Characterization of Pili Nut (*Canarium ovatum*) Oil: Fatty Acid and Triacylglycerol Composition and Physicochemical Properties

Yukio Kakuda[a,*], Firouz Jahaniaval[a], Massimo F. Marcone[a], Lourdes Montevirgen[b], Quintin Montevirgen[b], and Joselyn Umali[b]

[a]Department of Food Science, University of Guelph, Guelph, Ontario, Canada N1G 2W1, and [b]Industrial Technology Development Institute, Department of Science and Technology, Bicutan, Taguig, Metro Manila, Philippines

ABSTRACT: The fatty acid and triacylglycerol composition of pili nut (*Canarium ovatum*) oil and fractions were analyzed by gas chromatography and reversed-phase high-performance liquid chromatography, respectively. The oil obtained by solvent extraction was low in polyunsaturated fatty acids and high in saturates. The polyunsaturated fatty acid (18:2 and 18:3) contents were less than 11%, whereas palmitic (16:0) and stearic acid (18:0) were 33.3 and 10.9%, respectively. The saturated fatty acid level of the low-melting fraction oil was reduced from 44.4 to 35.5% and the total unsaturated fatty acid levels were increased from 55.6 to 65% by fractional crystallization. Triacylglycerol analysis showed that the high-melting fraction (HM) from pili nut oil consisted of POP, POS, and SOS + SSO (P = palmitic acid, O = oleic acid, and S = stearic acid) in the proportion of 48.6, 38.8, and 8.7%, respectively. The physicochemical properties of the HM fraction were studied using differential scanning calorimetry and pulsed nuclear magnetic resonance. The results showed that the melting range and solid fat content of the HM fraction were very similar to those isolated from cocoa butter and olive oil. The content of POP played an important role in determining the melting range of the HM fraction. It is suggested that this HM fraction may have applications as a cocoa butter substitute in confectionery products.

Paper no. J9520 in *JAOCS 77*, 991–996 (September 2000).

KEY WORDS: *Canarium ovatum*, cocoa butter substitute, fractional crystallization, hard fraction, pili nut oil, triacylglycerol composition.

Canarium ovatum is native to the Philippines and known locally as pili. The pili is a tropical tree with about 600 species in the Burseraceae family (1). It grows wild in southern Luzon, parts of Visayas, and Mindanao (The Philippines), in low- and medium-elevation primary forests. The bulk of the raw nuts is supplied from wild stands in the mountains around Sorsogon Albay and Camarines Sur in the Bicol region of southern Luzon (2,3). The pili fruit is a drupe, 4 to 7 cm long and 2.3 to 3.8 cm in diameter and weighs 15.7 to 45.7 g (2,3). The pili fruit can be consumed raw or cooked, and its kernel has been used in chocolates, baked goods, and ice cream. The production standard for a mature pili tree is between 100–150 kg of in-shell nuts over one growing season (4).

The most important product from pili is the kernel, which is composed of approximately 8% carbohydrate, 11.5 to 13.9% protein, and 70% fat (2,3). In contrast, the fruit was shown to contain approximately 73% fat, 10% water, 11% protein, 3% ash, and 3% carbohydrate(s). Extraction of the kernel yields a light yellowish oil containing mainly oleic (44.4 to 59.6%) and palmitic (32.6 to 38.2%) acids (5,6). The kernel is an important food source and may represent a valuable export commodity. Few papers are currently available on pili nut oil, and more information on its properties is needed to help promote the utilization and development of this new oil. The objective of this study therefore was to characterize pili nut oil and its fractions in terms of their chemical composition and physicochemical properties.

EXPERIMENTAL PROCEDURES

Materials. Raw pili nuts (*Canarium ovatum*) were obtained from the Bicol region of the Philippines. Cocoa butter was obtained from Trophy Foods Inc. (Toronto, Ontario, Canada), and extra virgin olive oil was purchased from a local supermarket. Methanolic sodium hydroxide (0.5 N) was prepared by dissolving 10 g of NaOH in 500 mL of methanol. Boron trifluoride (BF_3, 12.5% in methanol) was purchased from Sigma-Aldrich (Oakville, Ontario, Canada). Hexane, petroleum ether, and sodium chloride were reagent grade and purchased from Fisher Scientific (Toronto, Ontario, Canada).

Oil extraction. Fifty grams of ground pili nuts were weighed, placed in thimbles, and extracted for 3 h with petroleum ether in a Soxhlet apparatus. The solvent was removed by rotary evaporation at 40°C and the oil stored in sealed vials at −18°C until analyzed.

Gas chromatographic (GC) analysis. Fatty acid methyl esters were prepared by the American Oil Chemists' Society (AOCS) Official Method Ce 2-66 (9) with minor changes. The 50-mL reaction flask was replaced with 15-mL screw-capped test tubes. A Shimadzu gas chromatograph (GC), model GC-14 A (Mandel Scientific Co. Inc., Guelph, Ontario, Canada), equipped with a split mode injection system, flame-ionization detector, and a 30 m × 0.25 mm i.d., 0.25 μm film

*To whom correspondence should be addressed.
E-mail: ykakuda@uoguelph.ca

thickness SP-2330 fused-silica capillary column (Supelco, Oakville, Ontario, Canada) was used to analyze the fatty acid methyl esters. The GC conditions were as follows: initial oven temperature (145°C), initial time (2.0 min), heating rate (6°C/min), final temperature (235°C), final hold time (10 min), injection port temperature (260°C), detector port temperature (260°C), hydrogen gas flow (30 mL/min), air flow rate (300 mL/min), and hydrogen gas carrier flow rate (1.0 mL/min). Injection volume was 0.1 μL, and the data were integrated with a Shimadzu Model CR4A Chromatopac (Mandel Scientific Co.). The fatty acids were identified by comparing retention times to pure standards purchased from Sigma-Aldrich.

Fractional crystallization. The oil extracted from the pili nut was separated into high-melting (HM), medium-melting (MM), and low-melting (LM) fractions by fractional crystallization from an acetone/ethanol solvent mixture. Ten grams of oil were mixed with 100 mL of acetone/ethanol (70:30) in a 250 mL Erlenmeyer flask at room temperature. The dissolved oil was placed in a freezer at −30°C and held for 45 min. When cooled to −30°C, the HM and some MM triacylglycerols (TAG) crystallized while the LM TAG remained in solution. The crystals were quickly vacuum-filtered on Whatman #40 filter paper in a fume hood at room temperature. Since there was a slight temperature rise to −20°C during filtration, the resolubilization of the HM crystals was kept to a minimum by immediately filtering the mixture upon removal from the freezer. As well, the evaporation of the acetone helped to keep the mixture cold during filtration. However, some TAG such as POP and POS (where P = palmitic acid, O = oleic acid, and S = stearic acid) were resolubilized to a small extent in the solvent. The collected crystals were redissolved in 100 mL of acetone/ethanol (80:20) and recrystallized as described above to remove MM TAG and any remaining LM TAG from the HM crystals. The HM crystals were further purified by dissolving the second crop of crystals in 100% acetone at 40°C, cooling to –30°C, and holding for 45 min. The final crop of HM crystals was vacuum-filtered and stored at −30°C for TAG and fatty acid analyses. The filtrates from all three steps (70:30 + 80:20 + 100% acetone) were pooled and cooled to –30°C to crystallize the MM TAG. The MM crystals were collected by vacuum filtration on Whatman #40 filter paper at −20°C as described above. The filtrate collected from the MM crystals was evaporated to recover the LM fraction. These last fractionation procedures were not completely clean and some overlap of MM and LM TAG occurred.

To compare the physicochemical properties of the HM fraction from pili nut oil with commercially available fats and oils, we prepared the HM fractions from cocoa butter (HM fat) and olive oil (LM oil) and analyzed them by reversed-phase high-performance liquid chromatography (RP–HPLC). Cocoa butter (10 g) was dissolved in 100 mL of acetone/ethanol (80:20) at 40°C then cooled to −30°C to crystallize the HM fraction. The HM crystals were collected by vacuum filtration and further purified by dissolving in 100% acetone at 40°C, cooling to −30°C, and filtering. The fractionation step was performed only twice since the majority of TAG in cocoa butter was composed of POP, POS, and SOS. For the olive oil sample, the HM TAG were separated and purified in a series of acetone/ethanol mixtures. The olive oil (10 g) was dissolved in 100 mL of acetone/ethanol (70:30) and cooled to −30°C. Olive oil is completely soluble in acetone/ethanol (70:30) when held at room temperature, but when held for 30 min at −30°C, a phase transition occurs and the mixture separates into an oil phase and solvent phase. The solvent phase contains polar components (i.e., color, flavor, squalene, mono- and diglycerides, and LM TAG). The oil phase contains the MM and HM TAG with some residual LM TAG. The oil phase was carefully separated from the solvent phase at −10°C using a 500-mL separatory funnel. The separated oil was treated with 100 mL acetone/ethanol (80:20), using the same procedure as described above to extract the remaining polar components. Removing the polar components from olive oil facilitated the crystallization of the HM TAG. In the (80:20) solvent, the HM TAG crystallized at −30°C but formed an oil phase when removed from the freezer. However, after two extraction steps with acetone/ethanol (80:20), the HM fraction was easily crystallized when the oil phase was placed into acetone/ethanol (90:10) and held at −30°C for 45 min. These crystals did not redissolve when removed from the freezer. To improve crystal recovery, the crystals were quickly separated from the solvent by decantation of the liquid phase instead of vacuum filtration. An additional crystallization step was performed in acetone/ethanol (95:5) and finally in 100% acetone using vacuum filtration.

RP–HPLC. The AOCS official method Ce 5b-89 (9), after slight modifications to the mobile phase ratio, was used to determine the TAG compositions of the pili nut, cocoa butter, and olive oil fractions. The separation was performed on two Econosil C18 columns (5 μm, 4.6 × 250 mm, Alltech, Deerfield, IL) in series. The analysis was carried out isocratically with a mobile phase consisting of 60% acetone and 40% acetonitrile (vol/vol). Fat samples (5%) were dissolved in HPLC-grade acetone, and 20-μL aliquots were automatically injected onto the column (Waters 700 Satellite WISP; Millipore, Milford, MA) and eluted at a flow rate of 1 mL/min. The column was equilibrated at 30°C. The effluent was monitored with a Waters 410 RI detector (30°C and sensitivity 64). The TAG were identified by comparing retention times to pure standards purchased from Sigma-Aldrich.

Solid fat content (SFC). The SFC of pili nut oil and the isolated fractions were measured at 10, 15, 20, 25, 30, 35, and 40°C according to AOCS official method, Cd 16b-93 (9), using a Bruker pulsed NMR, equipped with a Minispec PC/20 data analyzer (Minispec, Milton, Ontario, Canada).

Differential scanning calorimetry (DSC). The thermal behavior of pili nut oil and isolated fractions were determined on a thermoanalyzer DuPont 2910 (Wilmington, DE) fitted with a DSC cell (DuPont 910) and equipped with a liquid nitrogen cooling attachment (TA Instrument, Wilmington, DE). Approximately 8 to 10 mg of pili nut oil or fraction was weighed into aluminum pans and hermetically sealed. The

TABLE 1
The Fatty Acid Composition of Pili Nut Oil: High-Melting (HM), Medium-Melting (MM), and Low-Melting (LM) Fractions

	Fatty acid (%)			
Fatty acid	Pili nut oil	HM fraction	MM fraction	LM fraction
14:0	0.05	—	0.05	0.05
16:0	33.3	43.0	49.1	28.2
16:1	0.30	—	0.12	0.36
18:0	10.9	26.3	11.9	7.10
18:1	44.7	29.9	31.9	52.6
18:2	10.1	0.34	6.21	11.4
18:3	0.53	—	0.27	0.66
20:0	0.24	0.41	0.32	0.18

heating curves were recorded from −30 to 80°C, at a heating rate of 5°C/min.

RESULTS AND DISCUSSION

Fatty acid composition. The fatty acid compositions of pili nut oil and its fractions are shown in Table 1. The unfractionated oil is very low in polyunsaturated (18:2 and 18:3) fatty acids. The combined linoleic and linolenic fatty acid content is less than 11%, while the saturates (palmitic and stearic acids) account for 33.3 and 10.9%, respectively, of the fatty acids. The fatty acid composition of pili nut oil is similar to palm oil. They both have approximately equal amounts of saturated and unsaturated fatty acids with palmitic and oleic acids as the main fatty acids.

Pili nut oil has poor nutritional value due to its low polyunsaturated fatty acid content. However, by fractionating the oil with acetone/ethanol mixtures, the nutritional as well as functional properties of the oil can be modified. Removing the HM fraction (POP, POS, and SOS) by fractional crystallization resulted in an LM fraction with increased levels of mono- and polyunsaturated fatty acids (Table 1). The mono- and polyunsaturates in the HM fraction were reduced to 29.9 and 0.34%, respectively, while the saturates were increased to 69.7% (Table 1). The HM fraction from olive oil has a fatty acid profile very similar to the HM fraction from pili oil (Table 2). The olive oil HM fraction has only a slightly lower 18:0 content (19.4%) and a slightly higher 18:1 content (33.5%). The cocoa butter HM fraction, on the other hand, contains half the amount of palmitic acid (23%) and almost twice the amount of stearic acid (43%) when compared to the HM fractions from pili nut oil. The total saturates, however, were very close for all three HM fractions (69.3% for pili, 66% for cocoa butter, and 64.2% for olive). The increased saturates in the HM fraction from pili nut oil have a significant effect on its thermal, oxidative, and functional properties.

Triacylglycerol composition. The TAG compositions of the pili nut oil and fractions are shown in Figure 1 and Table 3. The TAG were separated on an RP–HPLC column, according to their degree of polarity. The number of double bonds in the fatty acid (6), their position along the triacylglycerol backbone, and the carbon number (7) determine the overall polarity of the TAG. The greater the relative polarity of the TAG, the faster they will elute from the C18 column. With triolein (OOO) as the reference point, the more polar TAG were eluted in less than 50 min from the RP-column (Fig. 1). Generally these TAG have melting points below 5°C (8) and remain dissolved in acetone/ethanol (70:30) at −30°C. The composition of the separated LM fraction is given in Table 3. The dominant TAG were POO + PSL (L = linoleic acid) followed by POP + MSO (M = myristic acid), POL, OOO, OOS, PPL, PLL + PLnO, OOL + PoOO, POS, OLL + OOLn, and LLL (Ln = linolenic acid, Po = palmitoleic acid). The POO and OOS are less polar than OOO according to their retention time on HPLC, but since they have only one saturated fatty acid in their structure they dissolve in acetone/ethanol (70:30) and are retained in the solvent phase. The SOS + SSO and the majority of the POS and POP TAG were removed by the fractional crystallization procedure.

The less polar TAG eluted after triolein with retention times greater than 50 min (Fig. 1). These less polar TAG make up the MM and HM fractions and contain mainly palmitic, oleic, and stearic acids. The composition of the TAG in the MM fraction include POP + MSO as the dominant TAG followed by lesser amounts of POS, POO + PSL, PPL, OOS, SOS + SSO, OOO, POL, and OOL + PoOO (Table 3). The MM fraction contained TAG from the LM and HM fractions and the LM fraction contained TAG from the HM and MM fractions.

TABLE 2
Fatty Acid Composition of the HM Fractions from Pili Nut Oil, Cocoa Butter, and Olive Oil

	Fatty acid (%)		
	Pili nut oil	Cocoa butter	Olive oil
Fatty acid	HM fraction	HM fraction	HM fraction
14:0	—	—	0.01
16:0	43.0	23.0	44.8
16:1	—	0.06	—
18:0	26.3	43.0	19.4
18:1	29.9	31.9	33.5
18:2	0.34	0.71	0.07
20:0	0.41	1.10	1.76

[a]For abbreviation see Table 1.

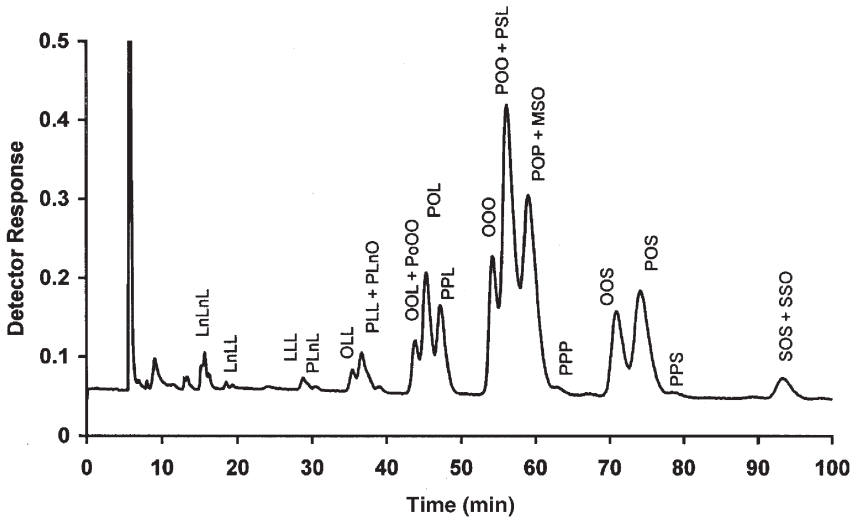

FIG. 1. The reversed-phase high-performance liquid chromatogram of pili nut oil. The separation was performed on two Econosil C18 (Alltech, Deerfield, IL) columns in series, with a mobile phase consisting of 60% acetone and 40% acetonitrile and eluted at a flow rate of 1 mL/min and monitored with a Waters 410 RI detector (WISP, Millipore Milford, MA) at 30°C and sensitivity 64. Abbreviations: Ln, linolenic acid; L, linoleic acid; P, palmitic acid; O, oleic acid; Po, palmitoleic acid: S, stearic acid; M, myristic acid.

The HM fraction had the cleanest composition and the most interesting properties. This fraction contained high levels of POS and POP + MSO with lesser amounts of SOS + SSO and very small amounts of PSS and PPP (Table 3). The major TAG in this fraction have a melting range between 35 and 41.6°C (8). During fractional crystallization, the nonpolar TAG, which have at least two saturates in their structure, will crystallize in the acetone/ethanol mixtures and be separated from the more polar LM TAG. As seen in Figure 1, OOS has a retention time greater than POP (70.91 and 59.07 min, respectively) and should be less polar than POP and crystallize before POP. However, OOS did not crystallize because it had only one saturated fatty acid in its structure whereas POP with two saturated fatty acids crystallized readily. Based on these properties and the careful utilization of the fractionation procedure, the disaturated TAG (POP, POS, and SOS + SSO) can be easily separated from the pili nut oil.

It should be noted that tristearin (SSS) was not present in any of the TAG chromatograms. From the fatty acid analyses (Table 1), approximately 10.9% stearic acid was present in

TABLE 3
TAG Composition of Pili Nut Oil, HM, MM, and LM Fractions[a]

No.	TAG	Pili nut oil (area %)	HM fraction (area %)	MM fraction (area %)	LM fraction (area %)
1	Unknown	0.28	—	—	0.5
2	LnLnL	0.40	—	—	0.53
3	LnLL	0.13	—	—	0.13
4	LLL	0.52	—	—	0.70
5	PLnL	0.14	—	—	0.13
6	OLL + OOLn	0.81	—	—	1.10
7	PLL + PLnO	2.43	—	—	3.75
8	OOL + PoOO	2.38	—	0.12	3.24
9	POL	7.79	—	1.45	10.6
10	PPL	5.58	—	7.15	6.37
11	OOO	7.79	—	1.66	10.2
12	POO + PSL	25.5	—	8.12	34.1
13	POP + MSO	21.2	32.1	51.0	12.3
14	PPP	—	1.82	—	—
15	OOS	7.53	—	3.52	10.2
16	POS	11.9	50.2	22.1	2.99
17	PSS	0.55	1.43	—	—
18	SOS + SSO	2.24	14.4	2.10	—

[a]Abbreviations: Ln, linolenic acid; L, linoleic acid; P, palmitic acid; O, oleic acid; Po, palmitoleic acid; S, stearic acid; M, myristic acid; for other abbreviations see Table 1.

TABLE 4
Comparison of Pili Nut HM TAG Composition with Cocoa Butter and Olive Oil HM Fraction

No.	TAG	Pili nut oil HM fraction 1[a] (area %)	Pili nut oil HM fraction 2[a] (area %)	Cocoa butter HM fraction (area %)	Olive oil HM fraction (area %)
1	PPL	1.28	—	—	
2	POP	48.6	32.1	10.6	42.2
3	PPP	0.95	1.82	—	—
4	POS	38.8	50.2	45.3	41.0
5	PSS	1.00	1.43	—	—
6	SOS + SSO	8.72	14.4	43.4	15.4

[a]10 g pili nut oil initially crystallized from 100 mL of acetone/ethanol, 70:30 for HM Fraction 1, 80:20 for HM Fraction 2. See final paragraph of triacylglycerol composition in the Results and Discussion section for further details. For abbreviations see Tables 1 and 3.

pili nut oil, which was distributed among OOS (7.5%), POS (11.9%), and SOS + SSO (2.2%), leaving 3.5% stearic acid unaccounted for. If the missing stearic acids were in the form of PSL and MSO, they would account for only a small percentage of the missing stearic acid. It is more reasonable to assume that the missing stearic acids were in the form of trisaturates (SSS, SPP, SSP), which did not dissolve in acetone and were therefore removed in the filtration step during the HPLC sample preparation procedure.

The composition of the TAG in the pili nut oil HM fraction was highly dependent on the acetone/ethanol ratio and the crystallization temperature. The composition of POP, POS, and SOS in the HM fraction can be changed if the solvent ratio is changed (Table 4). When a 10-g sample of pili nut oil was crystallized in 100 mL of acetone/ethanol (70: 30), recrystallized in 100 mL of acetone/ethanol (80:20), and purified with 100 mL acetone (100%), a composition of 48.6% POP, 38.8% POS, and 8.7% SOS + SSO was obtained (pili nut oil 1). However, when crystallized twice in 100 mL acetone/ethanol (80:20) and purified in 100 mL of acetone (100%), a composition of 32.1% (POP), 50.2% (POS), and 14.4% (SOS + SSO) was obtained (pili nut oil 2). The second fractionation procedure produces a TAG composition closer to that of cocoa butter. In both procedures the POP was reduced when compared to POS and SOS. By calculation, the POP/POS and POP/SOS ratios in native pili nut oil were 1.77 and 9.46, respectively. These ratios changed to 1.25 and 5.57 in pili nut oil 1 and to 0.63 and 2.22 in pili nut oil 2 (Tables 3 and 4). The fractionation procedure selectively removed POP due to its greater solubility in the less polar solvent. The olive oil HM fraction had a TAG composition very similar to the HM fraction from pili nut oil (Table 4). It appears that the fractionation procedure can be used on common oils to produce an HM fraction composed primarily of POP, POS, and SOS.

Physicochemical properties of HM fraction. The fatty acid analyses (Table 1) of pili nut oil and its fractions show an increase in the levels of palmitic and stearic acids in the HM fraction and a concomitant decrease in these same fatty acids in the LM fraction. The fatty acid composition of the LM fraction shows 65% mono- and polyunsaturates and 35% saturated fatty acids. Although the amounts of saturated fatty acids are still relatively high when compared to olive, canola, and soybean oils, the LM fraction remains liquid at 10°C, has good nutritional value, and can be used as a liquid cooking or frying oil.

The fatty acid compositions of the HM fraction from pili nut oil, olive oil, and cocoa butter are shown in Table 2. The major fatty acids were palmitic, stearic, and oleic. In comparing the fatty acid compositions, the HM fraction from pili nut oil looks very similar to olive oil and very different from cocoa butter. The fatty acid composition, however, may not be the best predictor of the properties of the hard fraction. It is more important to control the TAG composition (POP, POS, and SOS) if the physicochemical properties are to be modified. As discussed above, the composition of POP, POS, and SOS can be manipulated by adjusting the ratio of acetone/ethanol and the temperature. By varying the TAG composition in this manner it may be possible to alter the physicochemical characteristics of this fraction. The dominant TAG in pili nut oil are POO (25.5%), POP (21.2%), and POS (11.9%) (Table 3). Fractional crystallization produced a HM fraction with 0% POO, 32.1% POP, and 50.2% POS. The high concentrations of POS and POP impart unique melting and functional properties to this hard fraction.

DSC analysis. The similarities in melting properties of the HM fractions from pili nut oil, cocoa butter, and olive oil were clearly shown by DSC analysis (Table 5). The onset temperatures for pili nut oil 1 and olive oil were 30.5 and 30.5°C and peak melting temperatures were 34.6°C and 33.5°C, respectively. Cocoa butter had a slightly higher onset temperature (32.5°C) and peak melting temperature (36.3°C).

The peak melting temperature of the pili nut oil HM fraction can be increased by altering the fractionation procedure. Pili nut oil 2 was fractionated twice with acetone/ethanol (80: 20) to produce a HM fraction with a peak melting temperature of 39.9°C (Table 5). This is slightly higher than cocoa butter, but there is the possibility of further adjusting the fractionation procedure or blending two pili nut oil HM fractions to obtain a product closer to cocoa butter. The role of POP in changing the melting range of pili nut HM fraction is very important since it is more soluble in higher ratios of acetone/ethanol than POS and SOS. These changes in composition can have a significant effect on the melting behavior, mouth feel, and stability of pili nut oil HM fraction.

TABLE 5
Differential Scanning Calorimetric Thermal Analyses of Pili Nut, Cocoa Butter, and Olive Oil HM Fractions[a]

Hard fraction	Peak start (°C)	Onset (°C)	Max melt. temperature (°C)	Height (W/g)	Stop (°C)	Area (J/g)
Pili nut oil 1	25.1	30.5	34.6	−1.95	42.6	134.1
Pili nut oil 2	26.7	30.4	39.9	−1.55	48.0	175.5
Cocoa butter	23.6	32.5	36.3	−1.71	42.4	121.6
Olive oil	25.4	30.5	33.5	−2.16	39.9	140.4

[a]For abbreviation see Table 1.

TABLE 6
Solid Fat Content (%) of Pili Nut Oil and Pili Nut HM Fraction[a]

	Temperature (°C)						
Oil	10	15	20	25	30	35	40
Pili nut oil	29.1 ± 0.2	—	3.35 ± 0.1	1.59 ± 0.14	0.44 ± 0.1	0.0	0.0
Pili nut oil, HM fraction	99.9 ± 0.05	97.9 ± 1.75	94.6 ± 1.3	71.0 ± 0.2	48.5 ± 0.16	6.06 ± 0.1	2.53 ± 0.05

[a]For abbreviation see Table 1.

SFC. The SFC results on pili nut HM fraction (Table 6) indicate that 94% of the solids disappear at 35°C. The presence of less than 5% solids at body temperature (37°C) is a good indication that this hard fraction will have a clean, cool mouth feel when consumed. The sharp decrease in solids from 20 (94.5%) to 35°C (5.93%) makes the HM fraction an ideal substitute for cocoa butter.

REFERENCES

1. Neal, M.C., *In Gardens of Hawaii*, Bernice P. Bishop Museum, Special Pub. Bishop Museum Press, Honolulu 1965.
2. Coronel, R.E., and J.C. Zuno, Note: The Correlation Between Some Fruit Characters of Pili, *Philipp Agric. 63*:163–165 (1980).
3. Coronel, R.E., and J.C. Zuno, Note: Evaluation of Fruit Characters of Some Pili Seeding Trees in Calauan and Los Banos, Laguna, *Ibid. 63*:166–173 (1980).
4. Coronel, R.E., J.C. Zuno, and R.C. Sotto, *Promising Fruits of the Philippines*, University of Philippines at Los Banos, College of Agriculture, Laguna, 1983, pp. 325–350.
5. Mohr, V.E., and G. Wichmann, Cultivation of Pili Nut *Canarium ovatum* and the Composition of Fatty Acids and Triglycerides of the Oil, *Fett Wiss. Technol. 89*:128–129 (1987).
6. Sassano, G.J., and B.S.J. Jeffrey, Gas Chromatography of Triacylglycerols in Palm Oil Fractions with Medium-Polarity Wide-Bore Columns, *J. Am. Oil Chem. Soc. 70*:1111–1114 (1993).
7. Raclot, T., Selective Mobilization of Fatty Acids from White Fat Cells: Evidence for a Relationship to the Polarity of Triacylglycerols, *Biochem. J. 322*:483–489 (1997).
8. Weidermann, L.H., Margarine and Margarine Oil, Formulation and Control, *J. Am. Oil Chem. Soc. 55*:823–829 (1987).
9. *Official Methods and Recommended Practices of the American Oil Chemists' Society*, American Oil Chemists' Society, Champaign, Methods Ce 2-66 (1992), Ce 5b-89 (1995), and Cd 16b-93 (1996).

[Received January 21, 2000; accepted June 27, 2000]

[Received January 21, 2000; accepted June 27, 2000]