Trans-Free Vanaspati Containing Ternary Blends of Palm Oil–Palm Stearin–Palm Olein and Palm Oil–Palm Stearin–Palm Kernel Olein

I. Nor Aini[a], C.H. Che Maimon[a], H. Hanirah[a], S. Zawiah,[b] and Y.B. Che Man[b]

[a]Palm Oil Research Institute of Malaysia, Ministry of Primary Industries, Kuala Lumpur, Malaysia
[b]Faculty of Food Science and Biotechnology, Universiti Putra Malaysia, Serdang, Selangor

ABSTRACT: Four samples of *trans*-free vanaspati were made using palm oil–palm stearin–palm olein (PO–POs–POo) blends (set A) and another four samples (set B) using palm oil–palm stearin–palm kernel olein (PO–POs–PKOo). Palm stearin iodine value [iodine value (IV), 30] and soft palm stearin (IV, 44) were used in this study. The products were evaluated for their physical and chemical properties. It was observed that most of the vanaspati were granular (grainy) and had a shiny appearance. Chemical analyses indicated that vanaspati consisting of PO–POs–POo had higher IV (47.7–52.4) than the PO–POs–PKOo vanaspati (37.5–47.3). The higher IV demonstrated by set A samples was due to their higher content of unsaturated fatty acids, 46.0–50.0% compared to 36.6–45.0% in set B. Decreasing the amount of palm oil while increasing palm stearin in the formulations resulted in higher slip melting points and higher yield values. Eutectic interaction was observed in PO–POs–PKOo blends. The β′ crystalline form was predominent in PO–POs–POo samples (set A). One formulation in set B exhibited β crystallinity. From the differential scanning calorimetry thermograms, samples in set B showed a high peak at the low-melting region as well as a high peak at the high-melting region. In set A, the peak at the low-melting region was relatively lower.

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KEY WORDS: Iodine value, palm kernel olein, palm oil, palm olein, palm stearin, slip melting point, vanaspati.

Vanaspati was originally developed in the 1930s in India as an alternative to ghee, their traditional cooking fat. Ghee is made from milk fat from either the cow or buffalo, while vanaspati is an all vegetable oil-based product (1). Vanaspati is widely used in the Indo-Pakistan subcontinent, Middle Eastern countries, and Southeast Asia for cooking and frying. In certain countries, vanaspati may be formulated for general purpose applications, cooking, frying, and baking. In principle, vanaspati is a shortening and can be considered as a substitute for ghee just as margarine is for butter (2).

Initially, vanaspati formulations were based on a single hydrogenated oil, for example cottonseed or groundnut oil. As the industry grew, products based on blends of oils or animal fats were produced. Presently, soybean, rapeseed, cottonseed, and palm oil (PO) are the most commonly used oils in the formulation of vanaspati (3). These oils usually have to be hydrogenated in order to achieve the required characteristics for vanaspati. Hydrogenation is a fairly costly process and produces undesirable *trans* fatty acids.

Most of the *trans* fatty acid content in the human diet is derived from the partial hydrogenation of fats. It has been reported that *trans* fatty acids have a negative impact on plasma lipoprotein profile by lowering high-density lipoprotein (HDL) cholesterol and raising the low-density lipoprotein (LDL) cholesterol (4). This has raised the need to replace hydrogenated fats with natural solid fats in food product formulations (5). Palm oil, which has a melting-point between 33–39°C and iodine value (IV) between 50–55, has similar physical characteristics to vanaspati, and therefore does not require hydrogenation. In this context, palm oil is perceived as a suitable alternative.

The objective of this paper is to evaluate the characteristics of vanaspati based on PO and its products, namely, palm stearin (POs) and palm olein (POo). POs, the solid fraction obtained from the fractionation of PO, serves as a good hard stock and can be blended with any liquid oil. POo is the liquid fraction obtained from a similar process. On the other hand, palm kernel olein (PKOo) is the liquid oil obtained from the fractionation of palm kernel oil.

EXPERIMENTAL PROCEDURES

Materials. PO (IV, 50), POs (IV, 30), POs (IV, 44), POo (IV, 55), and PKOo (IV, 22) were obtained from local refineries. The oils were melted and mixed according to the formulations shown in Table 1. Ghee flavor (0.15 mL/kg oil) and natural red coloring (2 mL/kg oil) were added and mixed thoroughly. The products were poured into plastic tubs and kept at 5°C overnight. They were later stored at room temperature for further analyses.

Chemical analyses. Iodine values were determined first, using Wijs method as described in PORIM test methods (6) and second, were calculated based on fatty acid compositions.

*To whom correspondence should be addressed at Chemistry and Technology Division, Palm Oil Research Institute of Malaysia, P.O. Box 10 620 50720 Kuala Lumpur, Malaysia.
E-mail: aini@porim.gov.my.

TABLE 1
Formulations of Vanaspati

Oil blend ratios	Code
Palm oil/palm stearin/palm olein	
80 : 5 : 15	A1
80 : 10 : 10	A2
60 : 20 : 20	A3
40 : 30 : 30	A4
Palm oil/palm stearin/palm kernel olein	
80 : 5 : 15	B1
80 : 10 : 10	B2
60 : 20 : 20	B3
40 : 30 : 30	B4

Fatty acid composition (FAC) was determined according to the method proposed by Timms (5). Analyses were conducted by using a fused-silica capillary column, Supelco SP-2560 (Supelco, Inc., Bellefonte, PA) (100 m × 0.25 mm i.d., film thickness 0.20 μm) with a split ratio of 1:100. Flow rate was 0.8 mL He/min, oven temperature was set at 180, injector temperature at 230, and detector temperature at 240°C. Analyses were conducted under isothermal conditions on a Hewlett-Packard 6890 gas chromatograph (Avondale, PA).

Physical analyses. Appearance and consistency of vanaspati were noted by physical observation. Slip melting point (SMP) and solid fat content (SFC) were analyzed using PORIM test methods (7,8). Softening and dropping points were determined in triplicate using a Mettler FP90-thermosystem (Sonnebergstrasse, Switzerland). Texture measurements were done by the common cone penetrometric method using Seta Penetrometer–Universal Model 1700 (Stanhope Seta Ltd., Surrey, England). The cone angle used was 40° and the penetration time was 5 s. Measurements were taken at ambient temperature (23°C). Five penetration readings were taken and the results were averaged, then converted into yield values using the formula given by Haighton (9).

Crystal size of vanaspati was determined using an Olympus (Tokyo, Japan) BH-2 microscope attached to a Leica Q50 OMC data processor (Cambridge, England). X-ray diffraction analysis was used to determine the polymorphic forms of fat crystals in the samples as described previously (10). Thermal analysis was carried out with a Perkin-Elmer DSC-7 (Norwalk, CT). Program rates in all cases were 5°C/min.

Color of the vanaspati was determined 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

Iodine values of vanaspati in set A consisting of PO/POs/POo blends ranged from 51.1 to 52.4 using the Wijs method and 47.7 to 52.4 as calculated from their FAC. On the other hand, vanaspati in set B containing PO/POs/PKOo had lower IV ranging from 39.9 to 48.7 by Wijs method and 37.5 to 47.3 by calculation. The lower IV in set B was due to the FAC of PKOo which had more saturated fatty acids (i.e. C8:0, C10:0, C12:0, and C14:0) than POo present in set A samples (Table 2). These fatty acids were virtually absent in set A samples containing POo. The total saturated fatty acids in set A samples ranged from 49.1 to 53.0% while in set B it ranged from 53.9 to 62.7%. Samples in set A contained more unsaturated fatty acids, namely C18:1 and C18:2 (total unsaturated fatty acids ranged from 46.0 to 50.0%) compared to samples in set B (total unsaturated fatty acids ranged from 36.6 to 45.0%). The unsaturated fatty acids account for the higher IV of samples in set A. It was noted that IV using Wijs method produced slightly higher readings than IV calculated from the FAC. The latter method is preferred and is more reliable.

Most of the vanaspati were granular (grainy) and had a shiny appearance. Samples in set B were more granular than those in set A. This characteristic grainy structure is very important in India, Pakistan, Bangladesh, and certain Middle Eastern countries. In Malaysia however, grainy structure is not a requirement. Malaysian standards allow vanaspati to have a smooth or grainy structure, SMP between 37 to 44°C and use of flavoring and coloring substances in vanaspati is also permitted. By comparison, vanaspati produced by Malaysian manufacturers are not as granular as those produced by Indian manufacturers. Malaysian consumers are more concerned with the flavor of the product.

TABLE 2
Fatty Acid Composition and Iodine Value of Vanaspati Samples[a]

		Fatty acid composition (% wt)									Total saturated	Total unsaturated	Iodine value	
Code	Sample	C8:0	C10:0	C12:0	C14:0	C16:0	C18:0	C18:1	C18:2	Others	fatty acid	fatty acid	Wijs method	Calculated from FAC
PO/POs/POo														
A1	80:5:15	—	—	0.3	1.1	43.5	4.2	39.5	10.5	0.9	49.1	50.0	52.4	52.4
A2	80:10:10	—	—	0.3	1.1	44.5	4.1	39.5	9.5	1.0	50.0	49.0	51.9	50.9
A3	60:20:20	—	—	0.3	1.1	46.0	4.2	38.2	9.3	0.9	51.6	47.5	51.1	49.2
A4	40:30:30	—	—	0.2	1.2	47.4	4.2	37.0	9.0	1.0	53.0	46.0	51.3	47.7
PO/POs/PKOo														
B1	80:5:15	0.7	0.6	6.6	2.9	39.0	4.1	35.6	9.4	1.1	53.9	45.0	48.7	47.3
B2	80:10:10	0.5	0.4	4.5	2.4	42.1	4.0	36.4	8.6	1.1	53.9	45.0	48.1	46.7
B3	60:20:20	0.9	0.7	8.6	3.5	41.3	3.9	32.9	7.4	0.8	58.9	40.3	45.5	41.4
B4	40:30:30	1.4	1.1	12.9	4.8	38.7	3.8	30.0	6.6	0.7	62.7	36.6	39.9	37.5

[a]FAC, fatty acids composition; PO, palm oil; POs, palm stearin; POo, palm olein; PKOo, palm kernel olein.

TABLE 3
Slip Melting, Softening and Dropping Points of Vanaspati Samples Containing Hard Palm Stearin (IV 30)[a]

Sample code	Sample[a]	Slip melting point (°C)	Softening point (°C)	Dropping point (°C)
A1	PO/POs/POo 80: 5: 15	37.2	37.7	38.9
A2	PO/POs/POo 80: 10: 10	39.2	42.2	41.2
A3	PO/POs/POo 60: 20: 20	42.3	41.9	45.6
A4	PO/POs/POo 40: 30: 30	46.8	43.2	47.0
B1	PO/POs/POo 80: 5: 15	38.0	39.0	39.7
B2	PO/POs/POo 80: 10: 10	41.2	40.9	41.9
B3	PO/POs/POo 60: 20: 20	47.3	45.6	44.8
B4	PO/POs/POo 40: 30: 30	48.2	46.5	44.9
C	Commercial sample[b] (hydrogenated)	38.5	42.6	42.7

[a]IV, iodine value; for other abbreviations see Table 2.
[b]Godrej Vanaspati, manufactured by Godrej Food Limited, Mumbai, India.

In India, however, addition of flavoring or coloring material is not allowed. Indian vanaspati generally has a SMP not exceeding 39°C while in Pakistan, the SMP is pegged at 41°C maximum. In Yemen, the SMP is between 41 and 46°C.

Table 3 shows that vanaspati sample A1 recorded the lowest SMP of 37.2°C followed by sample B1 (38.0°C). SMP of these two samples were lower than SMP of the hydrogenated commercial sample (38.5°C). Decreasing the amount of PO while increasing POs in the formulations resulted in higher SMP in both sets of samples A (37.2 to 46.8°C) and B (38.0 to 48.2°C).

Softening point (or slip point) on the other hand, does not apply to samples which have been melted or otherwise modified (11). It was noted that the range for softening points was smaller than the range for SMP. Readings for dropping points for all set A samples were higher (38.9 to 47.0°C) than their SMP readings. On the other hand, two samples in set B (B3 and B4) showed lower dropping point compared to their SMP.

In set A, sample A1 showed the lowest solid fat content (SFC) profile followed by A2, A3 and A4 (Fig. 1A). With increasing amount of POs in the formulation, there was a corresponding increase in SFC of the product. Vanaspatis in set A and set B with similar PO/POs composition were compared for their SFC. It was noted that samples in set A generally showed higher SFC profiles. In set B (Fig. 1B), with increasing amount of POs in the formulation, there was a corresponding increase in SFC only at the higher temperatures (> 30°C). At 25°C and below, SFC of samples B2, B3, and B4 were very close. In fact, between 17 and 23°C, their SFC overlapped. This observation suggests that there was some eutectic interaction in the PO/POs/PKOo blends, particularly at around 20°C.

Yield values in the texture evaluation of vanaspati are shown in Table 4. Samples A1 and B1 were very soft and did not register any readings. Sample A2 was soft with yield values ranging from 61 to 82 g/cm^2. There were some fluctuations in the yield values during storage. Increasing the amount of POs in the formulations resulted in higher yield values in both sets A and B. In set A, increasing the amount of POs by 10% more than doubled the yield values (values obtained at 2 wk). It was not the case in set B at 2 wk where the yield value readings were similar for B2, B3, and B4 samples. However, at the end of 12 wk three samples differed significantly in their texture (B2 = 117, B3 = 204, B4 = 314). The results indicated that posthardening occurred during storage in sample B4 but not in sample B2.

Microscopic examination (Table 5) revealed that in set A, the mean diameters ranged from 0.286 to 0.338 Å while in set B, the mean diameters ranged from 0.349 to 0.429 Å. X-ray diffraction analyses showed that samples A2 and B2 were in the β′ polymorphic form. Both of these samples contained 80% PO, 10% POs, and 10% of either POo (A2) or PKOo (B2). β′ crystalline form is predominant in set A samples (A3 and A4) while sample A1 contained equal amounts of β′ and β. Set B samples also contained more β′ than β polymorphic form, with the exception of B4 which exhibited a β crystallinity.

Component enthalphies (ΔH) obtained from differential scanning calorimetry (DSC)–melting curves indicated that sample A3 required the least amount of energy to completely melt, followed by samples A1 and B2 (Table 6). In general, samples containing PKOo (set B) required more energy for melting than samples containing POo (set A). The commercial sample (a hydrogenated product) showed an enthalphy of

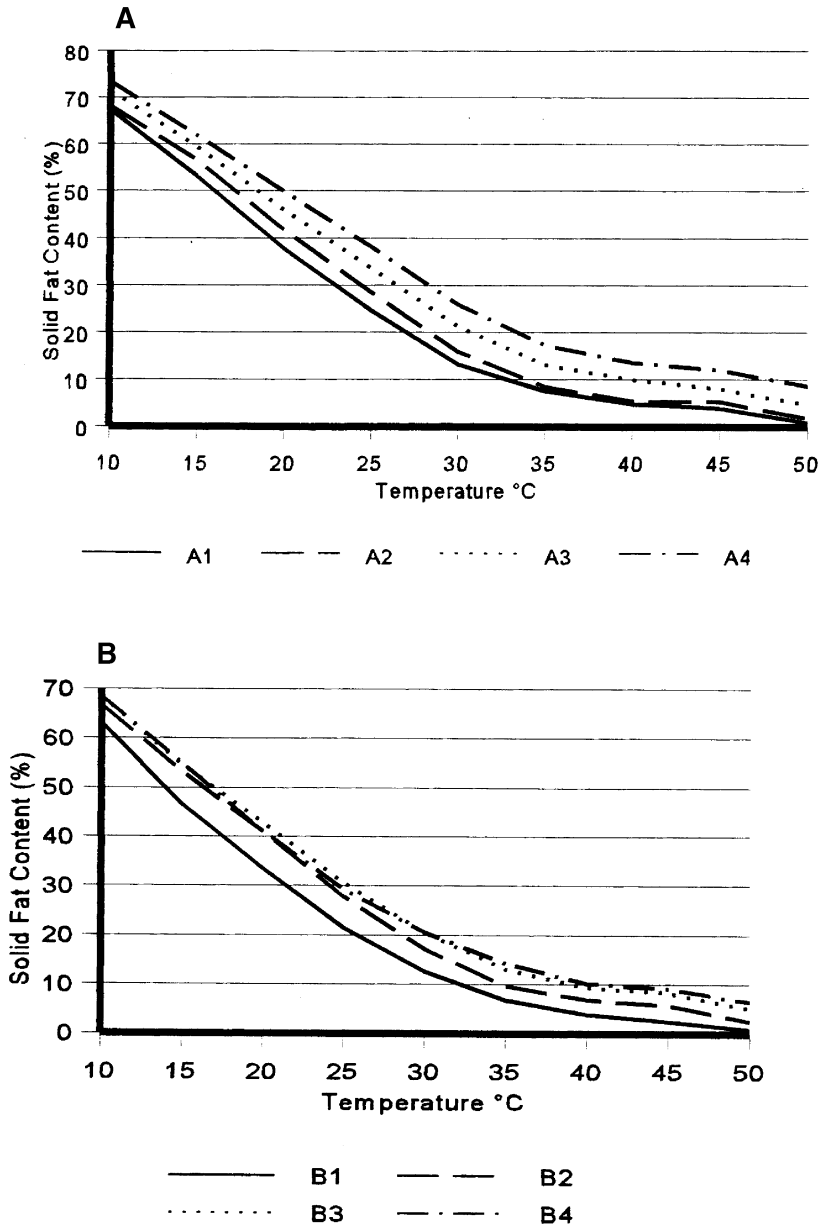

FIG. 1. Solid fat content profiles of (A) vanaspati A1 to A4 based on palm oil–palm stearin–palm olein (PO/POs/POo), and (B) vanaspati B1 to B4 based on palm oil–palm stearin–palm kernel olein (PO/POs/PKOo). Oil blend ratios, PO/POs/Poo, A1–A4: 80:5:15; 80:10:10; 60:20:20; and 40:30:30, respectively. PO/POs/PKOo, B1–B4: 80:5:15, 80:10:10; 60:20:20; and 40:30:30, respectively.

84.42 J/g, lower than that of sample B1 that showed the highest enthalpy (88.45 J/g). From DSC crystallization thermograms, it was noted that sample B2 emitted the least amount of energy among the experimental samples (–55.83 J/g), followed by sample A3 and B3. The commercial sample, however, emitted the highest amount of energy (–94.27 J/g).

In a previous DSC study it was reported that melting range and peak shape are the results of overlapping effects from composition (12). Figure 3 shows DSC–melting thermograms of POo, PO, and the vanaspati samples. DSC melting curve of POo showed a broad melting range at the lower temperature zone (0–20°C) while PO showed two main melting regions. Sample A1 showed a curve that indicated an overlap of melting ranges of PO and POo. Increasing the percentage of POs while decreasing the percentage of PO in the formulation shifted the major melting region to the right, indicating the presence of higher-melting triglycerides (samples A2, A3, B2, B3). In samples A4 and B4 that contained 40% PO and 30% POs (IV 30) it was noted that there were two peaks at the high melting region. One of the peaks was most likely due

TABLE 4
Texture of Vanaspati Samples by Cone Penetrometric Method and Expressed as Yield Values (g/cm^2)[a]

Code	Sample	Storage duration (wk) 2	4	6	8	10	12
	PO/POs/POo						
A1	80: 5: 15	Very soft	Very soft	Very soft	Very soft	Very soft	Very soft
A2	80: 10: 10	65	69	82	63	80	61
A3	60: 20: 20	221	204	229	250	146	181
A4	40: 30: 30	446	450	246	240	394	522
	PO/POs/PKOo						
B1	80: 5: 15	Very soft	Very soft	Very soft	Very soft	Very soft	Very soft
B2	80: 10: 10	130	106	114	122	138	117
B3	60: 20: 20	132	144	135	166	197	204
B4	40: 30: 30	172	174	275	275	261	314

[a]For abbreviations see Table 1.

to the high-melting triglycerides from PO and the other peak to the right, due to the higher melting triglycerides from hard POs.

Vanaspati containing PKOo (set B) showed more prominent low-melting region (B2, B3, B4) compared to set A samples. The probable reason for this is that the peak for PKOo overlaps with the peak for low-melting triglycerides of PO. Herrera and Anon (13) suggested that this kind of curve was due to the presence of triglyceride fractions with melting points too close to be differentiated under the conditions used. Numerous peaks in sample B1 suggest that they correspond to several components of different types of triglycerides with different melting points.

Table 7 shows the 'L,' 'a,' and 'b' values of the vanaspati. The 'L' value indicates lightness (whiteness). '+a' indicates redness, while '-a' value indicates greenness. '+b' value indicates yellowness. Products A1 and B1 containing 5% POs were moderately yellow with A1 having an 'L' value of 68.8, a 'b' value of 27.75 while B1 recorded an 'L' reading of 66.64 and a 'b' reading of 28.12. The rest of the vanaspati samples containing 10% or more of POs were of lighter yellow color with 'L' values ranging from 68.6 to 76.3 and 'b' values ranging from 18.6 to 20.1

The study showed that vanaspati using formulations A1, A2, A3, B1, and B2 are suitable for the Malaysian market with SMP not exceeding 44°C. Formulations A3 and B2 are recommended for Yemen market since in Yemen, the SMP is between 41 and 46°C. For countries requiring lower melting points, vanaspati manufacturers can use soft POs (IV 44) in place of hard POs (IV 30) in order to reduce the melting point of the product. These formulations are based on direct blending of PO and PO fractions and a liquid fraction from palm kernel oil. This provides an alternative to hydrogenated vanaspati. It does away with hydrogenation, thus there are no *trans* fatty acids.

TABLE 6
Component Enthalpies (ΔH) of Differential Scanning Calorimetry Melting and Crystallization Curves (J/g) of Vanaspati Samples

Sample code	ΔH melting	ΔH crystallization
A1	62.02	–63.29
A2	76.11	–63.79
A3	58.88	–56.77
A4	76.23	–68.38
B1	88.45	–87.53
B2	66.13	–55.83
B3	80.71	–68.00
B4	80.08	–68.91
C	84.42	–94.27

TABLE 5
Crystal Size (mean diameter) of Vanaspati Samples and Their Polymorphic Forms[a]

Code	Sample	Mean (Å)	S.D.	Polymorphic form
	PO/POs/POo			
A1	80: 5: 15	0.317	0.342	β′ = β
A2	80: 10: 10	0.338	0.331	β′
A3	60: 20: 20	0.286	0.219	β′>>>β
A4	40: 30: 30	0.331	0.197	β′>>β
	PO/POs/PKOo			
B1	80: 5: 15	0.371	0.587	β′<β
B2	80: 10: 10	0.349	0.360	β′
B3	60: 20: 20	0.409	0.635	β′>β
B4	40: 30: 30	0.429	0.180	β

[a]S.D., standard deviation; for other abbreviations see Table 1.

TABLE 7
Color Measurements (n = 2) in Terms of 'L,' 'a,' and 'b' Values of Vanaspati Samples[a]

Code	Samples	L	a	b
	PO/POs/POo			
A1	80: 5: 15	68.80	–5.50	27.75
A2	80: 10: 10	73.40	–5.43	19.78
A3	60: 20: 20	76.25	–5.05	19.95
A4	40: 30: 30	75.40	–5.15	20.14
	PO/POs/PKOs			
B1	80: 5: 15	66.64	–5.95	28.12
B2	80: 10: 10	71.17	–5.64	18.62
B3	60: 20: 20	68.56	–5.78	19.47
B4	40: 30: 30	71.61	–5.26	18.63

[a]For abbreviations see Table 2.

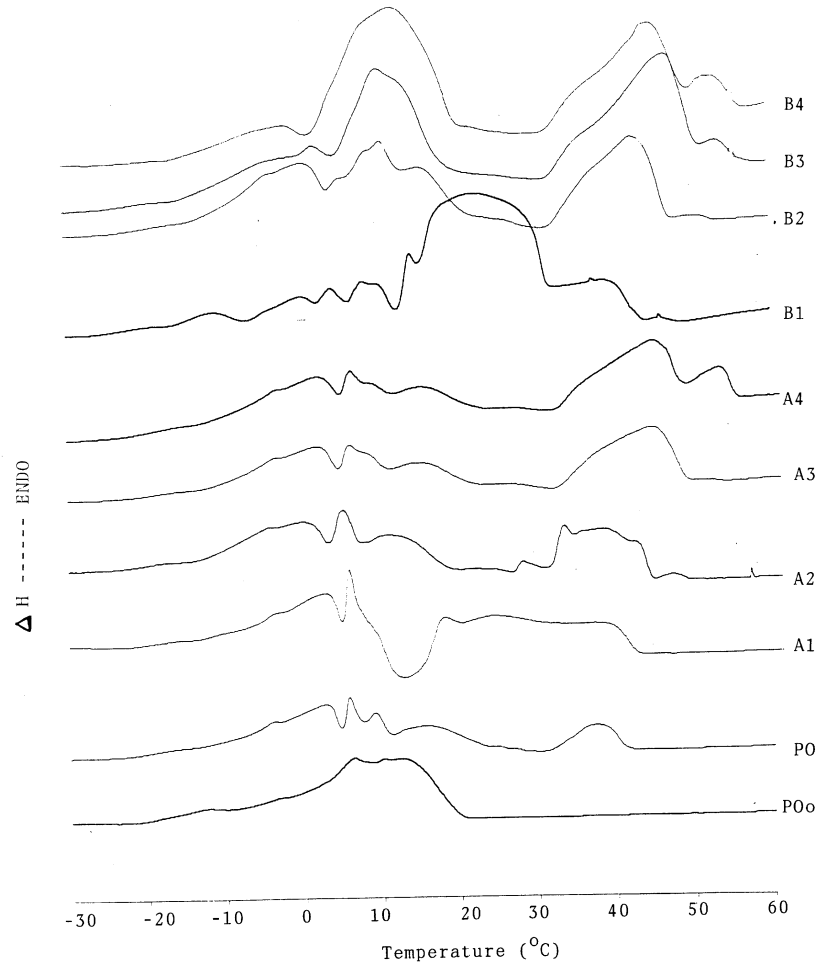

FIG. 2. Differential scanning calorimetry melting curves of POo, PO, and samples A1 to A4, B1 to B4. For description and abbreviations see Figure 1.

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