# *Trans*-Free Bakery Shortenings from Mango Kernel and Mahua Fats by Fractionation and Blending

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**ABSTRACT:** Bakery shortenings prepared by hydrogenation contain high levels of *trans* fatty acids, which are considered to be risk factors for cardiovascular disease. The shortenings prepared from mango kernel and mahua fats have no *trans* fatty acids. Mahua fat was fractionated by dry fractionation to obtain a high-melting fraction (10% yield, Mh1). Mango fat was fractionated by two-stage solvent fractionation, separating about 15% high-melting fraction (Mk1) in the first stage, followed by 40% stearin (Mk2) in the second stage. The formulation containing 80% Mh1 and 20% of mango middle stearin fraction (Mk2) showed melting characteristics and onset and enthalpy of crystallization similar to those of commercial hydrogenated shortenings designed for cakes and biscuits. The formulation suitable for puff pastry shortening was prepared by blending 50% mango 1st stearin (Mk1) and 50% mahua fat with addition of 5–7% of fully hydrogenated vegetable oil. The formulations having melting characteristics similar to those of commercial cake and biscuit shortenings were also prepared by blending 40% mango fat and 60% mahua fat with 5–7% incorporation of fully hydrogenated peanut oil. However, these formulations showed delayed transition to the stable forms compared to those of commercial samples. Fatty acid composition revealed that commercial hydrogenated shortenings consisted of 18–29% *trans* oleic acid, whereas the formulations we prepared did not contain any *trans* acids. The iodine values of commercial samples were 57–58, whereas the value for the formulations prepared were 47–53. The consistency of the prepared samples as measured by cone penetrometer was slightly harder than commercial samples. These studies showed that it is possible to prepare bakery shortenings with no *trans* fatty acids by using mango and mahua fats and their fractions.

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**KEY WORDS:** Bakery shortenings, differential scanning calorimetry, fractionation, hardened oil, *Madhuca latifolia*, mahua fat, mango kernel fat, *trans* fatty acids, vegetable fats/oils.

Shortenings are plastic fats consisting of a mixture of solid fat crystals and liquid oil. The solid fat components form a three-dimensional crystal matrix that holds the liquid portion of fat and imparts plasticity and rigidity to the system. Satisfactory performance of shortening depends mainly on consistency and crystal structure. The consistency depends on the solid to liquid ratio present at different temperatures. Shortenings are commonly used in the baking industry to impart desirable texture and mouthfeel to the products. Shortenings manufactured for the bakery industry vary dramatically with respect to consistency and melting characteristics, depending upon the application for which they are designed. Shortenings designed for cakes must produce an emulsion stable enough to withstand the heat of baking. They must emulsify, facilitate aeration, and provide structure when used in icings. Shortenings for roll-in application must have the approximate consistency of the dough with good plasticity to remain in a continuous, unbroken layer as it stretches and becomes thinner to create a large number of dough–fat layers that contribute flakiness to the finished product (1).

Currently, hydrogenated fats consisting of large quantities (as high as 20–40%) of *trans* fatty acids are being used in the baking industry. Although the nutritional significance of *trans* fatty acids is controversial, they may cause heart disease (2,3), and in a comprehensive review it was concluded that *trans* fatty acids consumed at 4% or more of total calories may raise plasma lipid levels (4). It has been reported that *trans* fatty acids have a negative impact on plasma lipoprotein profile by lowering the content of high-density lipoprotein cholesterol and raising the low-density lipoprotein cholesterol (2). This has raised the need to replace hydrogenated fats with natural fats in food product formulations.

Preparation of *trans*-free margarines from highly saturated soybean oil by interesterification and blending has been reported (5). Not much patented literature is available on the preparation of *trans*-free shortenings by blending, fractionation, and interesterification of vegetable/animal fats and oils (6–10). Here the preparation and evaluation of *trans*-free shortenings from vegetable fats such as mango (*Mangifera indica*) kernel and mahua fats by fractionation and blending are reported. Mahua or Mowrah (*Madhuca latifolia,* fam. Sapotaceae*)* trees, found in several parts of India, have green-colored egg-size fruits consisting of about 75% concave kernels that contain about 50% pale yellow semisolid fat (11). The fat is edible and can be used to prepare hydrogenated fat. Mango seeds, constituting 8–22% of the fruit, contain 45–73% kernel. The fat content in kernels ranges between 8 and 14% (12). Cocoa butter substitute has been prepared from mango fat (13). Preparation of value-added products like bakery shortenings and confectionery fats from these underutilized vegetable fats promotes the production and utilization of these fats, generates employment, increases the net availability of vegetable oils, and promotes economy in addition to nutritional benefits.

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## EXPERIMENTAL PROCEDURES

*Materials*. Crude mango kernel and mahua fats were procured from Hanuman Minor Oils Ltd. (Raipur, M.P. India) and Sarvodaya Oil Industries (Nagpur, India), respectively. Crude mango fat has 10% free fatty acid, and crude mahua contains 6.5% free fatty acid. Both fats are refined using alkali, and refined fats were used in the study. Fully hydrogenated peanut oil (hardened oil) and three types of commercial bakery shortenings designed for puff pastries, biscuits, and cakes were procured from Hindustan Lever Ltd. (Mumbai, India). Fatty acid methyl ester and triacylglycerol standards and $BF_3$/methanol were procured from Sigma Chemicals (St. Louis, MO).

*Fractionation: mahua fat.* Refined mahua fat (500 g) was heated to about 50°C, cooled gradually to 25°C, and held at this temperature for 5–6 h. It was then filtered through a Buchner funnel under vacuum to separate stearin (Mh1, yield 10–12%) and olein fractions.

*Mango kernel fat.* The refined fat (500 g) was melted and dissolved in 1 L of acetone. The solution was gradually cooled to 22°C and held at this temperature for 3 h. The partially crystallized mass was then filtered to separate stearin (Mk1, yield 10–15%) and olein fractions. The olein was further cooled to 18°C and held for 4 h and filtered. The yield of second stearin (Mk2) was 40–45% by wt of the fat.

*Formulations of bakery shortenings.* Various formulations using the fat fractions, parent fats, and hardened oil were prepared as shown in Table 1, and each was assessed for suitability as bakery shortenings. The formulations were based on triacylglycerol composition and consistency of the fats and fractions, keeping in mind the plasticity of bakery shortenings.

*Differential scanning calorimetry (DSC).* A Mettler (Zurich, Switzerland) differential scanning calorimeter was used to obtain melting and crystallization characteristics of the samples. The heat flow of the instrument was calibrated using indium. The PT-100 sensor was calibrated using indium, zinc, and lead. To ensure homogeneity and to destroy all crystal nuclei, the samples were heated to 60°C. About 15 mg of molten sample was accurately weighed into a standard aluminum crucible and the cover crimped in place. An empty aluminum crucible with pierced lid was used as a reference. For melting characteristics, the samples were stabilized according to the IUPAC method (14), which includes keeping the samples at 0°C for 90 min, 26°C for 40 h, followed by 0°C for 90 min prior to introduction into the DSC cell. Thermograms were recorded by heating at a rate of 2°C/min from –5 to 60°C. The peak temperatures, heats of fusion ($\Delta H$), and the percentages of liquid at various temperatures were recorded directly using a TC-10A data processor (Mettler). The solid fat contents (SFC) were calculated from percentage of liquid and the melting profiles were drawn by plotting SFC against temperature.

For crystallization behavior, the samples were maintained at 70°C for 5 min to destroy the crystal nuclei and immediately cooled to –10°C at 5°C/min. The cooling exotherms, crystallization peak temperatures, and enthalpy of crystallization were recorded. Also, the samples were immediately heated at 10°C/min to record the melting peak(s) of the crystals generated under the slow (5°C/min) rate of cooling.

**TABLE 1**
**Formulations of Bakery Shortenings[a]**

| Fat/fractions blends | | | Code |
|---|---|---|---|
| Mango fat: | Mahua fat: | Hardened oil (%) | |
| 40: | 60: | 5 | A1 |
| 40: | 60: | 7 | A2 |
| 40: | 60: | 10 | A3 |
| 30: | 70: | 7 | A4 |
| Mahua stearin (Mh1) : Mango middle fraction (Mk2) | | | |
| 80: | 20 | | B1 |
| 90: | 10 | | B2 |
| Mahua stearin (Mh1) : Mango fat | | | |
| 80: | 20 | | B3 |
| Mango stearin (Mk1) : Mahua fat | | Hardened oil (%) | |
| 50: | 50: | 5 | C1 |
| 50: | 50: | 7 | C2 |
| 40: | 60: | 7 | C3 |

[a]Mh1 = stearin (10%) obtained from mahua fat by dry fractionation; Mk1 = stearin (15%) obtained from mango fat by solvent fractionation; Mk2 = 2nd (middle) stearin (40%) obtained from mango fat by solvent fractionation. Hardened oil = fully hydrogenated peanut oil.

*Fatty acid composition.* The fatty acid compositions (including *trans* isomers) of the samples were determined by analyzing the fatty acid methyl esters by gas chromatography (GC). The methyl esters were prepared by using 14% $BF_3$/methanol (15) and were analyzed using a Fisons (Milano, Italy) GC-8000 series equipped with a flame-ionization detector operating under the following conditions: fused-silica capillary column 30 m × 0.25 mm (SP-2340; Supelco, Bellefonte, PA); column temperature 180°C; injector temperature 220°C; carrier gas nitrogen, 0.5 mL/min, splitless injector. The peaks were identified by comparing the retention times with those of authentic standards and reported as relative percentage of individual fatty acids.

Iodine values were determined using Wijs' method according to the American Oil Chemists' Society (16) procedure.

The consistency of the shortenings is measured using a precision cone penetrometer (Aimil, Mumbai, India) according to the procedure described in AOCS (16) at refrigerated (3°C), ambient (25°C), and 36°C temperatures after stabilizing for 4 h at each temperature. Hardness was calculated by dividing the mass of the cone (g) with depth of penetration in mm as reported by Moziar *et al.* (17).

## RESULTS AND DISCUSSION

Normally, fats having long plastic ranges are required for use in the baking industry. The proportion of solids and liquids present at various temperatures determines the plasticity or melting range of fats. Apart from the solid to liquid ratio, the crystalline nature of the fat is important for use in bakery

**TABLE 2**
**Solids Fat Content of Bakery Shortenings Determined by Differential Scanning Calorimetry (DSC)[a]**

| Sample | Solid fat content (%) at °C | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20 | 25 | 30 | 32.5 | 35 | 37.5 | 40 | 42.5 | 45 | 47.5 |
| 1) Puff (comm.) | 99 | 93 | 92 | 73.4 | 53.3 | 36 | 17.5 | 2.4 | 0.5 | 0.2 | 0 |
| 2) Biscuit (comm.) | 87 | 61 | 57 | 46 | 36.6 | 25 | 13 | 2.7 | 0 | | |
| 3) Cake (comm.) | 87 | 64.4 | 61 | 49.3 | 39.2 | 26.3 | 12 | 1.6 | 0 | | |
| 4) Mango fat | 93 | 80 | 64 | 42 | 9.2 | 1.8 | 1.1 | 0.8 | | | |
| 5) Mahua fat | | 28.4 | 12.4 | 6.8 | 3.4 | 0.2 | 0 | | | | |
| 6) Mango/mahua (4:6) | 89 | 79 | 73 | 28.5 | 2.4 | 0 | | | | | |
| 7) (6) +5% HGNO (Formulation A1) | 85.5 | 77 | 74 | 38 | 21 | 17.4 | 13.2 | 7.6 | 1.6 | 0.1 | 0 |
| 8) (6) +7% HGNO (Formulation A2) | 84 | 73 | 71 | 54 | 34 | 20 | 14.5 | 8.5 | 2.4 | 0 | |
| 9) (6) +10% HGNO | 87.4 | 69.2 | 66 | 55.4 | 43.2 | 33 | 28 | 21.6 | 13 | 3.2 | 0 |
| 10) Mango/mahua (3:7) + 7% HGNO (Formulation A4) | 89 | 66 | 64 | 52 | 38.7 | 23 | 16.5 | 10 | 4 | 0.3 | |
| 11) Mahua St (Mh1) | 85.3 | 36 | 34.3 | 32.2 | 29 | 25 | 20.3 | 15 | 9 | | |
| 12) Mango II St (Mk2) | 99 | 92 | 82 | 63 | 27 | 1 | 0 | | | | |
| 13) (11) + (12) (9:1) (Formulation B1) | 85.5 | 56.8 | 49.2 | 40 | 30.5 | 22.8 | 17.5 | 12.2 | 7 | 2.4 | 0.1 |
| 14) (10) + (11) (8:2) (Formulation B2) | 90.4 | 75 | 69.5 | 52.6 | 30 | 20 | 16 | 10.7 | 5 | 0.8 | 0 |
| 15) Mh1 + Mango fat (8:2) (Formulation B3) | 81 | 37 | 35.5 | 31 | 28 | 22.5 | 16 | 10 | 5.2 | 0.5 | 0 |
| 16) Mango I St (Mk1) | 100 | 99.7 | 99.6 | 95 | 85.4 | 60.7 | 13 | 0.6 | 0 | | |
| 17) Mk1 + Mahua (1:1) | | 89 | 85.6 | 58.7 | 26 | 3.3 | 0.7 | 0.1 | | | |
| (18) (16) + 5% HGNO (Formulation C1) | 96.3 | 92.4 | 90.5 | 70 | 42 | 15.8 | 11 | 7.2 | 3 | 0.2 | 0 |
| 19) (16) + 7% HGNO (Formulation C2) | 94 | 90 | 89 | 73 | 52 | 22.5 | 13 | 9 | 4.4 | 0.8 | 0.1 |
| 20) Mk1 + Mahua (4:6) +7% HGNO (Formulation C3) | 92 | 85.3 | 84 | 68 | 50 | 24 | 14 | 9.5 | 5 | 1 | 0 |

[a]St = stearin fractions; HGNO = fully hydrogenated groundnut oil; comm., commercial; see Table 1 for other abbreviations.

products. The β′ crystal structure is desirable to impart smooth consistency and good aeration properties. The suitability of fats for use in bakery products is assessed primarily by determining SFC at various temperatures and comparing with those of commercial hydrogenated bakery shortenings. Three types of commercial shortenings designed for puff pastry, biscuits, and cakes were analyzed and compared with the formulations based on mango and mahua fats/fractions. The commercial shortenings designed for cakes and biscuits showed similar melting characteristics, whereas that for puff pastry had different SFC (Table 2).

*Mango and mahua blends.* Mango and mahua fats are soft and have low SFC. The blends containing 40% mango and 60% mahua fats had a narrow melting range with high solids at 20–25°C and no solids at 35°C (Table 2). To increase the plastic range for use in bakery, fully hydrogenated groundnut (hardened) oil was incorporated into these blends. The mango and mahua fat blends containing 5 and 7% of hardened oil (Formulations A1 and A2) showed very small, broad melting peaks in the range of 42°C, which provided a long plastic range as shown by SFC data (Table 2). These formulations show low-melting fractions as well, which impart smooth consistency at normal ambient temperature. The formulations A1 and A2, particularly A2, showed melting characteristics similar to those of commercial hydrogenated shortenings designed for cakes/biscuits (Table 2). When the proportion of mahua fat increased to 70% (Formulation A4), two melting peaks were observed. There was no significant difference in SFC compared to that of Formulation A2 (Table 2), and the enthalpies of both melting peaks were similar to those of commercial shortening designed for biscuit (Table 3). The results also revealed that the high-melting peak and SFC at higher temperatures increased as the level of hardened oil increased from 5 to 10% (Table 2). By being fully saturated, by consisting of palmitic (45%) and stearic (50%) acids, and by having a melting point of 59°C with high SFC (86%) even at 55°C, hardened oil increased the plasticity of the blends by increasing the SFC at and above 30°C.

DSC cooling traces contained two distinct crystallization peaks at 8 and 23°C for Formulation A2 indicating heterogeneous types of triacylglycerols crystallizing at different temperatures. Formulation A4 also showed crystallization behavior similar to that of A2 (Table 4). Commercial biscuit shortening showed two distinct crystallization peaks and

**TABLE 3**
**Melting Peak Temperatures and Enthalpy of Crystals of Bakery Shortenings Obtained After Long Stabilization and After Slow Cooling**

| | After stabilization at 26°C-40 h (rate of heating 2°C/min) | | | | After slow (5°C/min) cooling and rapid 10°C/min) heating | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sample | Peak(s) (°C) | Δ*H* (J/g) | Peak(s) (°C) | Δ*H* (J/g) | Peak (°C) | Δ*H* (J/g) | Peak (°C) | Δ*H* (J/g) | Peak (°C) | Δ*H* (J/g) |
| Puff (comm.) | 12.4 | — | 36.8 | 64 | — | — | 35.4 | 66 | — | — |
| Cake (comm.) | 17.5 | 21 | 35.8 | 53 | — | 32.7 | 63.5 | — | — | |
| Biscuit (comm.) | 15.3 | 24 | 35.7 | 44 | 8 | | 28.6 | 47 | — | — |
| Formulation A1 | 17.4<br>29.5 | | 41 | 63<br>(all) | 11.7 | 24 | 29.8 | 4 | 41[a] | — |
| Formulation A2 | 12.1<br>17.1 | — | 32.2<br>42[a] | 44 | 12.2 | 23 | 30.7 | 4 | 42[a] | — |
| Formulation A4 | 13.7 | 20 | 33.3<br>42[a] | 45 | 11.1 | 26 | 30.9 | 4.3 | 40.6 | 1.5 |
| Formulation B1 | 11.4 | — | 31.7 | 47 | 12.1 | 26 | 31.8 | 3 | 42[a] | — |
| Formulation B2 | 14 | | 31.6<br>43[a] | 70<br>(all) | 13 | | 33[a] | | 43[a] | — |
| Formulation C2 | 10.9 | | 34.2<br>42[a] | 93 | 13.9 | 30 | 20[a]<br>30[a] | — | 40.8 | — |
| Formulation C3 | 11.4 | 9 | 34.3<br>42[a] | 79 | 13.1 | 20[a] | —<br>30[a] | 41.1 | 4.2 | |

[a]Shoulder. See Table 2 for abbreviation.

incomplete transition to the stable forms under slow rates of cooling. Also, the onset and enthalpy of crystallization of Formulation A2 were similar to those of commercial biscuit shortening (Table 4). However, commercial cake shortenings showed complete transition to the stable forms, as they showed similar peaks as obtained after long stabilization.

*Blends containing mango and mahua fat fractions.* Since the blends containing mango and mahua fats showed low SFC at all temperatures, the low-melting fractions were removed from these fats to improve SFC. Also, the high-melting fraction, which affects the smooth consistency at normal ambient temperature, was removed from mango fat. The high-melting mahua fraction (Mh1) showed two melting peaks at 16 and 41°C. The proportion of the lower one was higher and showed a flat melting curve with low SFC at 20–25°C and an extended melting range up to 40–42°C (Table 2). To increase SFC at 20–25°C, the mango mid fraction (Mk2) having high SFC at 20–25°C with short melting range was chosen for blending. The blend containing 20% Mk2 and 80% Mh1 (Formulation B1) showed a major melting peak at 31.6°C with small peaks at higher and lower temperatures and also showed a long plastic range, as expected (Table 2). The formulation containing 90% Mh1 and 10% Mk2 (Formulation B2) showed a higher proportion of low-melting fractions, which was reflected in lower SFC at 20–25°C compared to Formulation B1. The high solids at 20–25°C of Mk2 and low solids of Mh1 were improved by blending these two fractions to achieve a smooth consistency with long plastic range as required for bakery shortenings (Table 2). When mango fat was used in place of mango mid-fraction (Formulation B3), there was no improvement in SFC compared to those of mahua fraction (Mh1). This was mainly due to presence of low-melting fractions in mango fat. Formulations B1 or B2, especially B1, showed melting characteristics similar to those of commercial shortenings designed for cakes or biscuits (Table 2).

Formulations B1 and B2 showed onset of crystallization at about 23–24°C and two crystallization peaks during cooling from 70 to −10°C at 5°C/min; the onset of crystallization was similar to that of commercial cake and biscuit shortenings (Table 4). The melting endotherms obtained after cooling showed that the crystals were not completely transformed to the stable forms as they showed only small peaks at 31.8 and 43°C unlike those obtained after long stabilization (Table 3).

*Blends containing mango harder fraction and mahua fat.* For puff pastry, a roll-in fat that is very firm and waxy with good plasticity is required. As commercial puff shortening showed a high SFC at 20–25°C and long plastic range, the high melting fraction from mango fat (Mk1) was chosen to prepare shortening for puff pastry. However, Mk1 or its 50%

**TABLE 4**
**Crystallization Behavior of Bakery Shortenings Obtained by Differential Scanning Calorimetry After Cooling from 70 to −10°C at 5°C/min**

| | Crystallization | | | |
|---|---|---|---|---|
| | Temperature (°C) | | | Enthalpy |
| Sample | Onset | Peak 1 | Peak 2 | Δ*H* (J/g) |
| Comm. puff | 25 | 25[a] | 20.2 | 57 |
| Comm. cake | 23 | 23[a] | 18.2 | 42 |
| Comm. biscuit | 23 | 22.7 | 15 | 27 |
| Formulation A2 | 23 | 23 | 8 | 30 |
| Formulation A4 | 23 | 23 | 8.7 | 40 |
| Formulation B2 | 23 | 23 | 10 | 30 |
| Formulation C2 | 25 | 25 | 8 | 70 |

[a]Shoulders. See Table 2 for abbreviation.

**TABLE 5**
**Fatty Acid Composition of Bakery Shortenings[a]**

| Sample | Fatty acid (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 14:0 | 16:0 | 18:0 | 18:1 | 18:1 *trans* | 18:2 | Saturated |
| Comm. puff | — | 37.6 | 9.7 | 17.9 | 28.9 | 0.9 | 47.3 |
| Comm. cake | — | 46.3 | 6.9 | 20.4 | 18.5 | 1.6 | 53.2 |
| Comm. biscuit | — | 39.4 | 10.7 | 27.0 | 17.5 | 0.8 | 50.1 |
| Formulation A2 | 1.0 | 23.8 | 33.2 | 36.9 | Nil | 1.9 | 58.0 |
| Formulation C2 | 0.5 | 21.1 | 37.4 | 35.7 | Nil | 3.9 | 59.0 |
| Formulation B2 | — | 30.6 | 38.4 | 26.8 | Nil | — | 69.2 |
| Mango 1st St (Mk1) | 1.0 | 7.5 | 48.5 | 40.2 | Nil | 1.1 | 56.0 |
| Mango 2nd St (Mk2) | — | 10.4 | 37.8 | 46.1 | Nil | 4.4 | 48.2 |
| Mahua St (Mh1) | — | 36.5 | 34.5 | 29.0 | Nil | — | 71.0 |
| Refined mango fat | — | 10.3 | 35.4 | 49.3 | Nil | 4.9 | 45.7 |
| Refined mahua fat | 1.0 | 29.3 | 23.5 | 32.6 | Nil | 13.6 | 53.8 |

[a]See Tables 1 and 2 for abbreviations.

blend with mahua fat showed a short melting range although the SFC of the latter were lowered due to solubility effect of mahua (Table 2). As seen earlier, to improve the plasticity, 5 and 7% hardened oil was incorporated into the blend. A small broad melting peak in the range of 41°C was observed due to addition of hardened oil, which is responsible for improving the plasticity (Table 2). The results showed that increasing the content of hardened oil from 5 to 7% and altering the relative proportions of Mk1 from 50 to 40% have only marginal effects on melting characteristics (Table 2). The blend containing 40–50% of Mk1 and 50–60% of mahua along with 5 or 7% hardened oil (Formulations C1-3) showed melting characteristics similar to those of commercial shortening for puff pastry (Table 2).

DSC cooling traces of Formulation C2 showed onset of crystallization at about 25°C as well as two peaks unlike those of commercial shortening, and the enthalpy of crystallization was greater than that of a commercial sample (Table 4). Also, the melting endotherms obtained after cooling revealed that there was incomplete transition to the most stable forms, whereas the commercial sample showed complete transition to the stable form as it showed peaks and enthalpy similar to those obtained after long stabilization (Table 3).

The commercial shortenings contained 18–29% *trans* fatty acids, whereas the prepared formulations did not contain any *trans* acids (Table 5). The contents of total saturated fatty acids in the prepared samples were slightly higher than those present in commercial samples, which was mainly due to presence of *trans* fatty acids in commercial samples. The latter impart a hard consistency similar to that provided by saturated fatty acids. The palmitic acid content in the formulations is higher than 20% to impart smooth consistency to the products by promoting crystallization in β′ form. D'Souza *et al.* (18) examined the fatty acid chain length diversity in high-melting glycerides of vegetable stick margarines and found that for stick margarines to be in the β′ form, the 16:0 content of the high-melting fraction had to be *ca.* 20%.

The iodine value of commercial shortenings is 57–58, and those of prepared formulations ranged from 47 to 53, slightly less than commercial samples. This is mainly due to presence of a higher quantity of saturated fatty acids in the formulations (Table 5).

The consistency as measured by penetrometer showed that formulations were harder than commercial samples (Table 6). SFC is a contributing factor to hardness of products. Solids content affects the consistency since higher SFC will contribute a firmer fat. It can be seen from Table 2 that the formulations showed slightly higher SFC values at 25°C than those of commercial samples and hence showed higher firmness values. Thus, their use may be advantageous for use in warm climates.

In brief, three types of bakery shortenings for cakes, biscuits and puff pastry were prepared by blending the fractions of mango and mahua fats. These could also be prepared by blending the two parent fats, the plasticity of which could be adjusted by incorporating 5–7% of a fully hydrogenated vegetable oil. The *trans*-free formulations thus prepared had melting and cystallization characteristics, especially the onset and enthalpy, similar to those of commercial hydrogenated shortenings, although they showed delayed crystallization to the stable forms. Bakery shortenings without any *trans* fatty acids could be prepared from mango and mahua fats, These processes can be utilized by shortening manufacturers. Although hydrogenated shortenings are cheaper than fractionated and blended shortenings the latter could be preferred because of their health benefits.

**TABLE 6**
**Consistency of Bakery Shortenings as Measured by Cone Penetrometer**

| Sample | Firmness (g/mm) at °C | | |
|---|---|---|---|
| | 3 | 25 | 37 |
| Comm. puff | 16.8 | 4.1 | 2.2 |
| Comm. cake | 11.9 | 2.1 | 1.3 |
| Comm. biscuit | 9.5 | 1.8 | 1 |
| Formulation C2 | 26.7 | 6.6 | 1.8 |
| Formulation A2 | 22.7 | 2.7 | Soft |
| Formulation B1 | 21.6 | 2.7 | 1.7 |

[a]See Tables 1 and 2 for abbreviations.

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