KOREAN J. FOOD SCI. TECHNOL.
Vol. 14, *No.* 2 (1982)

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Palm Oil and Palm Kernel Oil

Chemical and Physical Characteristics and Current Research Programme at PORIM

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(Received February 1, 1982)

팜기름과 팜핵기름

물리화학적 성질과 PORIM의 연구현황

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(1982년 2월 1일 수리)

Palm oil

To-date Malaysia has planted over one million hectares of palms mainly of the "tenera" variety, obtained by crossing "dura" and "pisifera" palms. The two oil products obtained are palm oil (2.6 million tonnes) and palm kernel oil(240,000 tonnes) in 1980. More than 90% of the oils are exported.

Malaysian palm oil consists mainly of glycerides containing a range of fatty acids. Triglycerides constitute the major component with small proportions of di-and mono-glycerides. Malaysian palm oil also contains other minor constituents including free fatty acids and non-glyceride components. This composition determines the chemical and physical characteristics of Malaysian palm oil.

Fatty Acids A survey has been completed by PORIM on the fatty acid composition of crude Malaysian palm oil and the results are given in Table 1.

The results show that Malaysian crude palm oil has a narrow compositional range. About 50% of the fatty acids present in Malaysian palm oil are saturated, 40% mono-unsaturated and 10% di-unsaturated. This is reflected in the iodine value(Wij's) of about 53.

Glycerides The variation in which the different fatty acids can be attached to the glycerol molecule results in a large number of different triglycerides present in palm oil. Some insight into the structure of the glycerides has been obtained and lipolysis with pancreatic lipase followed by gas liquid chromatography (GLC).

Table 1. Fatty acid composition of Malaysian palm oil[15]

Fatty acid	% of total acids	
	Range	Mean
12 : 0	0.1∼1.0	0.2
14 : 0	0.9∼1.5	1.1
16 : 0	41.8∼46.8	44.0
16 : 1	0.1∼0.3	0.1
18 : 0	4.2∼5.1	4.5
18 : 1	37.3∼40.8	39.2
18 : 2	9.1∼11.0	10.1
18 : 3	0∼0.6	0.4
20 : 0	0.2∼0.7	0.4

The results of a typical analysis of crude palm oil (tenera) based on the component triglycerides grouped according to the number of saturated(s) and unsaturate(u) fatty acids are summarised in Table 2.

Table 2. Typical analysis of the triglycerides in palm oil[14]

Glyceride type	Composition (%)
Trisaturated (GS_3)	10.2
Disaturated (GS_2U)	48.0
Monosaturated (GSU_2)	34.6
Triunsturated (GU_3)	6.8

Table 3. Triglyceride composition of Malaysian tenera palm oil

No double bond			1 double bond			2 double bonds			3 double bonds			4 or more double bonds		
	A	B		A	B		A	B		A	B		A	B
MPP	0.29	0.5	MOP	0.83	1.4	MLP	0.26	—	MLO	0.14	0.2	PLL	1.08	0.8
PMP	0.22	0.2	MPO	0.15	0.2	MOO	0.43	0.7	PLO	6.59	6.0	OLO	1.71	1.4
			POP	20.02	23.7	PLP	6.36	6.3	POL	3.39	3.1	OOL	1.76	1.5
PPP	6.91	7.2	POS	3.50	3.1	PLS	1.11	0.8	SLO	0.60	0.4	PLL	0.56	—
PPS	1.21	1.0	PMO	0.22	—	PPL	1.17	1.0	SOL	0.30	0.2	LOL	0.14	0.1
PSS	0.12	0.1	PPO	7.16	6.9	OSL	0.11	—	OOO	5.38	5.1			
PSP	—	0.7	PSO	0.68	0.6	SPL	0.10	0.1	OPL	0.61	0.5			
			SOS	0.15	—	POO	20.54	21.5	MOL	—	0.1			
			SPO	0.63	0.5	SOO	1.81	1.4						
						OPO	1.86	1.6						
						OSO	0.18	0.2						
						PSL	—	0.1						
Others	0.16			0.34	0.3		0.19	0.6		0.15	—		0.22	
Total	9.57	9.7		33.68	35.8		34.12	34.6		17.16	15.6		5.47	3.8

A: Based on Kan-Ichi Hayakawa computation[7]
B: Based on Vander Wal's method[13]

Statistical computer analysis methods have provided even more information on the glyceride composition from lipolysis data as illustrated in Table 3.

A rapid analysis of the triglyceride composition can be obtained by determining the total carbon number of their three fatty acid moieties by high temperature GLC as indicated in Table 4.

Table 4. Triglyceride composition of Malaysian crude palm oil[16]

(Unit: mole%)

Carbon number	Range	Mean
C 46	0.4~1.2	0.8
C 48	4.7~10.8	7.4
C 50	40.0~45.2	42.6
C 52	38.2~43.8	40.5
C 54	6.4~11.4	8.8

The major components of the C 50 peak is dipalmito-olein (PPO, POP) which is reported at levels of 28~40%, in the C 52 peak the major component is dioleo-palmitin (POO) reported at levels of 20~23%.

A detailed survey for the presence of partial glycerides in palm oil has yet to be conducted. However, analyses of random samples of refined oil, refined olein and refined stearin show the presence of monoglycerides (trace amounts), 1,2-diglycerides(~2%) and 1,3-diglycerides (~4%)[15].

The melting point of a glyceride is dependent on the structure and poistion of the component fatty acids. The semi-solid nature of palm oil at about 20°C is mainly attributed to the oleo-disaturated fraction which is solid at temperatures.

Minor constituents The minor components consisting of carotenoids, tocopherols, sterols, phosphatides, triterpenic and aliphatic alcohols constitute not more than 1% of palm oil. However, some of them play a significant role in the stability and refining of palm oil besides conferring on palm oil its nutritional value.

The carotenoid content of palm oil varies between 500 and 700 ppm of which major constitutents are α and β carotene (approximately 90%), the precursors of vitamin A. Given the 1980 production of 2.6 million tonnes of crude palm oil, the available carotenoid was 1 500-1 820 tonnes but practically all would have been destroyed by thermal destruction during physical refining. A typical analysis of the different carotenoids is given in Table 5.

Tocopherols and tocotrienols are found in palm oil at levels of between 600 and 1000 ppm[15]. Several attempts at determining the composition of these natural anti-oxidants have been reported. A

Table 5. Composition of carotenoids in Zaire plantation palm oil[5]

Carotenoid	Percentage
α-Carotene	36.2
β-Carotene	54.4
γ-Carotene	3.3
Lycopene	3.8
Xanthophylls	2.2

typical analysis using TLC and capillary GLC has been carried out as shown in Table 6[8].

Table 6. Tocopherols and tocotrienols in crude palm oil

Tocopherol	Percentage
α-Tocopherol	21.5
β-Tocopherol	3.7
γ-Tocopherol	3.2
δ-Tocopherol	1.6
α-Tocotrienol	7.3
β-Tocotrienol	7.3
γ-Tocotrienol	43.7
δ-Tocotrienol	11.7

It is obvious that the two major components are α-tocopherol and γ-tocotrienol and this is confirmed by all the other workers. However, the presence of δ-tocopherol was not confirmed by Jacobsberg *et al.* (1978). Analysis by high performance liquid chromatography[1] shows the presence α-tocopherol, α-, β-, γ- and δ-tocotrienols and indications for the presence of the esterified forms of tocopherols and tocotrienols were observed. Tocopherols act as anti-oxidants and thus confer stability to the palm oil. This effect and the low percentage of polyunsaturated fatty acid render palm oil very resistant to oxidative deterioration. Hence, study on ways to minimise the loss of tocopherols during the refining process is important.

The concentration of sterol especially cholesterol is expected to be low in palm oil, being a vegetable oil. A preliminary study on the sterol composition of crude, degummed and bleached, and refined bleached and deoderised (RBD) palm oil and its fractions was completed recently. The results are summarised in Table 7.

Table 7. Sterol composition of crude and refined palm oil and its products[11]

(Unit: ppm)

Sample	Cholesterol	Campesterol	Stigmasterol	Sitosterol	Unknown
Crude palm oil	7~13	90~151	46~66	218~370	2~18
Degummed, bleached	5~10	49~116	22~51	113~286	Trace-8
RBD	1~5	15~61	8~30	45~167	Trace
Crude palm olein	6~8	57~104	30~51	149~253	24~28
Degummed, bleached	3~4	36~43	21~25	99~123	tr to 5
RBD	2	26~30	12~23	68~114	—

Table 8. Composition of phospholipids of palm oil

(Unit: mole %)

Phospholipid	Percentage
Phosphatidylcholine	36
Phosphatidylethamine	24
Phosphatidylinositol	22
Phosphatidylglycerol	9
Diphosphatidylglycerol	4
Phosphatitic acid	3
Lysophosphatidylethanolamine	2
Phosphatidylserine	Trace
Lysophosphatidylcholine	Trace

In general, the amounts of all the sterols were reduced during refining. The levels of cholesterol dropped from 7~13 ppm to 1~5 ppm for crude palm oil and 6~8 ppm to 2 ppm for crude palm olein.

Phosphatides and alcohols Phosphatides (500 ppm) and triterpenic and aliphatic alochols(about 300ppm) are other minor components of palm oil. A quantitative analysis of phospholipids of palm oil using TLC on silica gel G has been carried out by S.H. Goh *et al.*[4] as tabulated below:

Four components were identified among the triterpene alcohols and their concentrations are recorded in Table 9.

Table 9. Composition of triterpene alcohols in crude palm oil

Alcohol	Percentage
Cycloatanol	16.7
β-Amyrin	20.1
Cycloartenol	50.1
2,4-Methylene cycloartanol	13.1

Physical Properties Besides the slip melting point, relative density and refractive index, data on the solid fat content of palm oil for a range of temperatures have been obtained using wide-line nuclear magnetic resonance spectrometry (NMR). The melted sample was tempered for 90 min at 0°C and then 30 min at the measuring temperatures. Table 10 contains the information on the major physical properties of Malaysian palm oil[2,16].

Table 10. Major physical properties of Malaysian palm oil

Property	Mean (of 215 samples)	Range
Relative density at 50°C/water at 25°C	0.893	0.892~0.893
Refractive index at 50°C	1.455	1.455~1.456
Solid fat content		
5°C	60.5	50.7~68.0
10°C	49.6	40.0~55.2
15°C	34.7	27.2~39.7
20°C	22.5	14.7~27.9
25°C	13.5	6.5~18.5
30°C	9.2	4.5~14.1
35°C	6.6	1.8~11.7
40°C	4.0	0.0~7.5
45°C	0.7	0.0~4.5
Slip melting point, °C	34.2	31.1~37.6

The other important physical properties concern the crystallisation and melting behaviour of palm oil which can be studied by differential scanning calorimetry (DSC). Typical crystallisation and melting thermograms of Malaysian palm oil are found in Fig 1 and 2. The sample was heated from room temperature (295 K) to 353 K, held at 353 K for 10 min, cooled to 223 K at 10 K/min, held at 223 K for 10 min and finally heated to 353 K at 10 K/min.

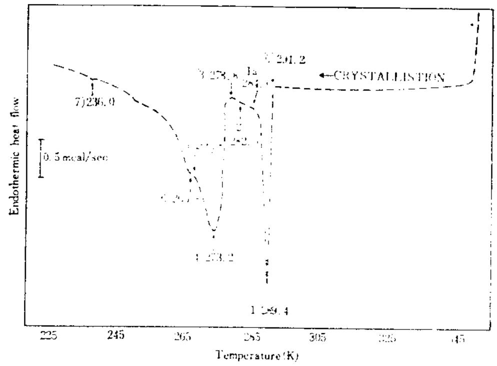

Fig. 1. Crystallisation thermogram of Malaysian palm oil

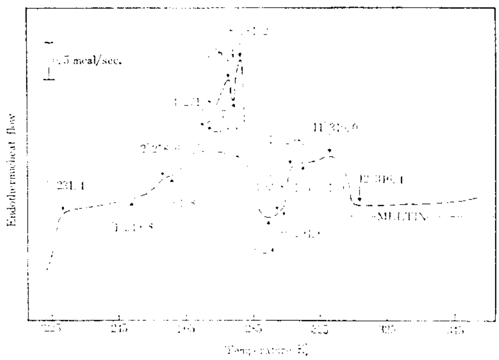

Fig. 2. Melting thermogram of Malaysian palm oil

Palm kernel oil

The chemical and physical properties of palm oil

Table 11. Chemical characteristics of Malaysian palm kernel oil[12]

Tests	Mean
Iodine value	17.8
Saponification value	245
Unsponifiable matter %	0.3
Fatty acid composition % (as methyl esters)	
C6	0.3
C8	4.4
C10	3.7
C12	48.3
C14	15.6
C16	7.8
C18	2.0
C18 : 1	15.1
C18 : 2	2.7
Others	0.2

have been presented. Similar study on palm kernel oil has been completed recently. Thus Table 11 and 12 show that Malaysian palm kernel oil is a well-defined product with only a narrow range of variation in its chemical composition in terms of the fatty acid composition as well as of the triglyceride composition.

Table 12. Triglyceride composition of Malaysian palm kernel oil[12]

Carbon number	Mean percentage	Carbon number	Mean percentage
C 28	0.2	C 42	9.1
C 30	0.8	C 44	6.4
C 32	5.3	C 46	4.9
C 34	7.8	C 48	5.7
C 36	25.1	C 50	2.2
C 38	18.2	C 52	2.1
C 40	9.7	C 54	2.5

Physical characteristics The major physical properties of Malaysian palm kernel oil are outlined in Table 13 while the crystallisation and melting behaviour are illustrated in Fig. 3 and 4[9].

Table 13. Physical characteristics of Malaysian palm kernel oil[12]

Tests	Mean value
Refractive index (a)	1.4509
Slip melting point, °C (b)	27.3
Colour (c)	5.5 Red 50 Yellow
(Lovibond 51/4″ cell)	
Colour (FAC) (d)	—
Carotene content(from absorption at 446 *nm*)	7.6
Solid fat content by wideline NMR (%)	
at 5°C	72.8
10°C	67.6
15°C	55.7
20°C	40.1
25°C	17.1
30°C	—

Current research programme in chemistry and technology

The Palm Oil Research Institute of Malaysia was formally established by the Malaysian Parliament in May 1979 and its proposed headquarters building is being built and expected to be completed by the end of 1983. In the meantime it has acquired two double-stored buildings (5600 sq. ft floor space)for the Chemistry and Technology Division. Though space is limited, it has the best facilities in the country

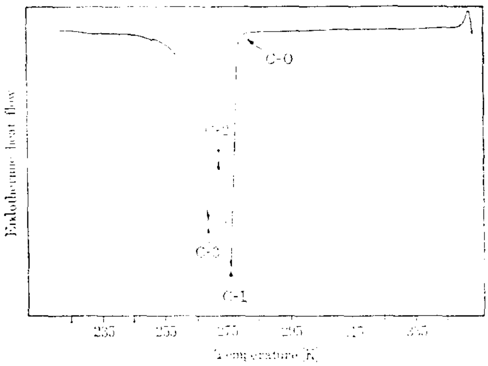

Fig. 3. Crystallisation thermogram of palm kernel oil

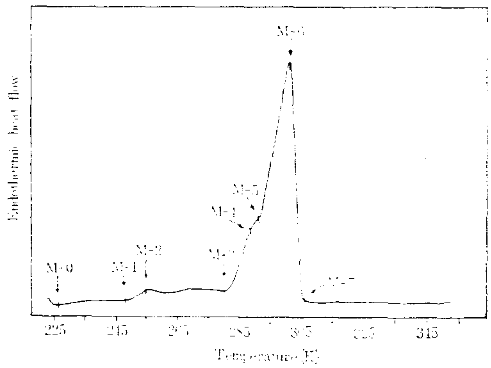

Fig. 4. Melting thermogram of palm kernel oil

for research and development in the oils and fats chemistry and technology. The current staff strength of 36 members includes 7 experienced research officers who lead the various research teams. Research projects were vetted by two committees known as the Technical Advisory Committee to the Director-General and the Programme Advisory Committee to the Palm Oil Research and Development Board.

The function of the Chemistry and Technology Division is to study the problems of the industry from the point of view of chemistry, technology, physics and biochemistry. The Division has undertaken a number of projects in finding suitable solutions to the problems mentioned above. These can be classified into the following areas.

Quality of palm oil The Division has built-up a comprehensive and up-to-date equipment to provide analytical services in the chemistry and physics of oils and fats. In fact, these facilities are considered to be the best in the country. With these facilities and competent manpower baseline-data have been obtained and published on the characteristics of crude and refined palm oil and their fractions and of palm kernel oil. It is also realised that in order that the quality of palm oil and its products be maintained, the quality control laboratories in the country need to have proper procedures in carrying out these analyses. Hence, a number of collaborative trials on quality parameters such as determination of free fatty acids, slip points, iodine values, fatty acid composition by gas liquid chromatography have been successfully carried out. These efforts have in fact resulted further investigations which lead to an improvement of the existing procedures. Further new procedures relevant to the analyses of palm oil have been developed such as the determination of adulteration of crude palm oil with palm stearin using slip points and iodine values. Work on quality of palm oil has also progressed to indepth study on oxidation and parameters which govern the stability of palm oil towards atmospheric oxidation such as the effects of metals and the role of tocopherols and tocotrienols which are the naturallyoccurring anti-oxidants present in palm oil.

A new spectrophotometric method to determine the solid liquid ratio of palm oil has been discovered and published[10].

A spectrophotometric assay procedure for palm oil quality has been proposed. In particular a new analytical method has been found for the determination of the determination of bleachability of crude palm oil on storage due to specific oxidation reactions. This deterioration of bleachability index (or DOBI) is being evaluated by the industry at both local and international levels. The application of DOBI in the definition of "sludge oils" which have very low values due to the rapid deterioration reactions taking place during the recovery of the oil from effluent ponds appears to be promising.

The relevant research projects are as follows:

Title	*Project leader*
a. Accelerated stability test by oxygen absorption	Abd. Gapor b. Mohd. Top
b. Characterisation of palm oil and hybrid oils	Dr. Tan Boon Keng
c. Characterisation of processed palm oil	Dr. Tan Boon Keng
d. Detection of stearin in palm oil	Dr. Tan Boon Keng
e. Collaborative trials of analytical methods for oils and fats	Ms. Siew Wai Lin
f. The contents and the effects of iron in crude and refined palm oil	Abd. Gapor b. Mohd. Top
g. Survey on Malaysian palm kernel oil	Ms. SiewWai Lin
h. Interaction between tocopherols and carotenes	Abd. Gapor b. Mohd. Top
i. Storage of palm oil in relation to quality analysis	Dr. Tan Boon Keng
j. Effect of oxidation on bleachability of palm oil	Dr. PAT. Swoboda
k. Specifications for sludge oil	Dr. Tan Boon Keng
l. New hybrid palm oils	Dr. Tan Boon Keng

Extraction of crude palm oil A major problem associated with the extraction of crude palm oil is the generation of palm oil mill effluent which is reasonably controlled by treatment methods developed by the industries. However, although most of the methods are found to be effective yet there are two problems to be solved namely the concentration of total solids (mainly dissolved) and the increase in the total nitrogen in the treated effluent. These problems have been observed in the number of surveys conducted by PORIM in collaboration with RRIM. A research contract is being worked out with University Pertanian Malaysian to find ways and means of overcoming these particular difficulties. A thorough examination of the extraction of crude palm oil with high quality by the current milling process is being planned.

Several research projects are being initiated including a survey of the effluent from refineries.

Refining of palm oil Palm oil is one of the few oils which contains relatively high concentration of carotenoids and this oil has to be bleached before it can be utilised. Since 95% of the oil is refined in Malaysia, it is important to study in depth the various unit processes in the refining of pamk oil. Most of the oil is physically refined and this involves pretreatment with phosphoric acid followed by treatment with activated earth and finally heated under vacuum at 250 to 270°C where the free fatty acids as well as the odoriferous compounds are removed and where carotenoids are broken down into colourless components. In this investigation, information is sought on the role of polar lipids and their removal by both phosphoric acid and earth treatment as well as on the role of the activated earth which no longer functions as a bleaching agent. The chemical changes induced in the different stages of refining are being studied to determine the extent of isomerisation of the double bonds, migration of the acyl groups, polymerisation etc.

Work on "improvement in palm oil refining" and "effect of oxidation on bleachability of palm oil" is pursued with Dr. Peter Armin Thomas Swoboda as project leader while Mr. Abdul Gapor bin Mohd. Top undertakes research on "interaction between tocopherols and carotenes".

Processing of palm oil Consistent with the objective of finding new uses for palm oil are investigations on fractionation of both palm oil and palm kernel oil and the study on the rate of crystallization of oil. The aim of the research on fractionation of palm oil is to obtain a better yield of the palm mid-fraction which has the potential of being used as a cocoa butter extender thus increasing the use of palm oil. A preliminary study has been carried out in this area. A report on palm mid-fractions produced in Malaysia has been completed. The rate of crystallisation of crude palm oil is an important aspect and needs to be understood in order that the difficulties in processing palm oil due to its slow rate could be overcome. An understanding of this will accelerate the processing of palm oil and increase its utilization in the end product. Study on the interesterification of palm oil and palm kernel oil is being continued.

The relevant research projects are as follows:

Title	*Project leader*
a. Crystallisation baviour of palm oil	Flingoh Oh Chuan Ho
b. Fractionation of palm kernel oil (PKO)	Dr. Tan Boon Keng
c. Fractionation of palm oil	Dr. Tan Boon Keng
d. Interesterification of palm oil and palm kernel oil	Flingoh C. H. Oh

Service functions With the facilities and expertise available in the Division, analytical services in the form of carbon number determination, fatty acid methyl ester determination by gas liquid chromatography, the solid fat content by wideline NMR, the melting and crystallsation behaviour as determined by differential scanning calorimetry as well as the determination of tocopherols and tocotrienols by HPLC are being offered to the industry. It is also carrying out some investigation for the Customs Department in determining the changes taking place in palm oil during storage and in defining the characteristics of sludge oils. Finally the Division offers the whole range of analytical services for work related to end uses of palm oil such as research on increasing the content of palm oil in vanaspati, instant noodles and frying oils, to industrial and biological problems. The good collaboration between those working on end-use research and those providing analytical services will be further strengthend.

The following research projects have been initiated:

Title	*Project leader*
a. New hybrid palm oils	Dr. Tan Boon Keng
b. Preservation of oil samples from further oxidation	Dr. Pat Swoboda
c. Storage test with customs	Dr. Tan Boon Keng
d. Specifications for sludge oil	Dr. Tan Boon Keng

Contract research projects Long term basic research relevant to the chemistry and technology of palm oil are being conducted at both local and overseas Universities. This arrangement will expand the capability of the Institute by utilising facilities available in the Institutes of Higher Learning and the special expertise available therein. Examples of such work are as listed:

1.	The adsorption of β-carotenes by bleaching earths	(U.S.M.)
2.	Fractionation by density gradient	(U.S.M.)
3.	Studies on better utilization of palm oil and palm oil fractions in products	(University of Calcutta)

4. Utilisation of oil palm empty bunch waste for industrial mushroom (Agaricus Bisporus) cultivation and production of compost from the media (U.S.M.)

5. Polar lipids of palm oil (U.M.)

6. An investigation on the possible biochemical causes for the increased free fatty acids in damaged oil palm fruit (U.M.)

Future developments A PORIM Technology Unit has been set up at Brickendonbury, England and will be operational with effect from 1 April 1982. Initial work will be mainly biochemical viz. (a) the thermal and oxidative degradation of β-carotene in palm oil; factors affecting the formation of permanent colour and (b) the isolation from palm oil and plant tissue of non-glyceride components of potential commercial value. Subject to the approval of the Programme Advisory Committee 15 new projects will be initiated this year directed at the improvement of the milling technology, effluent treatment technology and some aspects of basic biochemistry and chemistry besides the thrust areas described earlier. The Division has to work with the constraints of shortage of experienced manpower, limited time and space.

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