melt properties, since by definition, solids must still be present to a certain extent at ambient temperature.

Palm oil stiffened with either hardened palm oil or palm stearin can produce margarines of adequate emulsion stability, and although not essential, the incorporation of lauric oils can help to improve oral properties. Spreadability at ambient temperatures is not a problem, and posthardening effects are not a drawback in such circumstances.

Refrigerated Margarines

Requirements for refrigerated margarines are quite distinct, with a relatively low hardness at 10 C being necessary in order to achieve spreadability immediately upon removal from the refrigerator. Conversely, the product should remain stable and not too soft at ambient temperature (this is of course more of a problem in tropical countries). This is difficult to achieve with palm oil because of the posthardening effect, and although the use of interesterification can help, the corresponding increase in high-melting triglycerides leads to an undesirable tailing effect with high N_{35} values and correspondingly poor oral melt properties.

In practice this means that only limited use of interesterified palm oil, generally less than 15%, is customary, although in addition it is possible to incorporate palm olein as an alternative to other soft oils in the blend. It is also advantageous to interesterify palm oil with liquid or lauric oils, since this will reduce the trisaturated glycerides while a high asymmetrical triglyceride content is retained.

Another approach is to reduce the posthardening effect by injecting air to soften the blend. Although this may permit the use of higher percentages of palm oil, organoleptic properties become less than optimal, particularly when palm stearin is incorporated to initiate crystallization. In any case crystallization is very slow, which means that generally this technique is more appropriate for tub than for wrapped margarine.

High EFA Margarines

Palm oil has a low EFA content of only 10%. With a minimum EFA of 35% generally considered necessary to support health claims, the use of palm products is restricted. The most common application is incorporation of palm olein together with a highly polyunsaturated oil such as sunflowerseed oil.

Shortenings

Broadly similar considerations will apply to the use of palm oil in shortenings although in the absence of water the posthardening effect is substantially reduced. Hence, in tropical climates with high ambient temperatures, the use of palm/palm stearin and palm/hardened palm blends are acceptable, with softer blends being preferred in more temperate regions.

The difficult processing conditions related to the slow crystallization behavior of palm oil are again a major consideration, and much deeper cooling (a 30% increase in cooling surface per ton throughput) and increased residence time is required to minimize post crystallization.

Palm Oil Products in Cooking Fats

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ABSTRACT

Palm oil and its products are used widely, either on their own or in combination with other oils and fats, to make products for cooking and other applications such as baking, icing, filling and topping. Palm oil and its products are not only cheaper to process but also impart into the product the functional properties demanded by some of these applications. Legislation governing production and marketing of these products in some of the important countries is reviewed. The physico-chemical characteristics of products marketed in different countries are also presented. Formulations based on palm oil and its products are suggested to make low or no *trans* acid fats and high PUFA fats.

INTRODUCTION

Traditionally ghee, clarified and crystallized butter fat from buffalo and cow milks, and animal fats, especially tallow, were the main fats used in Southeast Asia for cooking foods. Because of high prices, especially of ghee, and declining production of tallow, cheaper hydrogenated vegetable oils were introduced as an alternative to ghee and tallow. These hydrogenated products were readily accepted by the consumers, especially in countries where animal fat was used as an all-purpose cooking medium.

In the beginning the fats based on only one hydrogenated oil, such as groundnut oil or cottonseed oil, were produced. As the industry became more sophisticated and due to the increased availability of a number of vegetable oils in the international market at competitive prices, the products based on blends of hydrogenated vegetable oils or animal fats were produced. It has now become normal practice to make these fats from blends of oils/fats rather than from a single oil/fat.

These products are used mainly for shallow and deep frying of foods. In some countries, however, these are formulated for such general-purpose applications as baking, filling, icing and toppings. The use of palm oil and its products in the formulation of these fats has some distinct economic and technological advantages. As such, in countries using a semi-solid product as a main source of edible fat, the export of palm oil has increased many fold during the last few years as shown in Table 1.

Cooking fats based on 100% palm oil products are now being marketed in a number of countries. In some countries, however, the level of use of palm oil products is restricted due to some technological and consumer constraints.

TABLE I

Import of Palm Oil by Selected Countries

	Year (tons)	
Country	1980	1983
India	88,589	282,920
Iraq	40,729	60,450
Jordan	–	44,517
Kuwait	–	29,997
Pakistan	100,235	326,523

TABLE II

Description and Specifications of Vegetable Ghee/Vanaspati Products in Some Countries

Country	Product	Definition	Specification	General composition	Remarks
United Arab Emirates, Abu Dhabi[a]	Vegetable ghee	Hydrogenated vegetable oil or mixture of vegetable oils	M.P.: 36-39 C β-carotene, flavor and antioxidant permitted	–	–
India[b]	Vanaspati	Hydrogenated vegetable oil meant for human consumption. No vegetable oils other than those specified are allowed. Addition of 5% unhydrogenated sesame, also synthetic vit. A mandatory	M.P.: 33-41 C Butyrorefractometer test: 2,0 red Addition of color, flavor and antioxidant permitted	CS, SBO, RSO, PO	Granular structure and no oil separation at ambient temperature (40 C)
Pakistan[c]	Vanaspati	Hydrogenated vegetable oil or mixture of vegetable oils. Addition of vit. A mandatory.	M.P.: 33-37 C ± 2 C Butyrorefractometer @ 40 C: 48.0 Addition of β-carotene, flavor and antioxidant permitted	CS, SBO, PO	Granular structure, granules dispersed in some liquid oil at ambient temperature
Singapore[d]	Vanaspati	Produced from refined edible oil and fat of vegetable origin	M.P.: 31-55 C Flavor and antioxidant permitted	PO, POS	Smooth or crystallized texture
Saudi Arabia[e]	Vegetable fat	Product that is solid or plastic at 20 C	M.P.: 20-40 C Permitted antioxidant and color added	SBO, CSO, POs, PO	Smooth crystalline texture
	Vegetable shortening	Product formed by the hydrogenation of a vegetable oil or mixture of vegetable oils with or without vegetable fats to obtain the desired consistency			
Iran[f]	Vegetable fat	Product of the process of hydrogenation of vegetable oils specified	M.P.: 30-40 C I.V. = 65-85	SBO, CSO, CO, SF, GNO, sesame	
Egypt[g]	Shortening	Vegetable or animal fats, hydrogenated oil specified, or mixture of hydrogenated vegetable oils and animal fat	M.P.: max. 40 C I.V. = 60-80	CSO, CSO, + animal fat, SBO	–
Iraq[h]	Hydrogenated fat	Hydrogenated CSO, pure or mixed with other hydrogenated vegetable oils	M.P.: 40 C max. I.V. = 60-80	CSO, PO, SBO	–
Turkey[i]	Shortening	–	M.P.: Household, max. 36 C Industrial, max. 45 C	CSO, SBO	
Kuwait[j]	Hydrogenenated vegetable oil	Vegetable oil treated with hydrogen	M.P.: 36-40 C	SBO, PO POS, COS	
	Vanaspati ghee	Mixture of vegetable oils hydrogenated partially or completely. Hydrogenated and nonhydrogenated animal fats (except lard) may be added	M.P.: 36-40 C		

[a] U.A.E. and Abu Dhabi standard specifications of vegetable ghee agreed on 25.5.1980.

[b] Vegetable Oil Products (standards of quality). Order dated 30th May 1975 with amendments up to 1st September 1978. Issued by Ministry of Agriculture and Irrigation (Department of Foods). Government of India.

[c] Specifications for Vanaspati. Pakistan Standard Institution Specification No. 221-1962.

[d] Specifications for Vanaspati. Singapore Standards 197:1976 issued by Singapore Institute of Standards and Industrial Research, Singapore.

[e] Saudi Arabian Standards No. SSA 71/1397 H(1977). "Edible and Vegetable Oils and Fats."

[f] Specifications for Vegetable Fats. Standard No. 144-1345 issued by Ministry of Commerce.

[g] Private communication.

[h] General Specifications of Edible Oils and Fats. People of Iraq Standards Specifications No. 451.

[i] Specifications for Margarine (Vegetable origin). Turkish Standards No. TS 2812/Haziran. 1977.

[j] Specifications for Vegetable Oils and Vegetable Ghee - Kuwaiti Standards.

LEGISLATION AND PRODUCT DESCRIPTION

Cooking fats are marketed under different descriptions, such as shortening, vegetable or imitation ghee, hardened vegetable oil and artificial butter. The legal description of these products and the consumer expectation about their physical characteristics also vary from country to country. In a number of countries the formulation, production and marketing of these fats are controlled by law.

Table II gives descriptions and specifications of the products used as cooking fats in some countries. Most countries allow only the use of vegetable oils/fats except Egypt and Kuwait, where the use of animal fat is also permitted. Permissible melting points of the products range from 33-55 C. The fats have been defined as "products of hydrogenation" by all the countries except Singapore and Saudi Arabia.

TABLE III

Characteristics of Some Fats from Several Countries

Country	Product description	Iodine value	Slip melting point (° C)	*trans* acids (% trielaidin)	Solid fat content (%) 20 C	25 C	30 C	35 C	40 C	Appearance
Australia	Vegetable shortening	57.0	35.8	4.7	28.6	16.6	10.2	5.1	–	Smooth
Bangladesh	Vanaspati	68.8	41.0	42.2	52.0	41.4	26.4	14.4	6.1	Granular
Egypt	Vegetable shortening	71.8	40.0	25.4	44.3	34.1	23.0	13.2	5.2	Granular
	Vegetable shortening	89.9	37.0	11.6	18.8	12.0	7.8	4.7	1.7	Granular
	Pure vegetable palm oil	52.2	37.0	–	26.4	15.1	10.2	6.9	5.8	Smooth
Holland	Vegetable shortening	67.0	37.0	44.9	28.6	16.6	10.2	5.1	–	Smooth
	Pure vegetable ghee	53.3	37.2	–	32.3	22.4	14.3	7.2	3.1	Smooth
India	Vanaspati	76.8	35.5	53.0	52.6	37.1	20.7	6.8	1.3	Granular
Japan	Vegetable shortening	60.7	36.6	N.D.	37.5	24.5	12.7	7.6	–	Smooth
Kenya	Cooking fat	49.6	41.1	–	32.0	21.2	15.7	11.2	7.4	Smooth
Kuwait	Shortening	60.4	42.0	N.D.	28.4	20.3	14.7	12.3	9.5	Smooth
Malaysia	Shortening	49.1	41.0	–	33.7	23.4	15.7	12.8	9.7	Smooth
New Zealand	Shortening	48.3	38.9	–	29.9	21.8	14.2	9.8	3.2	Smooth
Pakistan	Vanaspati	69.0	36.6	25.7	33.2	22.1	14.0	6.3	4.6	Granular
Saudi Arabia	Ghee	52.1	37.5	–	27.5	19.0	13.0	10.6	6.6	Granular
Turkey	Shortening	95.5	34.9	23.5	25.4	17.8	9.7	9.7	3.5	Smooth
	Shortening	75.9	34.0	N.D.	22.9	16.1	6.4	2.0	–	Smooth
United Arab Emirates	Ghee	76.4	39.5	22.7	31.5	24.1	17.1	10.6	5.9	Granular
United Kingdom	Cooking fat	71.0	35.8	33.5	34.6	24.9	15.1	7.0	3.0	Smooth
	Cooking fat	70.8	35.3	34.7	35.7	25.1	14.9	7.3	2.2	Smooth
	Cooking fat	51.3	39.4	–	31.9	20.7	15.1	11.7	9.0	Smooth
U.S.A.	Shortening for frying and baking	84.4	43.0	N.D.	27.1	21.8	18.8	13.3	9.6	Smooth

N.D. = not determined.

TABLE IV

Hydrogenation of Palm Oil (PO) and Palm Olein (POo)

	Palm oil		Palm olein			
Parameter	Po	HPo	POo	HPOo	HPOo	HPOo
Melting point (° C)	36.9	40.3	22.5	30.9	35.7	38.7
Iodine value	54	51	58	56	54	53
trans value (%)	0	13	0	9	18	25
SFC (%) at						
10 C	52	75	37	57	72	84
15 C	39	65	17	42	59	73
20 C	25	52	3	27	44	61
25 C	16	39	0	15	30	47
30 C	10	25	0	7	18	30
35 C	7	17	0	2	8	17
37 C	6	12	0	0	4	10
40 C	5	7	0	0	0	3

TABLE V

Palm Oil (PO) and Palm Stearin (POs) Blends

Composition (%)		Solid fat content					Melting point (° C)
PO	POs	20 C	25 C	30 C	35 C	40 C	
100	0	23.0	16.0	9.8	6.9	3.1	36.3
90	10	26.2	16.9	11.9	9.4	5.6	38.3
80	20	28.2	18.5	12.2	10.1	6.2	39.0
70	30	28.7	20.9	13.1	9.5	5.9	39.5
60	40	30.0	21.7	15.3	10.5	6.8	40.2
50	50	32.4	23.8	16.5	11.7	8.0	40.7
40	60	34.0	24.7	17.4	13.4	9.5	41.5
30	70	36.4	25.1	18.2	15.1	11.5	42.0
20	80	38.3	26.7	20.0	15.9	12.5	42.7
10	90	40.1	28.9	20.8	17.1	12.5	43.6
0	100	39.9	29.7	21.4	16.5	12.5	44.2

PO: I.V. 52.8
POs: I.V. 46.0

PRODUCT FORMULATION

Table III gives some physico-chemical characteristics of fats from selected countries. The melting points of the products range from 34-44 C. Most of these products were based on hydrogenated feedstock as was evident from their *trans* values which ranged from 4.7-53.0%. A number of samples are based on 100% unhydrogenated palm oil products.

The products analyzed can be classified, based on their appearance, into two categories: products having smooth texture and products having granular texture.

Smooth Products

Products with smooth texture are obtained by cooling the oil/blend on a scraped-surface heat exchanger. These crystallized products are packed either as bricks or in containers.

Palm oil, hydrogenated palm oil, hydrogenated palm olein and blends of palm oil and palm stearin, all crystallize in β'-crystalline form. These fats, when crystallized rapidly on a scraped-surface heat exchanger, give products of smooth consistency. Iodine value, melting point and solid fat content of these fats are shown in Tables IV and V.

Palm oil products or the blends of PO:POs of desired consistency and melting point can be chosen and texturized on a scraped-surface heat exchanger to give products having smooth consistency. Higher amounts of unhydrogenated palm oil in the formulation, especially in products packed as bricks in wrappers, adversely affect the packability of the products, due to the slow crystallization of palm oil. The problem of packability, however, can be overcome by incorporating in the heat exchanger an extra B unit between the two A units and by seeding the incoming oil feedstock, before it enters the first A unit, with the part of crystallized sample from the second B unit. Deep chilling the product without using the B unit would also give product stiff enough for trouble free packing.

Hydrogenated palm oil products and also blends of palm oil and palm stearin do not have the problem of slow crystallization. The products made wholly or partly from them can be packed into bricks with no problem.

Granular Products

In some countries, especially in India, Pakistan and Bangladesh, granularity is considered an important criterion of quality and purity of vanaspati, an all-purpose cooking fat used in these countries. These products are prepared by partial hydrogenation of one or more vegetable oils. To achieve granular texture the oil/blend packed in containers is cooled slowly in a cold room maintained at 15 C with adequate cold air circulation.

It is alleged that palm oil products, when used in higher amounts, cause:

- increase in melting point of the products beyond the legal maxima,
- separation into liquid and solid phase on slow cooling, and
- poor consistency and slimy texture products due to formation of fine crystals instead of large granular.

Melting Point. In determining melting point (softening point) by AOCS method no. Cc 3-25, the residual crystals that remain in the capillary are either pure crystals of high melting-point glycerides or mixed crystals of other intermediate melting-point glycerides. The high-melting glycerides are solubilized in them as solid solution. Such mixed crystals generally have lower melting points.

In palm oil high-melting glycerides are PPP (m.pt. 65.5 C). Palm oil at its melting point (about 37 C), has 3-4% solids. These are not pure PPP but are composed of a mixture of PPP and other intermediate melting-point glycerides such as POP and PPO which are also present in palm oil. These mixed crystals therefore melt completely at around 42 C, well below the melting point of PPP.

Figure 1 shows the relationship between C_{48} (mostly PPP in palm oil) and slip melting point in interesterified blends of palm oil products and liquid vegetable oils. The correlation coefficient (r) is 0.84, which would become even more significant when corrected for other trisaturates (SSS) present in the blends.

Decrease in the melting point is more in blends of palm oil products and hydrogenated liquid oils than in blends of palm oil products and unhydrogenated liquid vegetable oil as shown in Figure 2. This is due to higher solubility of PPP in elaidoglycerides than its solubility in *cis*-unsaturated glycerides. Palm stearin hydrogenated under the conditions of high *trans* selectivity (Si) also has slightly lower melting point than of palm stearin before hydrogenation, whereas the SFC of the hydrogenated palm stearin are significantly higher. This is shown in Table VI. In order to get sufficient decrease in the melting point of palm oil products, they should be blended with fats containing higher amounts of elaidoglycerides.

Figure 3 shows a ternary diagram of the composition of Indian and Pakistani vanaspati samples analyzed by the Palm Oil Research Institute of Malaysia (4). The Indian products consist of higher *trans* acids and lower saturated and *cis*-unsaturated acids to meet the requirements of consistency and melting point required in India. These requirements have prescribed the product to a very limited area of formulation. If the product composition is moved more toward saturated acid contents than this, it will significantly increase the melting point of the product. The consistency of the product will be adversely affected if the composition is moved toward a more *cis*-unsaturated acid content.

The level of palm oil products can be reasonably increased in the 37 C melting point formulation if the hydrogenated liquid oils used in the blends have high *trans*-acid contents, low *cis*-unsaturated and saturated acid contents. Liquid vegetable oils used in the formulation should therefore be hydrogenated under conditions promoting higher monoene

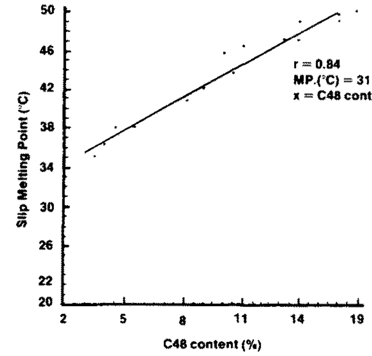

FIG. 1. Relationship between C_{48} and slip melting point.

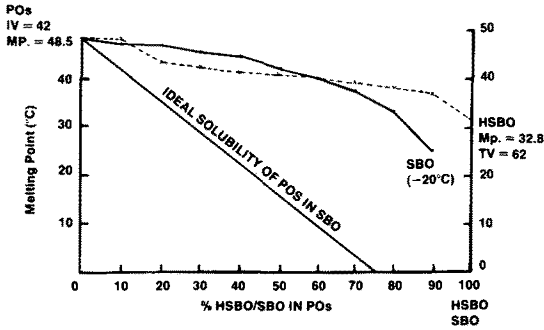

FIG. 2. Melting points of blends of palm stearin (POs) and hydrogenated (HSBO) and unhydrogenated soybean oil (SBO).

TABLE VI

Hydrogenation of Palm Stearin under the Conditions of High *trans*-Selectivity (S_i)

Parameter	Hydrogenation time (min)		
	0	90	120
Iodine value	45.2	38.0	36.8
trans value (%)	0	20.1	25.6
Slip melting point (° C)	49.6	45.8	46.0
SFC (%) at			
20 C	49.0	84.7	90.6
25 C	38.4	76.5	83.7
30 C	27.9	64.5	74.8
35 C	23.3	51.8	62.0
37 C	22.1	46.0	55.0
40 C	19.0	37.1	46.0

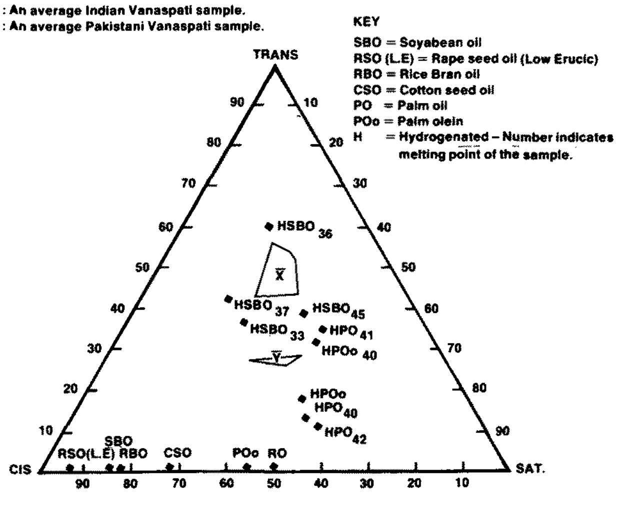

FIG. 3. Composition diagram of vanaspati product—a tertiary system consisting of saturated, *trans* and *cis*-unsaturated fatty acids.

TABLE VII

Suitable Blends for 37 C Vanaspati Formulation (Indian and Pakistani Samples Included for Comparison)

Blend composition	Melting point (° C)	SFC (%) 10 C	15 C	20 C	25 C	30 C	35 C	37 C	40 C
50% HPOo (m. pt. 42 C), 50% HSBO (m. pt. 32 C)	37	85	78	67	51	31	15	7	0
30% HPOo (m. pt. 42 C), 70% PO	37	66.0	57	45	32	19	12	8	0
50% HSBO (m. pt. 36 C), 50% HPO (m. pt. 42 C)	36	78	68	53	37	20	10	7	1
70% HSBO (m. pt. 36 C), 30% PO	35	72	62	46	26	14	5	3	0
Indian vanaspati	36	75	65	52	37	21	7	0	0
Pakistani vanaspati	37	57	45	33	22	14	6	5.5	5

selectivity (S_1) and *trans*-selectivity (S_i).

Some of the suggested blends for 37 C vanaspati formulation are given in Table VIII. Since the melting point of vanaspati in India was increased from 37 C to 41 C in 1983 (2), an acceptable vanaspati can now be made with 100% palm oil products.

Phase Separation. Phase separation is a function not only of the type and size of crystals in the products but also of solid fat content of the oil/blend at ambient temperatures. These two are again manifestations of the properties of individual glycerides and their mutual solubility.

Separation of phases occurs when the crystal surface area is insufficient to bind the liquid phase of the fat. Smaller crystals are greater in surface area. This enables the liquid phase to adhere more easily and effectively to the crystal surface, thus reducing the risk of oiling out. Singhal et al. (6) reported that oil separation will occur markedly in samples of coarse-grained vanaspati whether or not they contained palm oil. When the products are made to a smooth grainless state, the oil separation is negligible. Palm oil, when seeded with small amount of high melting crystals and cooled slowly, solidifies as a homogenous mass, and no separation occurs at ambient temperature. Seeding creates a large number of nuclei, which grow and generate crystals with enough surface area to bind the liquid, thus inhibiting phase separation.

Phase separation is also associated with melting points of the products. Due to increase in the melting point to 41 C in India, this problem (at least in this country) does not exist any more.

Product Consistency. The size and the type of crystals (granules) formed depend on the way the blends are cooled. Fast cooling results in fine crystals, whereas slow cooling causes crystals to grow, resulting in the formation of granules. Graininess can be defined as spherulite formation due to specific recrystallization around nuceli, giving hard spheres up to about 0.5 mm diameter.

It has been suggested that the graininess of margarine products is associated with asymmetrical/symmetrical triglyceride ratio. Graininess of the product increases with an increase in this ratio. It follows that the fat blends containing higher proportion of asymmetrical triglycerides will have a granular consistency on cooling.

Palm oil has a higher amount of symmetrical triglycerides, and as such the ratio of asymmetrical-symmetrical glycerides in it is low. This is increased by blending palm oil products with hydrogenated liquid oils that have higher amounts of asymmetrical elaidoglycerides, or by interesterification. Trimyristin (MMM) glycerides also promote graininess. Interesterification of palm oil products with lauric oil will also promote graininess in the products. However, to inhibit phase separation, the blend must also have enough solids or crystal surface area to bind the liquid phase.

LOW *TRANS* AND NO *TRANS* PRODUCTS

Cooking fats are semi-solid at ambient temperatures, and as such liquid vegetable oils when used in their formulation have to be hydrogenated. Hydrogenation of soybean oil under conditions of high *trans*-selectivity (S_i), as is the common practice in the production of granular products, results in the formation of not only high total *trans* acids but of significant amounts of 18:2 t,t acid. No 18:2 t,t acid is produced when the oil is hydrogenated under conditions of low *trans*-selectivity using an active nickel catalyst.

By contrast to its 18:2 c,c isomer, 18:2 t,t isomer is not only recognized as devoid of EFA activity but its very presence appreciably inhibit the elongation of 18:2 c,c into C20:4 (3). This *trans* acid has also been associated with elevated serum lipid level and with changes in kidney weight (5).

Indian vanaspati, on the average, has about 5.0% 18:2 t,t acid (4) which is five times the minimum recommended by the ad hoc committee on the composition of special margarine in Canada (1). Unhydrogenated or lightly hydrogenated palm oil products, especially palm stearin, can be interesterified with liquid vegetable oils to produce no *trans* and low *trans* acid products.

Directed or randomly interesterified palm oil product gives products with increased melting points and solid fat contents—except in case of palm stearin where there is a slight decrease in its melting point, as shown in Table VIII.

Interesterified palm oil and palm olein have higher SFC than the ones before interesterification. Since their consist-

TABLE VIII

Interesterification of Palm Oil Products

Parameter	Palm oil (IV=55) Before	Palm oil (IV=55) After	Palm olein (IV=60) Before	Palm olein (IV=60) After	Palm stearin (IV=45) Before	Palm stearin (IV=45) After
Melting point (° C)	33	43.5	20.8	40.6	49.6	48.3
SFC (%) at						
20 C	20	33	–	24	49	52
25 C	12	23	–	16	38	42
30 C	7	17	–	11	28	31
35 C	3	12	–	8	23	23
37 C	2	10	–	7	22	20
40 C	2	9	–	5	19	18

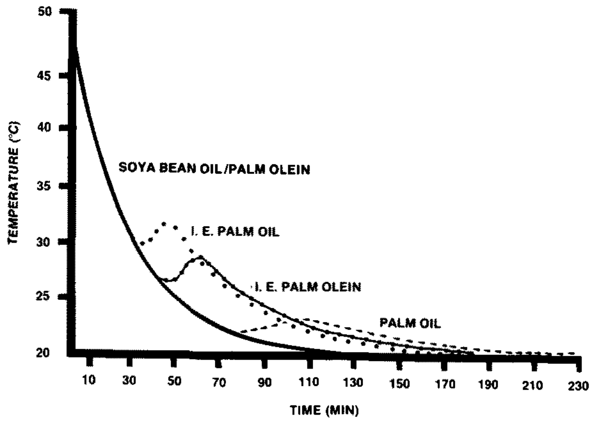

FIG. 4. Pichard cooling curves of palm oil and palm olein before and after interesterification.

TABLE IX

Interesterified Blends Suitable for Making Cooking Fats

Blend composition (%)	70% POs 30% SBO	60% POs 40% CSO	70% POs 30+ RSO (LE)
Melting point (° C)	41	42	40
I.V.	71	70	65
SFC (%) at			
20 C	22	23	22
25 C	16	16	15
30 C	11	12	10
35 C	8	8	8
37 C	6	8	6
40 C	5	5	4
Total saturated acid (%)	35.9	46.1	43.1
Total monounsaturated acid (%)	22.8	27.2	41.2
Total polyunsaturated acid (%)	41.3	26.7	15.6
trans acid (%)	–	–	–

TABLE X

Hydrogenated Palm Stearin

Parameter	Sample	
	POs	HPO
Melting point (° C)	49.6	46.0
Iodine value	45	37
SFC (%) at		
20 C	49	91
25 C	38	84
30 C	28	75
35 C	23	62
37 C	22	55
40 C	19	46
Total saturated acids (%)	56.7	57.9
Total monounsaturated acids (%)	35.0	41.8
Total polyunsaturated acids (%)	8.3	0.3
Total *trans* acid (%)	–	25.6
18:1, tt (%)	–	25.6
18:2tt (%)	–	–
18:2 t,c (%)	–	–

TABLE XI

Interesterified Blends of Palm Kernel Oil Products

Parameter	Blend composition			
	90% PO 10% PKO	80% POs 20% PKO	70% POs 30% PKO	70% POs 30% PK olein
Melting point (° C)	37	39.5	37	37.5
SFC (%) at				
20 C	29	45	38	35
25 C	21	33	27	24
30 C	13	23	17	15
35 C	8	14	8	8
37.5 C	6	10	5	5
40 C	4	5	0	0

ency is higher, there is also no oil separation at ambient temperatures. After interesterification, there is also an increase in their asymmetrical glyceride content and as such the products based on them will also have granular structure. Interesterified products also have improved crystallization rates, as shown in Figure 4. These fats will therefore have no packability problem. Unfortunately, their melting points, especially that of interesterified palm oil, are higher than the permitted maximum in a number of countries (Table I).

Palm stearin can also be interesterified with liquid vegetable oils. To achieve 37 C melting point in the final product the blend, before interesterification, must have less than 35% saturated fatty acids. Higher levels of saturated acids result in products having melting points higher than 37 C. Unfortunately, the products with less than 35% saturated acids and no *trans* acids have lower consistency, and as a result there is phase separation in granular products at ambient temperatures. Such interesterified blends, however, are quite suitable for smooth products and 41 C melting point granular products. Some of the physico-chemical characteristics of interesterified blend are included in Table IX.

The only way to improve the consistency of these products without increasing the melting point is to introduce some *trans* acid into the composition. Palm stearin can be hydrogenated under the conditions of high *trans* selectivity (S_i) until all C18:2 acids are converted to C18:1 acids. Physico-chemical characteristics of such hydrogenated palm stearin are given in Table X.

This hydrogenated palm stearin can be interesterified with 20-50% liquid vegetable oils to give products having low *trans* acids (less than 20%), no 18:2 t,t acid and high *cis,cis*-polyunsaturated fatty acids.

Interesterification of palm oil or palm stearin with lauric oils markedly decreases the level of symmetrical glycerides in the blend. There is a significant drop in melting point, and the SFC tail at body temperature is also considerably shortened giving improved melting in the mouth. Products with melting point of 37 C and having consistency similar to vanaspati can be made by interesterifying palm oil or palm stearin with palm kernel olein or palm kernel oil. Characteristics of such promising blends are shown in Table XI.

In Malaysia palm oil is fractionated into a stearin fraction and an olein fraction. The stearin fraction, though it has a consistency similar to vanaspati, has a very high melting point. The olein fraction, on the other hand, is liquid at ambient temperature. None of these two fractions can be marketed as cooking fat. However, a mid-fraction with right consistency and acceptable melting point can be produced by fractionating either of the two primary fractions. Economically, it will be more attractive to refractionate the stearin fraction to produce these products.

Table XII gives melting points and SFC of some of the mid-fractions produced by Malaysian refiners. Some of these fractions can be used directly or blended in higher amounts with hydrogenated liquid oils to produce vanaspati.

PROCESSING COST

The processing steps required for formulations based on dif-

TABLE XII

Palm-Mid-Fractions Produced by Malaysian Refiners

	Code					
Parameter	627	642	664	799	800	1028
Slip melting point (° C)	32.6	37.3	28.7	25.8	32.0	32.5
Iodine value	40.9	46.7	48.9	52.1	52.7	35.7
Stabilized SFC (%) at						
20 C	63.8	26.2	33.8	27.0	20.3	79.6
25 C	39.4	18.9	12.7	5.5	11.0	65.4
30 C	19.8	15.0	5.1	2.8	7.7	35.2
35 C	5.2	10.0	–	–	3.4	3.4
37 C	3.1	8.1	–	–	0.5	–
40 C	–	5.9	–	–	–	–

ferent types of oils/fats are given in Table XIII. Products based on single hydrogenated vegetable oil involve seven steps. The process traditionally used in India and Pakistan involves thirteen steps. However, if RBD palm oil is blended without hydrogenation the number of steps can be reduced to ten. Deodorization time will also be reduced as RBD palm oil is already deodorized. There will also be savings in the cost of catalyst and bleaching earth. On the other hand, if 100% RBD palm oil is packed, only three processing steps will be involved.

In the hydrogenation process used in making vanaspati products the major cost element, apart from the cost of catalyst, is the cost of hydrogen. It is difficult to obtain valid costings for the operation practiced worldwide. However, one relationship is constant worldwide—power requirements for the production of hydrogen. Thus, by comparing the power requirements for hydrogen production and applying applicable power tariffs in the area under consideration, a reasonable comparison of costs is obtained. Table XIV shows the power requirements for the production of hydrogen to reduce the I.V. of different oil to give products of 36 C.

It is clear that SBO, CSO and RSO oils commonly used in the production of these fats have significantly higher hydrogen consumption than any of the palm oil products. In most of the countries that use these products as the main source of edible fat, electricity is in short supply. These countries not only use expensive raw materials in their formulations, but they use oils that are most expensive to process and have higher demand for energy supply.

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TABLE XIII

Processing Steps Involved in the Production of Cooking Fats

	Code						
Unit operations	A	B	C	D	E	F	G
Preneutralization	+	+	+	+			
Prebleaching	+	+	+	+	+		
Hydrogenation	+	+ +	+	+	+		
Postneutralization	+	+ +	+	+	+		
Postbleaching	+	+ +	+	+	+	+	+[a]
Deodorization	 +	+ +	+[a] +	+[a] +	+[a] +	+[a] +[b]	 +[b]
Blending		+ +	+[b] +	+[b] +	+[b] +	+[b] +	
Cooling	+	+	+	+	+	+	+
Total	7	13	10	10	9	6	3

[a] Only neutral earth is used clarifying the oil.

[b] Duration is shorter because the oil is already deodorized.

Raw material:
(A) Hydrogenated vegetable oil
(B) Hydrogenated vegetable oil + hydrogenated neutralized palm oil
(C) Hydrogenated vegetable oil + RBD palm oil
(D) Hydrogenated vegetable oil + RBD palm stearin
(E) Hydrogenated neutralized palm olein + RBD palm oil
(F) RBD palm oil + RBD palm stearin
(G) RBD palm oil

TABLE XIV

Power Requirements

	I.V.				
Oil	Initial	Final	Drop	Slip melting point (°C)	Power requirement (KWH)
Soybean oil	130	70	60	36	348
Rapeseed oil	102	69	33	36	192
Sunflower oil	136	75	61	36	354
Groundnut oil	92	66	26	36	151
Cottonseed oil	108	63	45	36	261
Palm oil	55	51	4	40.3	23
Palm olein	58	54	4	36	23
Palm oil	55	55	–	36	–