Composition of Oil

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ABSTRACT

International trade in palm oil has increased considerably over the last ten years, and so too has the trade in processed palm oil products, especially palm fractions. It is important to establish reliable purity criteria for palm oil, not only because of the commercial need to verify oil authenticity, but also to comply with foodstuff labelling legislation in many countries.

Palm kernel and coconut oils both contain about 47% lauric acid. This gives the oils close similarities in physical and chemical properties. The oils do differ, however, and it is important to be able to distinguish between them.

Purity problems can arise as a result of commingling of oils with one another, or as a result of fractionation perhaps coupled with subsequent blending. A research program jointly funded by the (U.K.) Ministry of Agriculture, Fisheries and Foods, the Federation of Oils, Fats & Seeds Associations Ltd (FOSFA International), and the Leatherhead Food RA, was established to study purity characteristics of the major edible vegetable oils.

Forty-seven samples of crude palm oil were obtained from reliable sources, often plantation managers, together with five samples of palm olein and eight samples of palm stearin. Fifty-four palm kernel and 23 coconut oils were obtained in the laboratory from seed samples of known geographical origins and authenticities.

These oil samples were analyzed for fatty acid, triglyceride, sterol and tocopherol compositions; the melting properties were also determined, and in the case of palm oil the compositions of the acids at the triglyceride 2-positions were measured. Compositional ranges will be presented for the different geographical production areas in each case and related to existing data, e.g., of PORIM and Codex. An initial statistical analysis of the results has shown that a combination of values from the carbon number analysis differentiates palm kernel and coconut oils, and can be used to decide on the proportion of each in a blend. In the case of palm oil samples suspected to be contaminated with palm fractions, it was found useful to plot melting point against iodine value, and to compute the product of the C48 triglyceride content and the palmitic acid enrichment factor.

INTRODUCTION

A knowledge of vegetable oil characteristics is important not only with regard to the commercial importance of establishing edible oil authenticity, but also with regard to the need to comply with foodstuff labelling legislation in many countries. In addition, Government departments and nutritionists need up-to-date information about the compositions of foods when considering national diets. As already reported (1) these factors led to the joint funding of the present study of vegetable oil compositions by the (U.K.) Ministry of Agriculture Fisheries and Foods, the Federation of Oils Fats and Seeds Associations Ltd (FOSFA International), and the Leatherhead Food RA.

Almost 400 oil samples have now been examined, representing authentic samples of palm, peanut, sunflower seed, maize germ, soybean, rapeseed, palm kernel and coconut oils. The samples were analyzed for fatty acid, triglyceride, sterol and tocopherol compositions; in many cases the compositions of the fatty acids at the triglyceride 2-positions were determined. The melting properties of the semisolid fats were also evaluated. Ranges and mean values were computed for each of these products, and where appropriate related to the geographical origin or agricultural strain. Correlations were also sought between the different parameters in an effort to establish new purity criteria.

Adulteration has been a problem in the oil and fat trade for a long time (2). It is sometimes deliberate, sometimes accidental. Indeed, accidental contamination is hard to avoid in modern bulk handling installations. However, it is sometimes remarked that it is the expensive oil that usually gets contaminated with the cheaper one. For these reasons tests were developed long ago for the characterization of oils and fats. These include determination of iodine value, to give a measure of an oil's unsaturation, and of saponification value, which gives a measure of the average molecular weight of the constituent fatty acids. Some tests are so useful that they are used widely today, and are part of the common language of our nontechnical colleagues who buy, sell and trade the oils. We now have more sophisticated methods of analysis available, but should not overlook the utility of some of the more traditional tests in detecting the presence of specific oils in suspected blends. The Halphen test (3,4), for instance, is claimed (2) to detect as little as 0.1% of crude cottonseed oil, or stearine, in oil mixtures. Oils containing as little as 1% sesame oil will give a crimson color in the Baudouin (5) or modified Villavechia test (6); while the Fitelson (or modified Lieberman-Burchard) test (7) gives a positive indication of the presence of teaseed oil or shea butter (8). Other traditional tests may be laborious and no longer of value, or even misleading, especially when determination of a fatty acid composition is required. The Reichert-Polenske-Kirchner test (9) gives a measure of (a) the water-soluble volatile acid content, (b) the water-insoluble fatty acid content, and (c) the butyric and valeric acid contents, but it has largely been replaced by accurate determination of the fatty acid composition of a fat by gas liquid chromatography (GLC) of the derived methyl esters. The Evers (10) and modified Renard (11) tests claim to be able to detect as little as 5-10% peanut oil in a mixture, and are used as a criterion of purity for peanut oil itself (12). Together with the Bellier index (13,14), they rely on the crystallization characteristics of arachidic, behenic and lignoceric acids. In the authors' view these tests are of limited reliability due to the fact that the fractional crystallization of arachidic acid from a mixture of other solids is probably affected by the amount and type of other acids present (15). Another complicating factor with these tests is that newer agricultural strains, and cultivation in different geographical areas, can lead to different levels of both saturated and unsaturated fatty acids. Perhaps for these reasons the AOCS does not list these three tests in its Official and Tentative Methods. In any case, a far more reliable method for the determination of arachidic, behenic and lignoceric acids is by GLC analysis.

A balance must therefore be kept between the need to update and improve analytical techniques, and the need to retain those traditional tests that still have a useful function.

More recent work on oil authenticity has concentrated on the determination of fatty acid composition by GLC. Many papers have appeared on this topic and the Codex Committee on Fats and Oils, which was established by the joint FAO/WHO Codex Alimentarius Commission, published fatty acid composition ranges for typical commercial samples of bona fide fats and oils. However, it was recognized that these ranges were not definitive, and work therefore continued on this topic. Spencer, Kwolek & Princen (16) devised a simple graphical procedure for the interpretation of fatty acid composition data of unmodified oils. They also calculated the saponification value, iodine value and refractive index of each oil examined, and showed that in all cases except one the calculated values lay within the appropriate Codex range. However, only pure oils were

studied, and the influence of minor amounts of other oils was not considered. Other workers (17,18) have studied the influence of seed maturity on fatty acid composition.

As oils and fats are natural products, their compositions vary within certain ranges, and even when these ranges are positively identified it is nevertheless possible for an oil to be adulterated or contaminated with another, and yet have a composition within the specified range. Adulteration is, of course, increasingly difficult to detect when the contaminant has a composition approaching that of the original oil. Various additional tests have therefore been devised. Itoh, Tamura & Matsumoto, (19,20) and Kornfeldt & Croon, (21) have determined oil sterol compositions. This is an attractive approach as it helps resolve many issues where a fatty acid composition is indecisive. The Codex Committee on Fats and Oils discussed at its tenth session a list of sterol ranges for 15 oils determined with each of two different types of stationary phase in the GLC stage of the analysis (OV-17 versus SE30, JXR or SE52 (22). Nevertheless, Padley & Timms (23) claim that sterol levels can be lowered by a variety of processes such as solvent crystallization, bleaching and deodorization, thus reducing the reliability of sterol analysis for the detection of adulteration. Kochhar (24) has reviewed the influence of processing on sterol compositions. Padley & Timms (23) therefore developed a sensitive method for the detection of foreign fats in cocoa butter, or chocolate, which relies on the analysis of the triglycerides according to their carbon number (molecular weight) classification by high-temperature GLC. This method is particularly useful with cocoa butter as it has a composition comprising three main triglycerides (POP, POS and SOS) of different molecular weights. Although the technique can be applied to the analysis of other oils, it is often less searching. Many of the liquid oils, for instance, differ from one another mainly on the basis of unsaturation, rather than the chain length (i.e., molecular weight) of their fatty acids.

More recent work by Taylor & Barnes (25) drew attention to the analysis of tocopherols and tocotrienols, collectively known as tocols. These were traditionally estimated by saponification of the oil, recovery of the unsaponifiable material and analysis of this by GLC, or by paper and thin-layer chromatography techniques. However, these procedures often involved losses of the tocols, e.g., by oxidation, and much early data is claimed (25) to be of insufficient reliability as a result. High-performance liquid chromatography (HPLC), coupled with fluorescence detection, enables rapid analysis of the whole oil sample, there being no need for any sample pretreatment or workup. As there are eight different tocol compounds, and as the relative proportions of these vary considerably from oil to oil (1), tocol determination by HPLC with fluorescence detection provides another useful purity criterion.

A variety of methods therefore exists for the analysis and characterization of oils and fats. Many of these have been documented, and ranges of data tabulated. Unfortunately, however, these different techniques have been used on different samples and in different laboratories. No collection of data on a single set of samples has been published. The present project, jointly funded by the (U.K.) Ministry of Agriculture, Fisheries and Food (MAFF), by the Federation of Oils, Seeds and Fats Associations Ltd (FOSFA International), and by the Research Co-ordination Committee of the Leatherhead Food RA, was set up with the object of collecting such a set of data. Nine oils have been analyzed, by whatever tests are appropriate in each case but concentrating on quantitative chemical, rather than physical tests, as these chemical tests vary directly in relationship to the proportions of oils in a blend. The oil types analyzed, and the number of samples used, up to the present date, in each case, are shown in Table I. We concentrated, in the main, on oils with commercial problems (palm, palm kernel, peanut) or of EEC significance (rape), but a sufficient number of samples of other oils (coconut, maize, etc.) was studied to establish reliable analytical ranges. The main interest in this conference is, of course, with palm, palm kernel and coconut oils. Some of our results on palm oil have been published already (1), although some slight revision of the compositional ranges has in the meantime been necessary. The main purity problem with palm oil is contamination with palm oil fractions. This can also occur with the two lauric fats, where there is also an additional problem of commingling of the oils one with another.

TABLE I.

Samples Studied in Authenticity Project

Oil types studied	No. of samples
Palm oil and fractions	60
Groundnut oil	53
Sunflowerseed oil	34
Soybean oil	32
Rapeseed oil	74
Maize oil	32
Cottonseed oil	27
Palm Kernel oil	54
Coconut oil	23
Total	389

EXPERIMENTAL

Materials

The palm oil samples were obtained as described previously (1). The 21 Malaysian samples comprised 11 from mainland Malaysia, 8 from Sabah and 2 from Sarawak.

Palm kernels and copra samples were obtained from FOSFA International and Food RA contacts. Palm kernels were obtained from Malaysia (8), Ivory Coast (7), Nigeria (7), Cameroun (6), Sumatra (5), Guinea Bissau (4), Togo (4), New Britain (3), Honduras (2), Sierra Leone (2), Costa Rica (1), Liberia (1), Papua New Guinea (1), Sabah (1), Sarawak (1), and the Solomon Islands (1). Copra origins were Philippines (10), Papua New Guinea (4), Vanuatu (4) and North Sulawesi (1). Two samples of dessicated coconut from Sri Lanka were also analyzed.

These oil and seed samples were, with the exception of the two samples of dessicated coconut, normal commercial palm oil or lauric seed samples representing the qualities traded on world markets. Care was taken to avoid any samples representing experimental varieties, hand selected specimens, or seeds from botanical collections.

Methods

Seed samples were manually cleaned to remove admixture, note being taken of any foreign oleaginous seeds in the samples, as these would lead to the presence of impurity in the recovered oil. Oil was extracted from the cleaned seeds in our routine seed analysis laboratory, using methods corresponding to ISO 659.

Analytical methods used were as described previously (1), except that in the sterol analysis the derivatization was speeded up to 15 minutes at room temperature by the addition of 1% trimethylchlorosilane to the derivatizing agent (26). In the preparation of methyl esters from lauric oils for fatty acid analyses by GLC extra care was taken to

TABLE II.

Distribution of Fatty Acid Compositions for Whole Palm Oil and Fractions

Origin (no. of samples)	Fatty acid compositions (wt%)								
	C12	C14	C16	C16:1	C18	C18:1	C18:2	C18:3	C20
Malaysia (21)	ND-0.1	0.9-1.1	43.1-45.3	0.1-0.3	4.0-4.8	38.4-40.8	9.4-11.1	0.1-0.4	0.1-0.4
Mainland Malaysia (11)	ND-0.1	0.9-1.0	43.1-45.0	0.1-0.3	4.0-4.8	39.2-40.8	9.4-10.8	0.1-0.4	0.1-0.4
Sabah (8)	ND-0.1	0.9-1.1	43.2-45.3	0.1-0.3	4.3-4.7	38.4-40.1	10.1-11.1	0.2-0.4	0.1-0.4
Sarawak (2)	ND[a]	0.9-1.0	43.5-45.0	0.2-0.3	4.5-4.8	38.5-39.4	10.4-10.5	0.2-0.3	0.2-0.4
Ivory Coast (8)	0.1-0.2	0.8-1.0	43.4-45.2	0.1-0.2	4.9-5.5	37.1-39.9	9.6-10.9	0.2-0.4	0.2-0.4
Sumatra (4)	ND-0.2	1.1-1.3	44.6-46.3	0.1-0.2	4.1-4.6	36.7-38.6	10.1-11.5	0.2-0.3	0.2-0.4
Papua New Guinea (3)	ND-0.1	0.9-1.0	43.4-45.4	tr- 0.1	4.4-4.6	37.5-39.4	11.0-11.1	0.3[a]	0.2-0.4
Solomon Islands (4)	ND-0.1	1.0-1.1	44.4-44.7	tr- 0.1	4.4-4.8	37.6-38.9	10.3-11.0	0.3-0.4	0.4[a]
New Britain (4)	0.1[a]	1.0-1.3	43.5-44.1	tr- 0.2	4.6-5.0	37.4-38.3	11.8-11.9	0.2-0.3	0.4[a]
Nigeria (1)	0.2	1.0	45.4	0.1	4.6	37.7	10.6	0.2	0.3
Overall Range (45)	ND-0.2	0.8-1.3	43.1-46.3	tr- 0.3	4.0-5.5	36.7-40.8	9.4-11.9	0.1-0.4	0.1-0.4
Mean	0.1	1.0	44.3	0.15	4.6	38.7	10.5	0.3	0.3
Stearins (8) (Mainland)	0.1-0.2	1.0-1.3	46.5-68.9	tr- 0.2	4.4-5.5	19.9-38.4	4.1-9.3	0.1-0.2	0.1-0.3
Oleins (5) (Malaysia)	0.1-0.2	0.9-1.0	39.5-40.8	tr- 0.2	3.9-4.4	42.7-43.9	10.6-11.4	ND-0.4	0.1-0.3

[a]All samples had the same value within experimental error
ND = not detected
tr = trace (unquantified level of less than 0.05%)

avoid loss of short chain acids. Vials of methyl esters were kept cool, and stoppered whenever possible.

RESULTS AND DISCUSSION

Palm Oil

Forty-seven samples of whole palm oil, from a variety of geographical origins, were analyzed for overall fatty acid composition. The ranges, broken down into geographical origins, are shown in Table II. Some problems arose with two of the samples from Sumatra, as these had characteristics outside the ranges established on the other samples. Consultation with other laboratories (27,28) and with the trade (29) led to a belief that these two samples were not representative of whole Sumatran palm oil. Contact with the supplier subsequently established that the samples were in fact unreliable, due to bad sampling practices. Previously published results (1) have therefore been amended in the present tables to take this correction into account.

As may have been expected, the samples obtained from different parts of Malaysia show no significant differences in fatty acid composition. On the other hand those from the Ivory Coast had a higher stearic acid content, and the authentic samples from Sumatra had higher palmitic and lower oleic acid concentrations, in comparison to the Malaysian oils. The palm stearins and oleins showed much wider variations, a reflection of the different manufacturing conditions used.

Comparisons of the present results with those published by Codex (30), MARDI (32,33), and PORIM (32,33) are shown in Table III, where values for Iodine Values (IV's) and slip melting points are also given. The MARDI values in Table III have also been used in the recently issued Malaysian Standard 813 (1983) for Palm Oil. Results of the present work are in good agreement with the other ranges, but are generally narrower, especially with the Malaysian samples.

It can be concluded that the fatty acid compositions of commercial palm oils fall within a relatively narrow range, with only minor differences due to geographical origin, e.g., higher stearic contents for Ivory Coast Samples, and higher palmitic acid contents for Sumatran oils.

PORIM has also reported (33) ranges of fatty acid compositions for palm stearins and oleins. Again, our results show good agreement. This is to be expected as all of the palm fractions analyzed were from mainland Malaysia, as were PORIM's.

From the fatty acid compositions, iodine values (IV) could be calculated for each individual sample (Table IV). An interesting plot is that of IV against slip point (Fig. 1) — an approach that PORIM found to give good separation between palm oils and stearins (34). Our results are in agreement with PORIM's findings.

Results of triglyceride carbon number analysis are shown in Table V, again in comparison with PORIM (32) values, there being some slight differences between the ranges for Malaysian oils. The results show a greater range in stearin compositions compared to the ranges found for the palm oils, especially with regard to the C48 content.

Correlations between triglyceride groups have been observed for various oils (35). Indeed, such correlations have been used to determine low levels of adulteration of cocoa butter with other oils (23,36). A plot of percentage C48 against percentage C52 shows the best linear correlation for palm oil. However, although the method does differentiate palm oil from its fractions, additions of stearin or olein to a palm oil do not upset the linearity of this relationship, but it is likely that linearity will be distorted if palm oil is

TABLE III.

Comparison of Fatty Acid Composition Ranges with Those Published by MARDI (32), PORIM (32) and Codex (30), for Whole Crude Palm Oil

Fatty acid	Present work (variety of geographical origins) range (mean) (wt%)	Present work Malaysian oil samples range (mean) (wt%)	MARDI Malaysian palm oil range (mean) (wt%)	PORIM Malaysian palm oil range (mean) (wt%)	Codex range (%)
C12	ND-0.2 (0.09)	ND-0.1 (0.05)	0.0-0.4 (0.1)	0.1-1.0 (0.2)	up to 1.2
C14	0.8-1.3 (1.01)	0.9-1.1 (1.0)	0.6-1.7 (1.0)	0.9-1.5 (1.1)	0.5-5.9
C16	43.1-46.3 (44.3)	43.1-45.3 (44.1)	41.1-47.0 (43.7)	41.8-46.8 (44.0)	32-59
C16:1	tr-0.3 (0.15)	0.1-0.3 (0.15)	0.0-0.6 (0.1)	0.1-0.3 (0.1)	up to 0.6
C18	4.0-5.5 (4.63)	4.0-4.8 (4.4)	3.7-5.6 (4.4)	4.2-5.1 (4.5)	1.5-8.0
C18:1	36.7-40.8 (38.7)	38.4-40.8 (39.6)	38.2-43.5 (39.9)	37.3-40.8 (39.2)	27-52
C18:2	9.4-11.9 (10.5)	9.4-11.1 (10.1)	6.6-11.9 (10.3)	9.1-11.0 (10.0)	5.0-14.0
C18:3	0.1-0.4 (0.28)	0.1-0.4 (0.2)	0.0-0.5 (–)	0.0-0.6 (0.4)	up to 1.5
C20	0.1-0.4 (0.30)	0.1-0.4 (0.2)	0.0-0.8 (0.3)	0.2-0.7 (0.4)	up to 1.0
Iodine value	50.1-53.9 (52.1)[a]	51.1-53.5 (52.1)	50.6-55.1 (52.9)	51.0-55.3 (53.3)	50-55
Slip point (°C)	32.7-39.6 (36.0)[b]	33.2-39.6 (35.5)	30.8-37.6 (34.2)	32.3-39.0 (36.0)	–
C16 for stearins	46.5-68.9 (–)	46.5-68.9 (–)	–	47.2-73.8	–

[a]Calculated from fatty acid compositions
[b]By BSI method (31)
ND = not detected
tr = trace (unquantified level of less than 0.05%)

TABLE IV.

Ranges of Iodine Values Calculated from Fatty Acid Methyl Ester Analysis

Origin (no samples)	Range	Mean
Malaysia (21)	51.3-53.2	52.1
Ivory Coast (8)	50.8-52.5	51.4
New Britain (4)	53.2-54.0	53.5
Sumatra (4)	50.2-52.7	51.7
Papua New Guinea (3)	52.1-53.6	53.0
Solomon Islands (4)	51.9-52.5	52.2
Nigeria (1)	51.2	–
Overall range and mean (45)	50.2-54.0	52.16
Stearins (8)	24.4-49.5	41.1
Oleins (5)	56.8-57.6	56.3

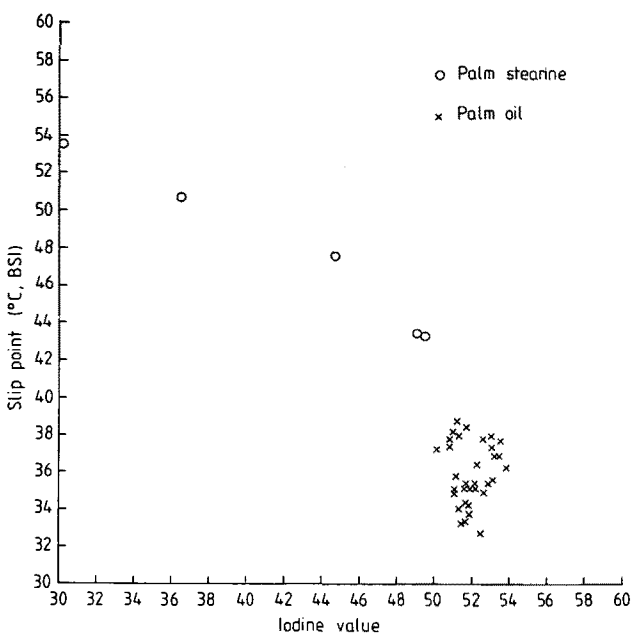

FIG. 1. Slip point (°C, BSI method) vs iodine value (calculated from GLC).

adulterated with a completely different oil, e.g., with rapeseed oil. Other combinations and manipulations of triglyceride results did not enhance the difference between whole palm oil and its fractions.

In the analysis of the fatty acids located at the glyceride 2-position, we found that the IUPAC method (37) could give somewhat variable results with hard fats. We concluded that this variation might be due to the influence of hexane in the reaction. It was therefore decided to compare results with various amounts of hexane added. Several hexane levels were evaluated as follows:

i) 1cm^3 of hexane;
ii) 0.2cm^{3}of hexane (several experiments);
iii) 0.1cm^3 of hexane;
iv) no hexane; instead, quickly melt fat, then equilibrate at 42 C before adding lipase (duplicate experiments).

Incubation and TLC stages of the experiment were the same in all cases. The monoglycerides were then analyzed for fatty acid composition with the following results:

Fatty acid profile at 2-position

	C14	C16	C18	C18:1	C18:2	C18:3
i)	0.7	21.1	1.2	56.7	20.0	0.3
ii)	0.6-0.8	16.5-17.5	0.8-1.0	61.5-63.0	18.5-19.3	0.2-0.3
iii)	0.6	17.3	1.0	61.5	19.6	0.3
iv)	0.6, 0.6	15.3, 15.4	0.8, 0.8	63.5, 63.4	19.5, 19.5	0.3, 0.3

The amount of hexane added to palm oil affected the final value. Much more reproducible results were obtained in the absence of hexane. We therefore avoided hexane addition except with the very hardest stearins, and instead quickly melted the fat, then equilibrated the sample at 42 C for 10 minutes before adding lipase. The following results

TABLE V.

Comparison of Triglyceride Carbon Number Compositions Obtained in Present Work with Those Obtained by PORIM, for Crude Whole Palm Oil and Stearins

Carbon No.	Present work (variety of geographical origins) range (mean) (wt%)	Present work Malaysian palm oil range (mean) (wt%)	PORIM (32) Malaysian palm oil range (mean) (wt%)	Present work Malaysian stearins range (wt%)	PORIM (33) Malaysian stearins (wt%)
C46	ND-1.8 (0.61)	0.6-1.8 (0.79)	0.4-1.2 (0.8)	0.9-3.0	0.5-3.3
C48	6.8-9.7 (7.91)	6.8-9.2 (7.88)	4.7-10.8 (7.4)	10.2-42.7	12.2-55.8
C50	38.3-44.0 (40.68)	38.3-43.1 (40.35)	40.0-45.2 (42.6)	39.4-42.2	33.6-49.8
C52	37.5-41.2 (39.93)	37.5-41.2 (39.93)	38.2-43.8 (40.5)	11.9-37.9	5.1-37.3
C54	8.5-11.9 (10.37)	9.2-11.9 (10.48)	6.4-11.4 (8.8)	2.5-10.3	t-8.4
C56	ND-0.7 (0.49)	ND-0.7 (0.56)	–	0.2-0.6	–

ND = not detected
t = trace

TABLE VI.

Ranges of Fatty Acids at the Triglyceride 2-position in Palm Oil and Fractions

Origin (no. of samples)	Fatty acid compositions (wt%) C14	C16	C18	C18:1	C18:2	C18:3	C20
Malaysia (17)	0.5-0.9	12.1-15.8	0.6-1.1	61.5-67.4	17.2-22.2	0.1-0.4	ND-0.1
Ivory Coast (6)	0.4-0.6	13.8-15.4	0.9-1.4	62.9-66.8	17.1-20.4	0.2-0.3	ND[a]
Sumatra (4)	0.5-0.6	12.6-15.3	0.6-0.8	63.5-67.3	18.6-21.3	0.2-0.3	ND-0.1
Papua New Guinea (3)	0.7-0.9	12.6-13.7	0.7-0.8	63.8-64.1	20.4-22.0	0.2[a]	ND[a]
Solomon Islands (4)	0.5-0.6	12.8-14.5	0.8-1.2	63.5-63.9	20.1-21.8	ND-0.3	ND[a]
New Britain (4)	0.4-0.7	12.8-13.2	0.6-0.9	62.6-63.6	22.0-22.8	0.1-0.3	ND-0.1
Nigeria (1)	0.4	13.6	0.6	64.9	20.2	0.3	ND
Overall range (39)	0.4-0.9	12.1-15.8	0.6-1.4	61.5-67.4	17.1-22.8	ND-0.4	ND-0.1
Mean	0.59	14.10	0.87	64.09	20.12	0.22	0.02
Stearins (5)	0.6-1.6	20.1-59.9	1.3-2.1	28.9-61.2	7.4-18.2	ND-0.2	ND-0.1
Oleins (1)	0.5	11.7	0.9	66.2	20.6	0.1	ND

[a]All samples had the same value within experimental error
ND = not detected

show the effect of hexane on C16 analyses of seven typical samples:

Sample number	%C16 0.2ml hexane	%C16 no hexane
30	16.6	13.2)
33	13.7	12.8)
34	17.1	13.5) whole
35	21.8	15.3) palm
41	16.3	12.6) oils
44	17.4	13.6)
48	20.8	20.1 palm stearin

Consideration of the results shows that omission of hexane not only gives a lower percentage C16 result but also enhances anticipated differences between palm oils and stearins. It was also found that comparison of carbon number compositions calculated from these results with experimental carbon number determinations were better when results obtained in the absence of hexane were used in the 1,3-random-2-random calculations. This substantiated our view that hexane reduced not only the reproducibility, but also the accuracy, of this determination.

We believe that the difference in results obtained by the two methods may be due to incomplete reaction and differential partition between the two phases when hexane is present in the reaction. The best separation between palm oils and stearins is provided by the values for the amount of palmitic acid (C16) at the 2-position (Table VI). Palm oil shows a range of 12.1-15.8% with a mean value of 14.1%. Stearins have a range of 20.1-59.9%. Thus, in favorable circumstances, it is possible to detect as little as 10% of the harder stearins in palm oil by use of this method.

Results obtained in the present work for the tocopherol, tocotrienol and sterol compositions of palm oil samples have been reported earlier (1). They showed no differences between palm oil and its fractions. Solid fat contents were measured by NMR, and although these do show differences they were insufficient to pinpoint adulteration or contamination of palm oil with "soft" stearins. This is perhaps due to the complicated phase behavior (38) of palm oil, which includes not only the triglycerides but also partial glycerides and free fatty acids. A further factor is that the solid content of a blend does not change in a linear manner as the proportion of the stearin is varied, due to the formation of solid solutions with some of the molecular species present, but of eutectics with others. These aspects make systematic interpretation more difficult than with the linear changes in chemical properties which occur as a blend composition is varied.

Results of the various tests were combined and contrasted in an effort to finalize new purity criteria. Some of these combinations have been reported already (1).

One parameter investigated was the ratio of percentages of C16-2-position and C16-overall, i.e., the palmitic enrichment factor (PEF) (39). Initially, it was hoped that this ratio would even out any natural variations in the percentage of C16 present in a sample, i.e., any sample that is high in percentage of C16 will have a high percentage of C16 in the 2-position. Results for stearins, which are fractionated products, would not even out in such a manner, as the 2-position percentage of C16 would be artificially raised by the concentration of high-melting tripalmitin in the stearin. The results in Table VII show differences between palm oils and stearins, but the natural variation between

TABLE VII.

Palmitic Acid Enrichment Factors (PEF), and the Product of PEF x C48, for Palm Samples

Origin (no. samples)	PEF	Mean	PEF x C48	Mean
Malaysia (17)	0.279-0.359	0.332	1.9-3.2	2.61
Ivory Coast (6)	0.305-0.345	0.323	2.2-2.9	2.48
Sumatra (4)	0.276-0.330	0.294	2.3-3.2	2.62
Papua New Guinea (3)	0.290-0.315	0.302	2.0-2.3	2.18
Solomon Islands (4)	0.288-0.325	0.311	2.3-2.5	2.37
New Britain (4)	0.294-0.301	0.297	2.2-2.3	2.23
Nigeria (1)	0.300	0.300	–	–
Overall (39)	*0.276-0.359*	*0.318*	*1.9-3.2*	*2.51*
Stearins (5)	0.430-0.869	0.544	4.5-37.1	a
Oleins (1)	0.293	0.293	0.79	–

[a]Process dependent

samples is too large to detect adulteration of crude palm oil with very low levels of "soft" stearin fractions. Nevertheless, this ratio is one of the most useful of those evaluated. The product of the palmitic EF and the percentage of C48 (Table VII) increased the relative difference between palm oils and "soft" stearins, and is a useful method of result manipulation.

The most useful palm oil purity criteria substantiated in the present work are therefore the plots of the melting point of a sample against its IV, and the product of PEF and C48 triglyceride content.

Lauric Fats

Palm kernel and coconut oils are somewhat alike in physical and chemical properties. Nevertheless the slight differences in their properties are real. It is frequently necessary to distinguish the oils, e.g., for labelling purposes, or decide on their proportions in a blend. Palm kernel oil can sometimes become contaminated with palm oil, another factor to be taken into account in assessing authenticity.

Fatty acid compositions of the palm kernel, and coconut, oil samples analyzed are shown in Tables VIII and IX. Table X shows the comparison of the present ranges with those of Codex (30) and PORIM (28,40).

Analyses of palm kernel samples from different origins show minor variations. Two of the samples from Guinea Bissau had unusually low concentrations of lauric but higher levels of myristic and palmitic acids, and may not have been typical of normal bulk cargoes. Further samples are therefore being sought from this region.

The Sumatran samples had higher levels of the shorter chain C8 and C10 acids than the other origin samples, while the Cameroun samples show a higher lauric acid content. The Togo samples had higher stearic acid contents than the other samples. The Cameroun samples showed the widest IV variation of from 14.4 to 20.0 units, in comparison to the narrower range of 15.7 to 19.1 for PK oil of Malaysian origin. The oleic acid concentrations show a somewhat larger spread than expected, mainly due to the somewhat higher level of oleic acid in the two unusual Guinea Bissau samples.

It has been suggested in the trade (29) that introduction of the so-called weevil to assist palm flower pollination may have led to changes in Malaysian palm kernel oil compositions, with higher concentrations of palmitic and oleic acids in recent crops, compared to previously. The work reported here provides no scientific basis for any such views. The survey made by PORIM on the compositions of palm kernel oils recently harvested (Table X) also shows that chemical compositions have remained unchanged (28).

TABLE VIII.

Distribution of Fatty Acid Compositions with Sample Origin for Palm Kernel Oil

	Fatty acid composition (wt%)											
Origin (no. of samples)	C6	C8	C10	C12	C14	C16	C18	C18:1	C18:2	C18:3	C20	C20:1
Nigeria (7)	0.1-0.2	3.2-3.5	3.4-3.8	46.6-48.5	16.5-16.9	8.5-9.3	2.7-2.9	14.1-15.7	1.4-2.2	t-0.1	0.1-0.3	t-0.5
Sierra Leone (2)	0.2-0.4	3.1-3.4	3.4	45.6-45.7	16.7-16.8	8.9	2.7	16.0-16.7	2.2-2.6	t-0.2	0.1	0.1
Ivory Coast (7)	0.2-0.3	2.6-3.4	3.0-3.5	46.4-47.6	16.0-16.9	8.5-9.0	2.3-2.8	15.3-16.7	1.9-2.5	t-0.2	0.1	t-0.1
Guinea Bissau (4)	0.1-0.2	2.5-3.0	2.8-3.2	43.6-46.8	16.9-17.2	9.0-10.0	2.3-2.9	16.4-18.5	1.4-1.9	t	0.2	ND-0.1
Malaysia (8)	0.2-0.8	3.0-4.4	3.3-4.0	46.2-49.6	15.9-16.8	7.9-8.6	1.9-2.2	13.7-16.1	1.9-2.9	t-0.2	0.1-0.3	0.1-0.4
Honduras (2)	0.2	3.4-3.6	3.6	48.5-49.8	15.3-16.1	7.8-8.4	2.0-2.4	13.9-15.6	1.9-2.5	0.1-0.7	0.1	0.1
New Britain (3)	0.2-0.3	3.0-3.8	3.4-3.7	48.0-49.3	15.7-16.0	7.8-8.1	2.2-2.3	14.7-15.0	2.8-3.3	t-0.1	0.1	0.1-0.3
Solomon Islands (1)	0.2	3.3	3.3	49.2	16.1	8.6	2.2	14.2	2.7	t	0.1	0.1
Sumatra (5)	ND-0.5	3.3-4.7	3.5-4.5	47.3-50.2	15.6-15.9	7.3-8.1	1.9-2.1	13.8-15.0	2.4-2.7	t-0.1	0.1	0.1
Camerouns (6)	0.2-0.5	2.8-3.8	3.0-3.8	46.2-51.4	16.0-17.1	7.2-9.4	2.3-2.6	11.9-16.0	2.3-3.2	t-0.3	0.1-0.2	t-0.2
Costa Rica (1)	0.2	3.4	3.5	48.8	16.0	8.3	2.8	14.4	2.4	t	0.1	0.1
Togo (4)	0.2-0.3	3.0-3.5	3.2-3.7	46.2-47.8	16.3-16.8	8.6-9.4	2.7-3.0	14.8-16.5	1.9-2.3	t-0.2	0.1-0.2	0.1
Liberia (1)	0.5	3.5	3.5	46.6	16.4	8.5	2.7	15.7	2.4	t	0.1	0.1
Papua N.G. (1)	0.1	3.4	3.5	47.9	16.3	8.3	2.1	15.5	2.7	t	0.1	0.1
Sarawak (1)	0.2	3.0	3.3	46.9	15.7	8.9	2.3	16.0	3.2	0.1	0.2	0.2
Sabah (1)	0.2	3.3	3.4	47.7	15.8	8.9	2.2	15.2	2.9	t	0.2	0.2
Overall range (54)	ND-0.8	2.5-4.7	2.8-4.5	43.6-51.4	15.3-17.2	7.2-10.0	1.9-3.0	11.9-18.5	1.4-3.3	t-0.7	0.1-0.3	ND-0.5
Mean	0.3	3.3	3.5	47.5	16.4	8.5	2.4	15.3	2.4	0.1	0.1	0.1

t = trace (unquantified level of less than 0.05%)
ND = Not detected

The fatty acid compositions of the coconut oil samples in Table IX again show small variations with sample origin, the main difference being with regard to the two samples of oil extracted from desiccated coconut from Sri Lanka. The white flesh or meat of coconut is covered with a thin brown skin or membrane. This is removed prior to drying during the production of desiccated coconut, but not in the production of dried copra for oil milling. As this skin contains oil (vis: coconut parings oil) of slightly different composition to that present in the white flesh, its presence or absence causes slight changes in the composition of the

TABLE IX.

Distribution of Fatty Acid Compositions with Sample Origin for Coconut Oil

Origin (no. of samples)	Fatty acid composition (wt%)										
	C6	C8	C10	C12	C14	C16	C18	C18:1	C18:2	C20	C20:1
Philippines (11)	0.4-0.6	7.1-8.3	6.2-6.8	46.2-48.7	18.0-19.2	8.3-9.5	2.3-3.2	5.6-7.1	1.3-2.1	0.1-0.2	t-0.1
Papua New Guinea (4)	0.4-0.6	6.9-7.5	6.4-6.8	47.1-50.3	17.8-18.1	8.3-9.3	2.3-3.0	5.8-6.3	1.4-1.6	0.1	t
Vanuatu (5)	0.5-0.6	7.3-9.4	6.6-7.8	47.1-48.4	16.8-17.9	7.7-9.1	2.3-2.9	5.4-6.5	1.4-2.0	t-0.2	t-0.2
North Sulawesi (1)	0.5	7.3	6.3	45.9	18.1	9.7	2.7	7.4	1.9	0.1	0.1
Sri Lanka (2)[a]	0.4-0.5	7.3-7.4	5.9-6.2	49.3-52.6	18.6-19.6	7.0-7.9	2.9	4.5-5.3	0.6-0.9	0.1	t
Overall Range (21)	0.4-0.6	6.9-9.4	6.2-7.8	45.9-50.3	16.8-19.2	7.7-9.7	2.3-3.2	5.4-7.4	1.3-2.1	t-0.2	t-0.2
Mean (21 samples)	0.5	7.8	6.7	47.5	18.1	8.8	2.6	6.2	1.6	0.1	t

t = trace (unquantified amount of less than 0.05%). Traces of C18:3 were found in all origins ranging up to 0.2% in one Vanuatu sample.
[a]These results relate to desiccated coconut and were not used in calculation of ranges and means. All other oil samples were extracted from samples of commercial copra.

TABLE X.

Comparison of Fatty Acid Composition Ranges with those Published by CODEX (30) and PORIM (28,40) for Palm Kernel and Coconut Oils

	PALM KERNEL OIL				COCONUT OIL		
	Present work Variety of geographical origins range (mean) (%)	Codex range (%)	Present work Mainland Malaysian oil range (mean) (%) ('81 & '82 samples)	PORIM (40) Malaysian oils range (mean) (%) (pre Sept '81)	PORIM (28) Malaysian oils sampled in 1983 range (mean) (%)	Present work Variety of geographical origins range (mean) (%)	Codex (30) range (%)
C6	ND-0.8 (0.3)	up to 0.5	0.2-0.8 (0.3)	0.1-0.5 (0.3)	0.2-0.4 (0.3)	0.4-0.6 (0.5)	up to 1.2
C8	2.5-4.7 (3.3)	2.4-6.2	3.0-4.4 (3.6)	3.4-5.9 (4.4)	3.5-4.1 (3.9)	6.9-9.4 (7.8)	3.4-15
C10	2.8-4.5 (3.5)	2.6-7.0	3.3-4.0 (3.7)	3.3-4.4 (3.7)	3.3-3.6 (3.5)	6.2-7.8 (6.7)	3.2-15
C12	43.6-51.4 (47.5)	41-55	46.2-49.6 (47.6)	46.3-51.1 (48.3)	46.6-48.3 (47.6)	45.9-50.3 (47.5)	41-56
C14	15.3-17.2 (16.4)	14-20	15.9-16.8 (16.2)	14.3-16.8 (15.6)	15.4-15.9 (15.7)	16.8-19.2 (18.1)	13-23
C16	7.2-10.0 (8.5)	6.5-11	7.9-8.6 (8.3)	6.5-8.9 (7.8)	7.9-8.5 (8.1)	7.7-9.7 (8.8)	4.2-12
C18	1.9-3.0 (2.4)	1.3-3.5	1.9-2.2 (2.1)	1.6-2.6 (2.0)	1.5-2.1 (2.0)	2.3-3.2 (2.6)	1.0-4.7
C18:1	11.9-18.5 (15.3)	10-23	13.7-16.1 (15.4)	13.2-16.4 (15.1)	15.4-16.8 (16.0)	5.4-7.4 (6.2)	3.4-12
C18:2	1.4-3.3 (2.4)	0.7-5.4	1.9-2.9 (2.5)	2.2-3.4 (2.7)	2.5-2.7 (2.6)	1.3-2.1 (1.6)	0.9-3.7
C18:3	t-0.7 (0.1)	–	t-0.2 (0.1)	–		–	–
C20	0.1-0.3 (0.1)	–	0.1-0.3 (0.1)	–	0.2-0.3 (0.2)	t-0.2 (0.1)	–
C20:1	ND-0.5 (0.1)	–	0.1-0.4 (0.2)	–		t-0.2 (t)	–

t = trace (unquantifiable level of less than 0.05%)

extracted oil. As the work reported here is intended as a guide for the commercial oil trade, the results corresponding to samples of desiccated coconut were not used to evaluate ranges or means.

Comparisons of palm kernel and coconut oil results obtained in the present work with values published by CODEX and PORIM are shown in Table X. The present results generally substantiate the other published ranges but show narrower ranges than Codex except linolenic acid and the longer chain acids (C20 and C20:1), where CODEX and PORIM show zero levels. Comparison of the present results for both ranges and means for the Malaysian palm kernel oils, with those of PORIM, which originally analyzed 118 samples plus a further 44 of the 1983 crop, is particularly pleasing. Ranges in the present work are narrower, probably as a result of the smaller number of samples used.

Exclusion of results for oils extracted from desiccated coconut gives narrower ranges, but the authors feel that a more positive distinction should where possible, be made between these two types of coconut oil. This is particularly the case when sterol analysis is undertaken, as work on this topic (not reported here) has shown that coconut parings oil has a higher sterol content than oil from coconut meat, and that these sterols also have a different composition.

Triglyceride carbon number analyses are shown in Table XI. As expected, the main triglyceride in both oils is C36, while the higher level of shorter chain acids in coconut oil leads to increased concentrations of lower molecular weight triglycerides in this oil. Triglyceride carbon number analysis is therefore a useful method for distinguishing between the two lauric fats. It has an advantage over the determination of fatty acid composition as the short chain acids are not separated or converted to methyl esters, and there is therefore no danger of their being accidentally lost by volatilization. Results of triglyceride carbon number analysis can be used to construct the graph shown in Figure 2. The triglycerides C30 to C42, inclusive, are renormalized to 100%, to give new values K30, K32 etc to K42 in a similar way to that used (23) by Padley & Timms to calculate "P" values. A plot is then constructed of K34 and K40 against K36 and K38, as shown in Figure 2. This clearly differentiates palm kernel and coconut oils. Triglycerides of the normal vegetable oils have triglycerides with carbon number designations of C48 and above, and do not therefore interfere with this method of result interpretation, although diglycerides of 18 carbon atom acids might. The authors also studied other combinations of triglyceride carbon number analyses, but found the approach illustrated in Figure 2 the most sensitive for separating these two lauric oils.

OBSERVATIONS

Palm oil is distinguished from other oils by its very high level of palmitic acid. We found that it ranged from 43.1 to 45.3% in Malaysian palm oil samples, and from 43.1 to 46.3% for samples from several geographic origins. In comparison, PORIM found a range of 41.8 to 46.8% for Malaysian samples, but the Codex range for samples of all geo-

TABLE XI.

Triglyceride Carbon Number Composition (wt%)

Triglyceride carbon no.	Palm kernel oil			Coconut oil
	All origins Range (mean) (%)	Mainland Malaysia range (mean) (%)	PORIM Values range (mean) (%)	All origins Copra range (mean) (%)
C28	0.3-2.2 (0.6)	0.3-0.9 (0.45)	t-0.5 (0.2)	0.7-1.0 (0.8)
C30	1.0-2.6 (1.4)	1.2-1.5 (1.3)	0.7-1.5 (0.8)	2.8-4.1 (3.4)
C32	4.9-8.0 (6.7)	6.0-7.3 (6.4)	4.8-6.1 (5.3)	11.5-14.4 (12.9)
C34	6.9-10.0 (8.7)	7.9-9.1 (8.4)	7.0-9.1 (7.8)	15.6-17.6 (16.5)
C36	19.3-24.1 (21.8)	20.6-23.0 (21.5)	22.2-27.8 (25.1)	18.3-19.8 (18.8)
C38	15.5-17.4 (16.5)	15.8-17.2 (16.2)	17.3-19.4 (18.2)	15.1-17.7 (16.3)
C40	8.9-10.5 (9.8)	9.6-10.0 (9.7)	9.0-10.7 (9.7)	9.2-11.1 (10.2)
C42	8.1-9.7 (9.0)	8.9-9.7 (9.3)	8.7-9.6 (9.1)	6.5-8.0 (7.3)
C44	5.5-7.4 (6.5)	6.3-7.4 (6.9)	5.8-6.8 (6.4)	3.6-4.6 (4.2)
C46	4.1-6.3 (5.3)	4.9-6.0 (5.6)	4.2-5.3 (4.9)	2.1-3.0 (2.6)
C48	4.7-7.4 (5.9)	5.2-6.8 (6.3)	5.0-6.1 (5.7)	1.6-2.6 (2.3)
C50	1.6-3.3 (2.5)	2.1-3.3 (2.75)	1.6-2.6 (2.2)	0.8-2.0 (1.7)
C52	1.5-3.5 (2.5)	1.8-3.5 (2.8)	1.7-2.6 (2.1)	0.4-2.0 (1.6)
C54	1.7-4.0 (2.7)	1.8-3.0 (2.55)	1.6-3.4 (2.5)	0.1-1.5 (1.2)

ND = Not detected
t = trace

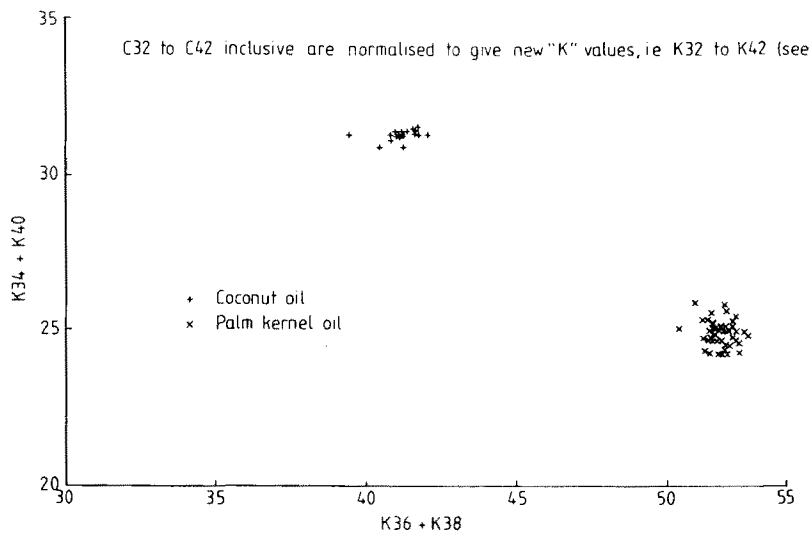

FIG. 2. Plot of K34 + K40 against K36 + K38 for palm kernel and coconut oils.

graphic origins is 32-59% (Table III). The high level of palmitic acid compares with a value of up to 26.4% in cottonseed oil, the next highest level of palmitic acid found in the present work on edible vegetable oils. The high concentration of palmitic acids in the constituent acids of palm oil is of course the reason why palmitic acid got its name. In addition, palm oil contains high levels of oleic acid, the ranges found in the present work – 36.7 to 40.8% for various origins and 38.4 to 40.8% for Malaysian samples – comparing with 37.3 to 40.8% found by PORIM for Malaysian samples, but 27-52% given by Codex for samples of all origins (Table III). In these comparisons, our ranges agree well with those determined by PORIM, but not so well with those published by Codex, which are much wider. Palm oil has a low level of polyunsaturated acids in comparison with other vegetable oils, containing up to about 12% linoleic acid, and a very small amount – less than 1% – of linolenic.

In view of the near equal levels of palmitic acid, which has 16 constituent carbons, and oleic acid, which has 18, palm oil comprises a mixture of triglycerides, two groups of which have nearly equal concentrations. In the carbon number designation, these range from C46 to C56, while C52 and C54 are both present at about 40% of the total. The lauric fats also have a wide range of triglyceride molecular weights. Peanut oil has triglycerides with carbon numbers of from 50 to 62. This is a more extensive range than in palm oil, but in the former case triglycerides with carbon numbers of 56 or over are each less than 10% of the total and there is one dominant group, designated C54. Most other liquid vegetable oils contain predominantly C54 triglycerides. Palm oil is therefore distinguished from other oils in containing high levels of the C48, C50 and C52 glycerides, the latter two glyceride groups being present at almost equal levels.

The high level of palmitic acid is again reflected in the composition of the fatty acids at the triglyceride 2-position, palm oil having more palmitic acid in these 2-position acids than any other common vegetable oil. This may have some nutritional significance as human breast milk also has a relatively high concentration of palmitic acid at the triglyceride 2-position (41,42).

In contrast to palm oil, and other vegetable oils, the lauric oils palm kernel and coconut, contain high levels of lauric and other saturated acids. The lauric acid content of the samples examined at Leatherhead ranged from 43.6 to 51.4% and 45.9 to 50.3% for palm kernel and coconut oils,

respectively, when all origins are considered. These compare with the ranges of 41-55% and 41-56% published by Codex (30). Two of the samples of palm kernels examined at Leatherhead, namely from Guinea Bissau had lower levels of lauric acid than any of the other samples, and it has been suggested (27,29) that these samples are not typical of normally traded commodities. Results obtained on Malaysian palm kernels however agree well with values published by PORIM (40).

In view of their fatty acid compositions, palm, palm kernel and coconut oils are classed by nutritional experts as saturated oils, the so-called P/S ratio (polyunsaturated fatty acid content/total saturated fatty acid content) being very low. On the other hand, they have the advantage of a solid texture at room temperature, and it is not necessary to hydrogenate the oil during manufacture of margarines or shortenings. *trans*-isomers are formed during catalytic hydrogenation, and margarines and shortenings produced from hydrogenated liquid oils such as soybean or rape therefore contain *trans*-isomers. Experts in the nutritional aspects of oils and fats appear to take an equal interest in the content of *trans*-isomers as they do in the P/S ratio (43,44).

The problem of detecting adulteration of palm oil with other oils, or of other oils with palm oil or its fractions, has been discussed above. The characteristic features which distinguish palm oil from other oils are its high palmitic acid content, the almost equal concentrations of the two triglyceride groups designated C50 and C52, and the presence of tocotrienols (1). Any comingling of different oils with palm oil will therefore lead to changes in the concentrations of these components. The problem of detecting the contamination of palm oil with palm fractions, such as the stearin fraction, is much more difficult, however. This is due to the wide variation in the hardnesses and compositions of stearins, which can have iodine values ranging from 24.4-49.5. However, adulteration of palm oil with the "harder" stearins can be easily detected even when the level is quite low. The fact that some of the "soft" stearins are so similar to palm oil means that it can be difficult to determine adulteration of whole, natural palm oil with these soft stearins, and in these cases it may be necessary to bring all of the techniques mentioned in this paper to bear on the problem. Even so, it may not be possible to decide finally in some cases. This is due to the natural variation in samples of whole palm oil as well as the similarity of some stearins to the natural oil.

The most useful criteria for the detection of adulteration or contamination of palm oil have been shown to be the plot of melting point against iodine value, and the product of the C48 content and palmitic enrichment factor.

In the case of the lauric fats, the most difficult problem of proving purity is the detection of comingling of one oil with another. The higher concentrations of the shorter chain acids in coconut oil are useful here, but there is the experimental difficulty that a proportion of these may be lost by volatilization during methyl ester preparation or storage. This experimental inconvenience is avoided by examination of the triglyceride carbon number compositions. Results from this test can be usefully interpreted by normalizing the C30 to C42 concentrations to give new K30 to K42 values, and plotting K34 and K40 against K36 and K38.

This work is now progressing with more detailed analyses of samples of the oil types so far studied, e.g., by examination of the triglyceride composition on the basis of unsaturation by HPLC, by analysis of the 4-methyl and 4,4'-dimethyl sterols and by separate analysis of free and esterified sterols. A more detailed statistical analysis of the total databank is also being undertaken, using for instance pattern recognition techniques, in the hope that new purity criteria will emerge.

As a further extension to the project some additional samples are being sought in order to fill gaps in the current "library" of samples and substantiate results for those areas based on the analysis of only a few samples. Any reader able to provide any such samples should please contact the authors (45). In addition, safflowerseed oil has been added to the list, and a limited number of samples of babassu kernels are being analyzed to enable proper distinction of this oil from the more extensively traded lauric fats.

ACKNOWLEDGMENTS

Permission to use the results of earlier investigations carried out by Sarah Mitchell and Christine Gaffey, on the analysis of palm oils and palm oil stearins, is gratefully acknowledged. S. Zilka and J.A. Turrell assisted in revision of the text to incorporate new results and information provided by FOSFA International and MAFF. The authors acknowledge the funds provided by The Federation of Oils Seeds and Fats Associations, by the Ministry of Agriculture Fisheries and Foods, and by the Leatherhead Food Research Association for this project, the permission from each of them to present this paper, and the numerous friends who have helped with the provision of authentic oil and seed samples.

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Biological Modification of Oil Composition

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ABSTRACT

Prospects for modification of palm oil composition through oil palm breeding, tissue culture and enzyme-catalyzed transesterification are reviewed. Present emphasis in oil modification is toward greater unsaturation. The greatest prospect for this area lies in the interspecific hybridization of *E. oleifera* and *E. guineensis*. The target recommended is for a hybrid oil of iodine value above 72 having a palmitic acid content below 25% and an oleic acid content above 60%. It is noted that the variability of linoleic acid in the oil palm is limited regardless of species. The greatest contribution towards unsaturation, therefore, lies mainly in oleic acid. Tissue culture is seen as a potential propagating tool for selecting progenies of important crosses from the hybridization of *E. oleifera* and *E. guineensis*, while enzyme-catalyzed transesterification using a 1,3 specific lipase offers the possibility of enhancing the level of linoleic acid in palm oil. Besides breeding for unsaturation, production of palms giving oils of specific fatty acid or triglyceride types also may be possible ultimately.

INTRODUCTION

Malaysian palm oil and palm kernel originate mainly from the *tenera* variety of *Elaeis guineensis*. The oil palms in Malaysia originated from 4 seeds which came from Bogor, Indonesia, in 1848. Plant breeders have recognized the danger of too narrow a genetic base for the oil palm industry in Malaysia. Thus, several attempts have been made to expand the genetic range through selection of commercial and wild palms of *Elaeis guineensis* found in Zaire, Nigeria and the Cameroons (1). Seeds from the related species, *Elaeis oleifera*, also have been collected from South and Central America.

Palm oil is well endowed with properties which are suitable for many applications, notably in vanaspati, shortenings and margarines. In tropical countries its liquid fraction is used as a cooking oil. Its share in the salad and cooking oils category is limited, however, because of its composition. To enhance its usage in this category, efforts must be made to produce a more liquid palm oil through plant breeding. In recognition of this need, hybridization of palms belonging to *Elaeis guineensis* and *Elaeis oleifera* have been studied (2,3). Whereas past efforts of plant breeders have focused largely on improvements in yield, morphological and vegetative characteristics, there is growing emphasis on oil composition in breeding programs.

PROSPECTS FOR MODIFYING PALM OIL COMPOSITION

Present Status

World usage of oils and fats is divided equally between liquid oil and solid fat. While palm oil usage in the solid fat market is substantial, its share in the liquid oil market is limited because of its composition. Any emphasis on modifying composition should, therefore, be toward greater unsaturation of palm oil. Viewed in this perspective, it is relevant to discuss the composition of the major seed and olive oils in relation to palm oil. Table I shows the typical fatty acid composition of the major seed and olive oils. The following features are of interest when compared with palm oil.

(a) The total saturated acid content is below 20%, except for cottonseed oil.

(b) All the oils have greater than 70% unsaturated acids.

(c) Soybean, sunflower, cottonseed and corn oils have below 30% oleic acid and greater than 50% linoleic acid. Olive oil and rapeseed (low erucic type) have high oleic (60%) and low linoleic (20%) acid contents. Peanut oil has about equal percentages of oleic and linoleic acids.

(d) Soybean and rapeseed oils have a significant amount of linoleic acid.

(e) Iodine values of all the oils are above 80.

For comparison, note the composition of Malaysian palm oil. Rossell (5) has reported the fatty acid composition of oils from various areas. In general, the composition of palm oil falls into a narrow range regardless of geographical regions. Minor differences observed are due to plantings of mixed varieties rather than the predominance of a single variety. Palm oil commercially available today thus consists of an almost balanced proportion of saturated and unsaturated acids falling into a narrow range.

To compete with the seed oils for a major share of the salad and cooking oils market, the unsaturation level of palm oil must be increased. The question is, to what extent could the unsaturation be increased, and which unsaturated fatty acid should be increased. Noiret and Wuidart (7) have studied the variability of the fatty acid composition of *Elaeis guineensis* obtained from different origins and their hybrids (Table II). Their studies show that the level of