR oil (1C, 2C and 3C) were high in C_{54} whereas blends with soya bean oil (1A, 2A and 3A) were high in both C_{52} and C_{54} . The standard shortening, however, had a much higher C_{54} content. The experimental shortenings contained relatively higher C_{48} than standard shortening due to the palm oil components.

Fatty acid analysis of the experimental shortenings showed that shortening based on palm-LEAR oil blends (1C, 2C and 3C) had higher proportions of oleic as well as linolenic acids but lower proportions of linoleic acid than palm-soya bean or palm-cottonseed oil blends. Shortenings based on palm-soya bean oil (1A, 2A and 3A) had lower proportions of oleic and linoleic acids than those based on palm-LEAR oil but higher than those based on palm-cottonseed oil (1B, 2B and 3B).

In each group (1, 2 and 3) of the experimental shortenings, the palm-cottonseed oil blends had higher solid fat contents at all temperatures compared with the other two experimental blends (Fig 1a-c). Palm-soya bean oil and palm-LEAR oil shortenings had more or less similar solid fat profiles. The profile of the standard shortening was somewhat steeper than that of all the experimental shortenings except inter-esterified palm olein. For a shortening to perform well in cakes, it should have a solid fat content between 15 and 25% at its temperature of use (Berger and Pollitt 1974). Under the testing conditions used, shortenings 1C, 2A, 2B, 2C, 3A, 3C and 4A showed good baking performance with specific volume greater than 95% of the standard shortenings even though two of them (shortenings 3A and 3C) had less than 15% solid at the temperature of testing.

The experimental and the standard shortenings were of good consistency. During storage, the yield values of the shortenings in group 1 ranged from 130 to 265 g cm^{-2} ; those of the shortenings in group 2 ranged from 200 to 440 g cm^{-2} , and for the shortenings in group 3 and 4 the range was 300 to 400 g cm^{-2} . The standard shortenings had yield values of 190 to 315 g cm^{-2} during the one-month evaluation period.

3.2 Creaming performance

The ability to trap air is a highly important factor in determining the value of fat as a shortening agent. The amount of air that can be incorporated into a fat-sugar mix

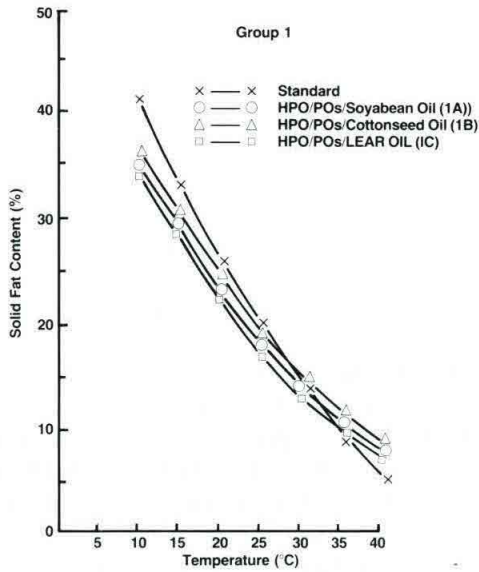


Fig 1(a). Solid fat content of the standard and the experimental shortenings in Group 1.

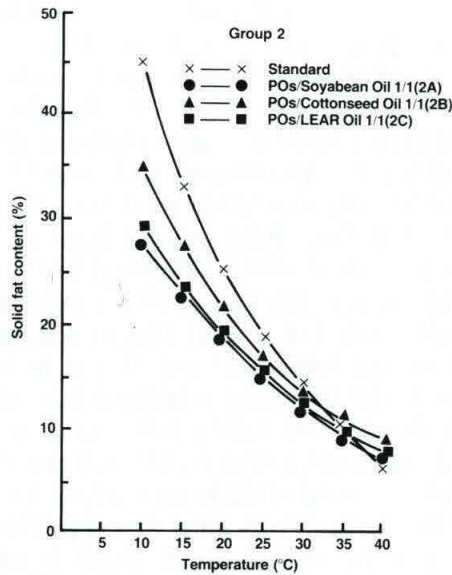


Fig 1(b). Solid fat content of the standard and the experimental shortenings in Group 2.

when beaten together under standard conditions can be obtained by determining the specific volume of the cream, ie the volume per unit mass, the value of which is commonly known as the creaming power of the fat or shortening. The conventional method was that of beating the mixture for a certain number of times at specific intervals permitting the scraping down of material which had been thrown out of

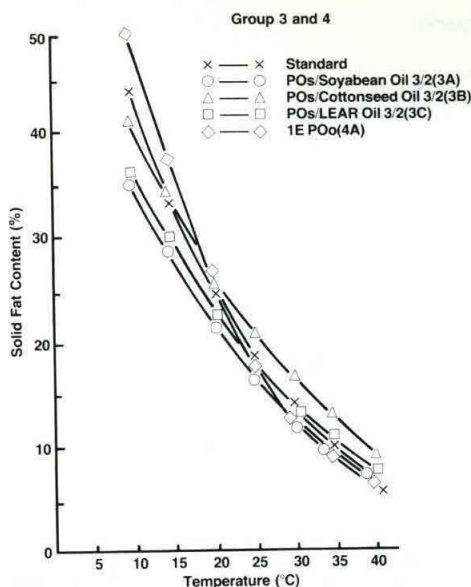


Fig 1(c). Solid fat content of the standard and the experimental shortenings in Groups 3 and 4.

reach of the beater. Manual scraping could lead to variability in results and discrepancies in creaming power determinations of the same shortening by different operators. In this study, a scraper blade attached to the rotor arm of the beater was used, which helped overcome the problem by allowing any material thrown up beyond the beater range to be continuously ploughed back into the mix.

In general, the creaming properties of the experimental shortenings did not vary much during the storage period. The creaming power fell within 1.55 to 1.77 $\text{cm}^3 \text{g}^{-1}$ after 12 min of beating. According to Meara *et al* (1974) an adequate amount of 'free' or available liquid component is necessary for a product to have a good creaming performance. Meara *et al* (1974) determined consistency, content of saturated and *trans* acids, solid fat index at 20°C and slip melting point of eight shortenings, but found no correlation to creaming properties. However, they found that creaming performance correlated to the type of crystalline arrangement and crystal size. Shortenings of good creaming properties are associated with β' crystalline form; β' crystals are normally of smaller size than β crystals. Crystal habit is affected by the palmitic acid content of a fat. Palm oil and palm products are rich in palmitic acid (44%) and are stable in the β' form. Cottonseed oil has 22% palmitic acid and is also stable in the β' form. On the other hand, soya bean and LEAR oils have lower palmitic acid contents, 10% and 4%, respectively; they too are stable in the β form (Wiedermann 1987). Blends of palm product with cottonseed oil (1B, 2B and 3B) had the highest palmitic acid content of 37.6%, 38.6% and 41.0% compared with 34.9%, 30.2% and 26.6% in palm-soya bean blends (1A, 2A and 3A) and 31.4%, 27.7% and 23.1% in palm-LEAR oil blends (1C, 2C and 3C). The 100% inter-esterified palm olein had about 40% palmitic acid. Results of the creaming test obtained in this study (Figs 2a and b) showed that, in each group,

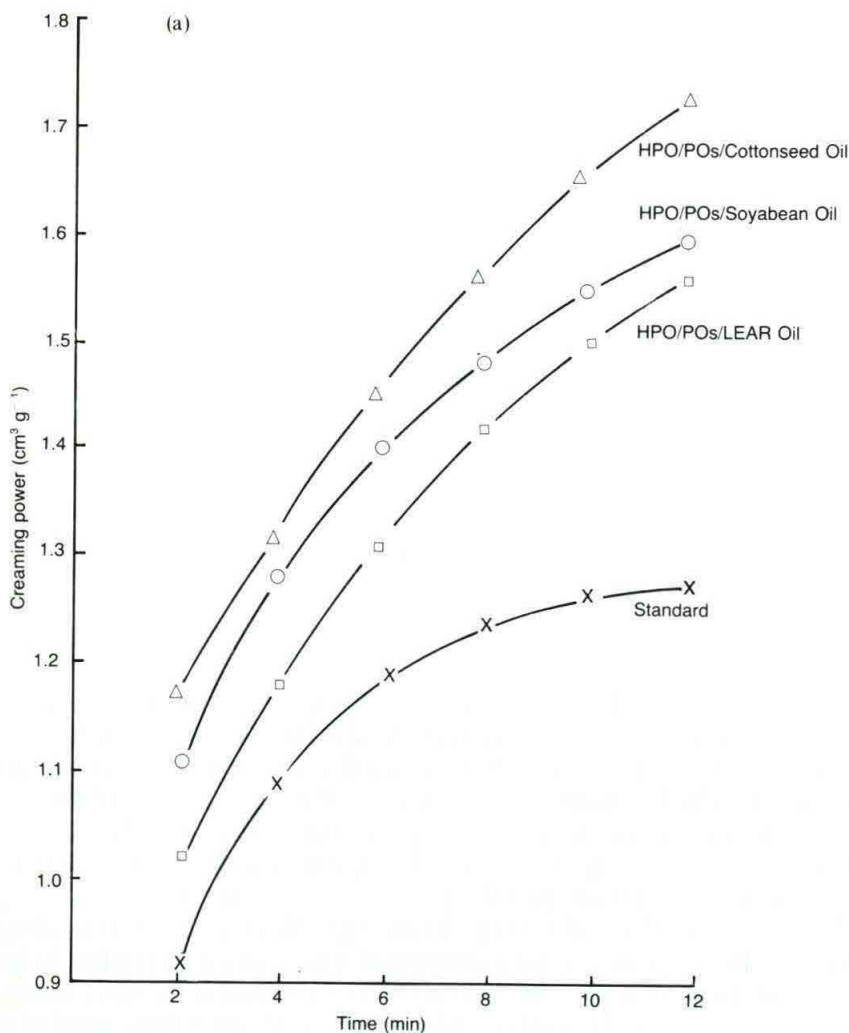
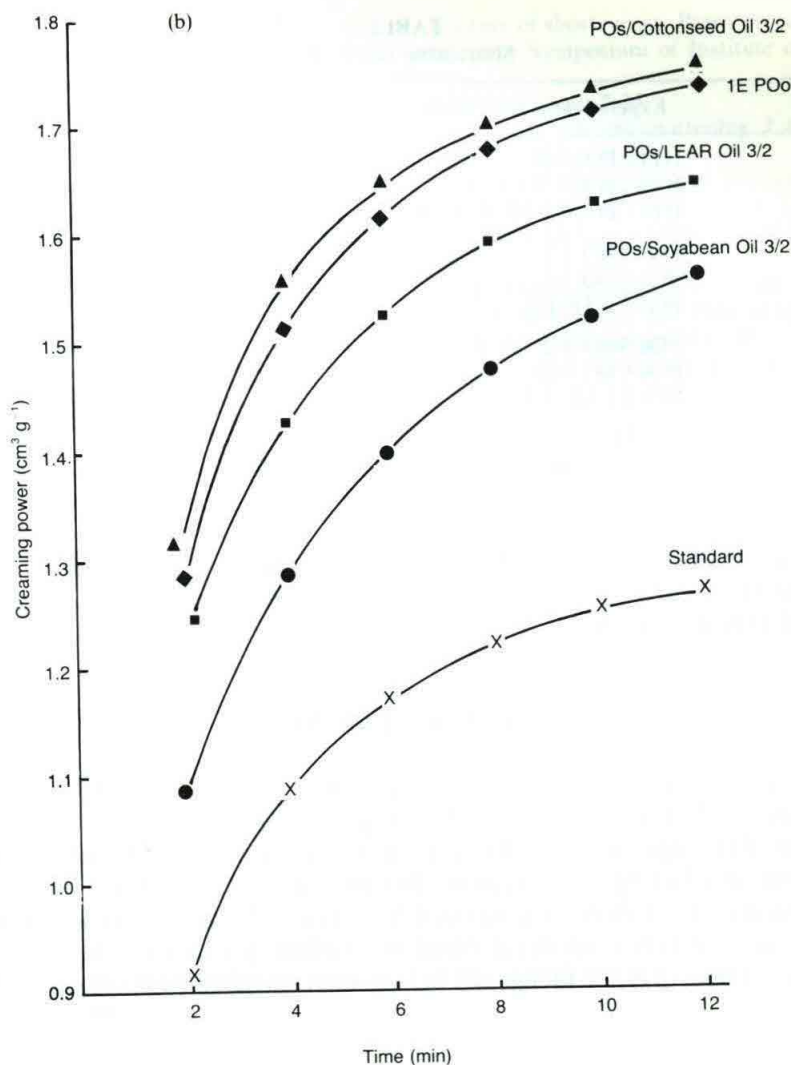


Fig 2. Creaming performance of the standard and the experimental shortenings.

palm-cottonseed oil blends had the best creaming performance. Inter-esterified palm olein, which had a palmitic acid content similar to that of palm-cottonseed oil blends, also showed very good creaming performance, better than palm-soya bean or palm-LEAR blends. The results suggest that the creaming properties of the shortenings were affected by their fatty acid composition which in turn affected their crystal character, and are thus in agreement with earlier reports (Meara *et al* 1974; Wiedermann 1987). Under the testing conditions, the creaming properties of experimental shortenings were better than those of the standard shortening.

3.3 Baking performance

The specific volume of experimental cakes obtained from baking tests ranged from



90 to 101 % of that of the control cake (Table 4). In terms of specific cake volume, promising results were obtained with palm-soya bean oil and palm-LEAR oil blends as well as 100% inter-esterified palm olein with cake volumes greater than 95 % of the control cake. Even though palm-cottonseed oil shortenings had the best creaming performance, their baking performance in terms of specific cake volume was less than that of palm-soya bean oil or palm-LEAR oil shortenings. It is suggested that good creaming performance does not necessarily ensure good baking performance in cakes. Creaming performance is important in applications such as cream fillings and some icings. Between soya bean and LEAR oils, the latter seemed to be a better liquid oil to be blended with palm product for making cake shortening

TABLE 4
Shortening baking tests

<i>Code</i>	<i>Experimental shortening</i>	<i>Specific cake volume E/C × 100</i>
1A	HPO/POs/SBO 9/21/20	95%
1B	HPO/POs/CSO 9/21/20	90%
1C	HPO/POs/LEAR 9/21/20	101%
2A	POs/SBO 1/1	96%
2B	POs/CSO 1/1	96%
2C	POs/LEAR 1/1	101%
3A	POs/SBO 3/2	96%
3B	POs/CSO 3/2	95%
3C	POs/LEAR 3/2	97%
4A	IE POo	99%

as palm-LEAR oil shortenings produced cakes of higher specific volume (101 % of the standard). Inter-esterified palm olein is suitable for both applications as it showed very good creaming and baking performances.

4 CONCLUSIONS

Fatty acid composition and crystal arrangement of the shortenings had some influence on their creaming properties. High palmitic acid content is good for aeration of fat/sugar mixtures. However, there was no direct relationship between creaming and baking performances. Results indicated that palm oil stearin-cottonseed oil (3:2) shortening was best for aerated fillings, and palm stearin (IV 44)/LEAR is a very economical blend of excellent performance in cakes. For application both in cream fillings and baking, inter-esterified palm olein is the most suitable.

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