FATTY ACID COMPOSITION OF EDIBLE OILS IN THE MALAYSIAN MARKET, WITH SPECIAL REFERENCE TO *TRANS*-FATTY ACIDS

TANG, T S*

ABSTRACT

A total of 113 samples of various types of palm and palm kernel oil products, their fractions, palm-based and non-palm-based cooking oils obtained from local manufacturers and the retail market were analysed for their trans-*fatty acid compositions and contents by capillary gas chromatography.* Trans-*fatty acids were generally absent in crude palm and palm kernel oils. However, they were present at 0.01%-0.06% in refined palm kernel products and 0%-0.61% in refined palm products, all well below the 1.0% level stipulated by some importers. These* trans-*fatty acids were formed from their natural* cis-*isomers as a result of the high temperature used during deodorization.*

In cooking oil, the trans-*fatty acid contents of palm-based products were 0.25%-0.67%, again well below 1%. However, in the non-palm-based cooking oils, the contents of the 14 samples ranged from 0.43%-3.83%. The higher contents in the non-palm-based oils were expected as they had high contents of unsaturated fatty acids, which are more prone to isomerization at elevated temperatures.*

Keywords: *trans*-fatty acids, fatty acid composition, edible oils, palm-based cooking oils, non-palm-based cooking oils.

INTRODUCTION

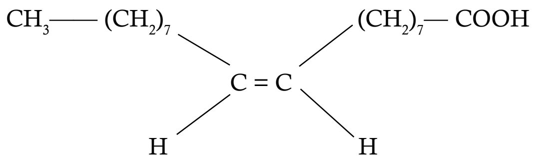
The nutritional attributes of *trans*-fatty acids have been a subject of concern among food scientists, nutritionists and consumers. A report by Mensink and Katan showed that *trans*-fatty acids affect cholesterol levels in much the same ways as saturated fatty acids (INFORM, 1990). Other animal studies have also revealed many adverse nutritional effects of *trans*-acids. They have been implicated as detrimental to health in terms of the metabolism of essential fatty acids, coronary heart and cardio-vascular diseases (Sundram and Chang, 2000), foetal and infant development, and in the treatment of hypercholesterolemia (Simopoulos, 1996; Ong and Chee, 1994; Sundram, 1993).

In natural vegetable oils, the unsaturated acids are present in the *cis*-form. However, highly unsaturated vegetable oils are not suitable for many food applications such as margarines, shortenings, confectionery fats and vanaspati, where solid fats are required. They are thus hardened by catalytic hydrogenation during which the naturally occurring *cis*-unsaturated fatty acids are partly converted to the unnatural *trans*-isomer (*Figure 1*). Small amounts of *trans*-fatty acids are also formed from heat-induced isomerization during deodorization under high temperature (Kovari *et al.*, 1997; Bertoli *et al.*, 1997). The extent of isomerization is more serious in polyunsaturated oils. Depending on the type of unsaturated acids, different *trans*-isomers can be formed from the original *cis*-unsaturated fatty acids. *Figure 2* illustrates the possible *trans*-isomers that can be derived from linoleic and linolenic acids.

As a result of the many suspected undesirable effects of *trans*-acids, scientists have been

* Malaysian Palm Oil Board, P.O. Box 10620,
50720 Kuala Lumpur, Malaysia.

Oleic acid (*cis*-9-Octadecadienoic acid)



Elaidic acid (*trans*-9-Octadecadienoic acid)

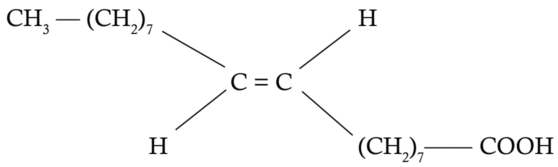
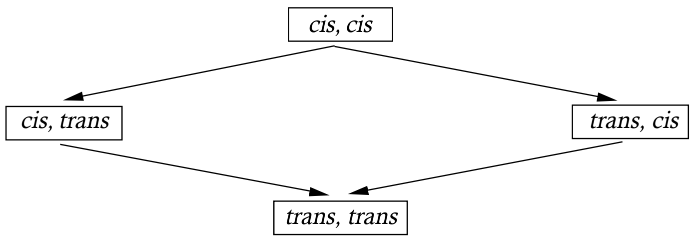


Figure 1. Cis-trans *-isomers of 9-Octadecadienoic acid.*

per reference amount customarily consumed and per labelled serving of the food. Generally, a serving is about 14 g for edible oil. The FDA is currently seeking comments on its proposals (FDA, 1999).

Since the early controversy in the eighties, many surveys on the content of *trans*-fatty acids in fatty foods, such as margarines, bakery fats and fried products, in several countries have been published. Amongst them are those for America (Enig *et al.,* 1983; Slover *et al.,* 1985; Postmus *et al.,* 1989), Canada (Ratnayake, 1991; Postmus *et al.,* 1989), France (Bayard and Wolff, 1995), Austria (Henninger and Ulberth, 1996), Belgium (De Greyt *et al.,* 1996), Denmark (Oveson *et al.*, 1996), Germany (Fritsche and Steinhart, 1997a, b) and the United Kingdom (Kohiyama *et al.,* 1991; Anon., 1997b). Several other similar surveys for Greece, Italy, New Zealand,

Isomerization pathway of linoleic acid (*cis, cis*-9,12-Octadecadienoic acid*)*



Isomerization pathway of linolenic acid (*cis-, cis-, cis*-9,12,15-Octadecatrienoic acid)

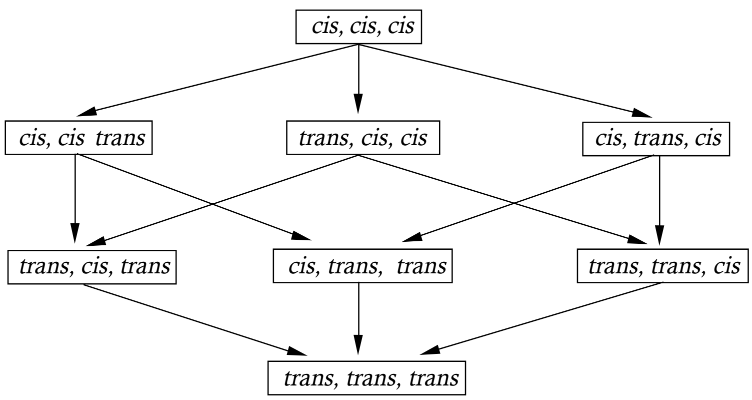


Figure 2. Isomerization of polyunsaturated fatty acids.

campaigning for the avoidance of hydrogenation in the processing of oils and fats for edible use (Anon., 1991; 1997a; Schwarz, 2000) and also for mandatory labelling of the content of *trans*-fatty acids as a separate category in food items (Simopolous, 1996). The United States Food and Drug Administration (FDA) proposed in November 1999 its rules for *trans*-fatty acids in nutrition labelling, nutrient content claims and health claims (Thiagarajan, 2000). The proposals recommended that the *trans-fat free* claim be permitted for foods that contain less than 0.5 g *trans*-fatty acids and less than 0.5 g saturated fats

Spain, Australia and Finland were mentioned in the report by Henninger and Ulberth (l996). A summary of the data from these reports is given in *Table 1.*

Of late, some European importers are preferentially sourcing palm oil products with a maximum *trans*-fatty acid content of 1.0% (Pantzaris, 1997). A short survey of palm oil products and cooking oils from refineries and available in the local market was therefore carried out to ascertain the levels of *trans*-fatty acids.

The determination of *trans*-fatty acids content in oils and fats is normally carried out by either infrared

TABLE 1. *TRANS*–FATTY ACID CONTENTS (%) IN FATTY FOODS IN SOME COUNTRIES

	Food		
Country	Margarine and shortening	Cooking and frying oil	Fries and snacks
America	21.61 - 40.65	-	4.6 - 35.1
Austria	<1 - 50	-	-
Belgium	n.d.* - 18.8	-	-
Canada	10.0 - 49.9	-	-
Denmark	1.4 - 22.3	-	-
France	0 - 62.5	-	-
Germany	0.15 - 4.88	-	0.44 - 22.01
Malaysia	0.6 - 10.2	-	-
United Kingdom	0.5 - 19.7	1.5 - 34.1	2.2 - 21.8

Note: * n.d. – not detected.

spectroscopy (IR) or capillary gas chromatography. In this survey, all the samples were analysed by gas chromatography as the IR method lacks sensitivity and is not reliable if the total *trans*-fatty acids content is below 5% (Duchateau *et al.*, 1996; Ulberth and Henninger, 1996). Capillary gas chromatography can detect down to 0.01%. It can also separate the different *trans*-isomers in polyunsaturated oils, provided a column of suitable length and coated with a higher polar stationary phase is used.

MATERIALS AND METHODS

Samples

A total of 113 different types of palm oil, palm kernel oil, their fractionated products (which were all unhydrogenated) and cooking oils were obtained from palm oil refineries throughout Malaysia and local retailers.

Chemicals

The fatty acid standards used were from Sigma Chemicals. They included lauric, myristic, palmitic, stearic, oleic and elaidic acids. The standard fatty acid mixture for calibration was obtained from Supelco, USA (RM-6 for palm products, RM-5 for palm kernel oil products and RM-1 for non-palm-based cooking oils). All the reagents and solvents used were of AR grade.

Preparation of Fatty Acid Methyl Esters (FAME)

FAMEs of the samples were prepared according to PORIM Test Method p3.4. About 0.05 g of the oil was dissolved in 0.95 ml hexane and 0.5 ml sodium methoxide. The reaction mixture (in a 2 ml vial) was then shaken vigorously in a vortex mixer. The clear, separated methyl ester layer was dried with anhydrous sodium sulphate prior to injection into the gas chromatograph for analysis.

Gas-liquid Chromatography

Analysis of the FAME was then carried out with a Hewlett Packard 6980 series chromatograph equipped with a flame ionisation detector and split injector. A fused silica capillary column coated with a highly polar stationary phase, Supelco SP2340 [100% poly(bis-cyanopropylsiloxane) – 60 m x 0.25 mm id x 0.2 µm], was used with He as the carrier gas. The oven temperature programmes for palm kernel oil products and non-lauric oils (palm oil products and other cooking oils) were:

Palm kernel oil products - 120°C to 185°C at 3°C min^{-1}
Palm oil and other non-lauric oils - 185°C isothermal

The injector and detector temperatures were both set at 240°C while the split ratio was 1:l00.

Quantitative Analysis

The identities of the fatty acids were established by comparing their retention times with either those of authentic standards from Supelco, or those reported in the AOCS method using a similar column (AOCS, 1997). A typical chromatogram showing the peaks and retention times of the fatty acids (including the *trans*-isomers) of palm olein is shown in *Figure 3*. Calibration was established with standard mixtures of methyl esters from Supelco and the quantitative results obtained from the Hewlett Packard Chemstation.

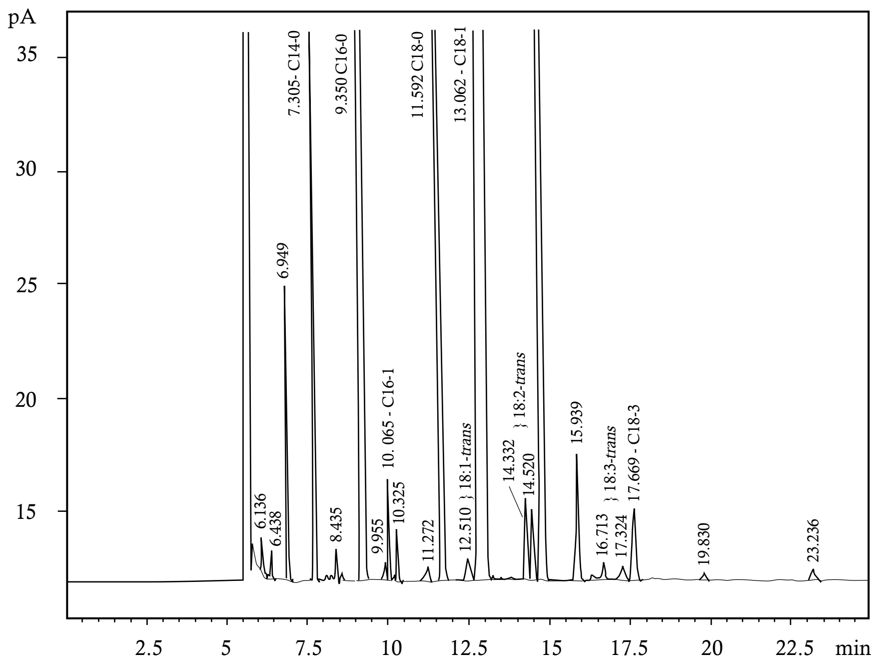


Figure 3. An enlarged GC chromatogram of fatty acid methyl esters from palm olein sample showing the retention times of various peak.

RESULTS AND DISCUSSION

One hundred and thirteen samples of various kinds of palm and palm kernel oils, their fractions, palm-based cooking oils and non-palm-based cooking oils were analysed. *Table 2* summarizes the contents of *trans*-fatty acids obtained. Some comments can be made on the presence of *trans*-fatty acids in the samples analysed.

Crude Palm Oil

No *trans*-acid was detected in all the 12 samples.

RBD/NBD Palm Oil, Palm Olein, Palm Stearin and Superolein

These products are discussed together as they had similar ranges of *trans*-fatty acids. Overall, their mean contents were 0.22% - 0.32%. If the individual samples are considered, then the range is wider at between 0.0% - 0.61%.

Only four NBD oils were analysed - two palm oleins, one palm superolein and one palm stearin. Their *trans*-fatty acid contents ranged from 0.29% - 0.27%. Although the range was narrower than that in RBD palm oil (0.07% - 0.60%), the number of NBD samples was too small to establish any definite difference between the physically and alkaline refined oils.

As *trans*-fatty acids were not detected in the crude samples, their presence in the refined products must be due to isomerization during deodorization which is normally carried out at 250°C - 260°C under vacuum. This is supported by the observation by Kochhar *et al.* (1982) that in the refining of crude soyabean oil (a highly unsaturated oil), *trans*-fatty acids were not detected in the neutralized and bleached oil, but only in the final product after deodorization.

Red Palm Olein

Red palm olein is a specialty cooking oil with a high carotene content. The two samples from the local retail market showed only 0.0% - 0.2% *trans*-fatty acids. These low levels can be attributed to the special refining process which uses a low deodorization temperature to preserve the carotenes from thermal degradation.

Crude Palm Kernel Oil

The oils were mechanically extracted using a screw-press. No *trans*-fatty acids were found in all the eight samples.

RBD/NBD Palm Kernel Oil, Olein and Palm Kernel Stearin

The mean *trans*-fatty acid contents of the RBD/NBD palm kernel oils and their fractions ranged from 0.0% - 0.06%. Overall, the minimum and maximum for the individual samples were 0% and 0.11%, respectively, considerably lower than those observed in the palm oil products. Again, it is quite obvious that the presence of *trans*-fatty acids was due to isomerization during deodorization. No

TABLE 2. *TRANS*-FATTY ACID COMPOSITIONS AND CONTENTS OF 113 SAMPLES OF PALM OIL AND PALM KERNEL OIL PRODUCTS, AND DIFFERENT COOKING OILS

Sample	No. of Sample	*Trans*-fatty acid			Total *trans*-acid		
		C18:1 *t*	C18:2 *tc, ct, tt*	C18:3*t*	Mean (%)	Ranges of values	Standard deviation
Crude palm oil	12	0.0	0.0-0.02	0.0	0.0	0.0-0.02	0.0
RBD palm oil	12	0.0-0.25	0.07-0.35	0.0-0.09	0.32	0.07-0.60	0.155
RBD palm olein	17	0.0-0.11	0.0-0.51	0.0-0.10	0.30	0.0-0.61	0.170
NBD palm olein	2	0.02-0.03	0.09-0.26	0.0-0.04	0.22	0.11-0.33	0.15
RBD superolein	4	0.0-0.04	0.08-0.36	0.0-0.05	0.22	0.08-0.45	0.143
NBD superolein	1	0.03	0.19	0.0	0.23	-	-
RBD palm stearin	12	0.0-0.12	0.0-0.40	0.0-0.03	0.26	0.08-0.40	0.132
NBD palm stearin	1	0.04	0.21	0.02	0.27	-	-
Red palm olein	2	0.0	0.0-0.2	0.0	0.1	0.0-0.2	0.14
Crude palm kernel oil	8	0.0	0.0	0.0	0.0	-	-
RBD palm kernel oil	7	0.0-0.07	0.0	0.0	0.01	0.0-0.07	0.021
NBD palm kernel oil	1	0.0	0.0	0.0	0.0	-	-
RBD palm kernel stearin	6	0.0-0.11	0.0	0.0	0.06	0.0-0.11	0.051
RBD palm kernel olein	3	0.0-0.03	0.0-0.06	0.0	0.03	0.0-0.06	0.031
NBD palm kernel olein	2	0.0	0.0	0.0	-	-	-
Cooking oil, palm-based	9	0.0-0.09	0.09-0.63	0.0-0.13	0.46	0.25-0.67	0.190
Cooking oil, non-palm-based	14	0.0-0.08	0.39-2.69	0.0-2.67	2.03	0.46-3.83	1.370
Total	113						

trans-fatty acid was detected in the two NBD products. The low contents were expected as palm kernel oil and its fractions are much less unsaturated than palm oil products.

Palm-based Cooking Oils

These were either pure palm olein or blends with peanut oil and sesame oil. However, the iodine values and fatty acid compositions suggested that these blends were mainly palm olein. *Trans*-fatty acids were found in every product at 0.25% - 0.67% with an average of 0.46%.

Non-palm-based Cooking Oils

These are consumed by only a small section of the population and are generally more expensive. Their detailed *trans*-fatty acid compositions and contents are given in *Table 3*.

Corn Oil

Four brands were analysed. The total *trans*-acids ranged from 1.13% - 1.96% with a mean of 1.64%. The main *trans*-isomers were those of linoleic acid and linolenic acid.

Sunflower Oil

Three brands were analysed. The *trans*-fatty acids ranged from 0.63% - 2.99% with a mean of 1.42%. The major *trans*-isomers were those of linoleic acid as the linolenic acid content of sunflower oil is low.

Safflower Oil

This is not a common cooking oil in the local market and only one brand was found. Though it was very high in diunsaturated acids, the *trans*-acids content was only 0.85%.

TABLE 3. *TRANS*-FATTY ACID COMPOSITIONS AND CONTENTS OF NON-PALM-BASED COOKING OILS

Cooking oil	No. of sample	*Trans*-fatty acid			Total *trans*-acid		
		C18:1 *t*	C18:2 *tc, ct, tt*	C18:3*t*	Mean (%)	Ranges of values	Standard deviation
Corn oil	4	0.03-0.05	0.75-1.50	0.18-0.43	1.64	1.13-1.96	0.356
Sunflower oil	3	0.0-0.08	0.55-2.69	0.0-0.24	1.42	0.63-2.99	1.360
Safflower oil	1	0.03	0.67	0.15	0.85	-	-
Soyabean oil	4	0.01-0.05	0.43-1.54	1.15-2.67	2.94	1.63-3.83	0.993
Peanut oil	1	0.0	0.46	0.0	0.46	-	-
Rapeseed oil (low erucic)	1	0.04	0.39	2.35	2.78	-	-
Overall non-palm-based cooking oil	14	0.0-0.08	0.39-2.69	0.0-2.67	2.03	0.46-3.83	1.370

Soyabean Oil

Four brands were obtained. They contained 1.63% to 3.83% *trans*-acids and the mean was 2.94%. They had quite similar fatty acid compositions considering only the distribution of fatty acid chain lengths and not the geometric isomers. Thus, the wide range in *trans*-acids content could be attributed to variation in the processing method. The influence of different refining and deodorization treatments on the chemical changes in soyabean oil has been thoroughly investigated by Kochhar *et al.* (1982). As soyabean oil is well known for its high (about 8%) linolenic acid content, it was not unexpected that the samples had higher contents of the *trans*-isomers of linolenic acid than the other common polyunsaturated oils.

Peanut Oil

Only one brand was analysed. It had high contents of arachidic acid (C20:0, 1.34%), behenic acid (C22:0, 3.54%) and lignoceric acid (C24:0, 0.16%) but the *trans*-acids were only 0.46%.

Rapeseed Oil

The only sample analysed was a low erucic acid type. The *trans*-fatty acid content was 2.78%, comprising mainly the *trans*-isomers of linolenic acid. It was reported by Denecke (1995) that natural rapeseed oil contains only traces of *trans*-fatty acids, but during deodorization the level can rise to as high as 9%, depending on the temperature and time of heating used.

CONCLUSION AND RECOMMENDATIONS

The palm and palm kernel oil products sampled in this survey were quite exhaustive, as attempts were made to obtain samples from refineries throughout Malaysia. All the refined products contained only very small amounts of *trans*-fatty acids, generally below 0.7%. Thus, they would easily satisfy the requirement for a maximum of 1.0% total *trans*-acids. As the refining conditions, especially the temperature of deodorization, are the causes of isomerization, care should be taken to optimize the refining conditions to minimize such changes (Siew, 1989).

In palm kernel oil and its fractions, the level of *trans*-isomers is not an issue as they are relatively low in unsaturation and the deodorization temperature used is often milder at 240°C or below. Many of the non-palm-based cooking oils contained more than 1% *trans*-fatty acids as they were more unsaturated and, therefore, more susceptible to isomerization during deodorization.

All in all, this survey provided further evidence that palm and palm kernel oil products are excellent hard-stocks for *trans*-free formulation of texturized fatty products such as margarines, shortenings, confectionery fats and vanaspati. These products can advantageously replace hydrogenated fats which contain not only *trans*-fatty acids, but also possibly a host of other unnatural and polymerized fatty acids formed during hydrogenation to reduce their unsaturation (Hoffman, 1989).

ACKNOWLEDGEMENTS

The author thanks the Director-General of MPOB for permission to publish this paper and all the palm oil refineries for their cooperation in providing the oil samples. The technical assistance provided by the staff of the AOTC Analytical Laboratory is also deeply appreciated.

REFERENCES

ANON. (1991). Hydrogenation should be avoided, researchers say. *Food Chem. News*. July 1. p. 63.

ANON. (1997a). Exposing the margarine myth. *New Straits Times*. 30 September 1991.

ANON. (1997b). *Trans*-fatty acids content of UK fried foods surveyed. *Lipid Technology, July*: 82-83.

AOCS (1997). *Trans* unsaturated fatty acids by capillary column gas chromatography- Cd 14c-94.

BAYARD, C C and WOLFF, R (1995). *Trans*-18:1 acids in French tub margarines and shortenings: recent trends. *J. Amer. Oil Chem. Soc., 72*: 1485-1489.

BERTOLI, C; BELLINI, A; DELVECHIO A; GUMY, D and STANCANELLI, M (1997). Changes occurring during the deodorization of low erucic rapeseed oil. Paper presented at the 22nd ISF World Congress. 8-12 September 1997. Kuala Lumpur.

DE GREYT, W; KELLEN, M and HUYGHEBAERT, A (1996). *Trans* and polyunsaturated fatty acid content of some bakery fats. *Fette/Lipid, 98*: 4, 141-144.

DENECKE, P (1995). About the formation of *trans*-fatty acids during deodorization of rapeseed oil. *Eur. J. of Med. Res.*, *(1995/1996)*:1, 109.

DUCHATEAU, G S M J E; VAN OOSTEN, H J and VASCONCELLOS, M A (1996). Analysis of *cis*- and *trans*-fatty acids isomers in hydrogenated and refined vegetable oils by capillary gas-liquid chromatography. *J. Amer. Oil Chem. Soc., 73*: 275-282.

ENIG, M G; PALLANSCH, L A; SANPUGNA, J and KEENEY, M (1983). Fatty acid composition of the fats in selected food items with special emphasis on *trans* components. *J. Amer. Oil Chem. Soc., 60*: 1788-1793.

FDA (1999). Food labelling: *trans*-fatty acids in nutritional labelling, nutrient content claims and health claims. Special Filing Docket No. 94P-0036, CFSAN 9727. 17 November 1999.

FRITSCHE, J and HANS STEINHART (1997a). *Trans*-fatty acids in German margarines. *Fette/Lipid 99*, *Nr. 6*: 214-217.

FRITSCHE, J and HANS STEINHART (1997b). Contents of *trans*-fatty acids (TFA) in German foods and estimation of daily intake. *Fette/Lipid 99*, *Nr.9*: 314-318.

HENNINGER, M and ULBERTH, F (1996). *Trans*-fatty acids in margarine and shortenings marketed in Austria. Z *Lebensm Unters Forsch, 203*: 210-215.

HOFFMAN, G (1989). *The Chemistry and Technology of Edible Oils and Fats and their High Fat Products*. Academic Press. p. 218-221.

INFORM (1990). Netherlands study puts *trans* in the spotlight again. *INFORM, 1*: 875.

KOCHHAR, S P.; JAWAD, I M and ROSSELL, J B (1982). Studies on soybean oil processing. *Leatherhead FRA Research Report No. 35*: 385-390.

KOHIYAMA, M; SHIMURA, M; MARUYAMA, T; KANEMATSU, H and NIIYA, I (1991). Properties of commercially available margarines on the market in England. *Yukagaku, 40*: 738-746.

KOVARI, K; DENISE, J; ZWOBODA, F; KEMENY, Z S; RECSEG, K and HENON, G (1997). Kinetics of *trans*-isomers fatty acids formation during heating. Paper presented at the 22nd ISF World Congress. 8-12 September 1997. Kuala Lumpur.

ONG, A S H and CHEE, S S (1994*). Trans*-fatty acids: nutritional significance in the diet. Paper presented at the First National Symposium on Clinical Nutrition. 28-30 March 1994. Kuala Lumpur.

OVESON, L; LETH, T and AHANSEN, K (1996). Fatty acid composition of Danish margarines and shortenings, with special emphasis on *trans*-fatty acids. *J. Amer. Oil Chem. Soc., 31*: 971-975.

PANTZARIS, T P (1997). Private communication. MPOB.

POSTMUS, E; deMAN, L and deMAN, J M (1989). Composition and physical properties of North American stick margarines. *Can. Inst. Sci. Tech. J., 22(5)*: 481-486.

RATNAYAKE, W M N; HOLLYWOOD, R and O'GRADY, E (1991). Fatty acids in Canadian margarines. *Can. Inst. Sci. Tech. J., 24(1/2)*: 81-85.

SCHWARZ, W (2000). *Trans* unsaturated fatty acids in European nutrition. *Eur. J. Lipid Sci. Technol., 102*: 633-635.

SIEW, S L (1989). Effects of refining on chemical and physical properties of palm oil products. *J. Amer. Oil Chem. Soc., 66*: 116-119.

SIMOPOULOUS, A P (1996). *Trans*-fatty acids. *Handbook of Lipids in Human Nutrition*. CRC Press Inc. p. 91-99.

SLOVER, H T; THOMPSON, J R; DAVIS, C S and MEROLA, G V (1985). Lipids in margarines and margarine-like foods. *J. Amer. Oil Chem. Soc., 62*: 775-779.

SUNDRAM, K (1993). *Trans*-fatty acids: their dietary and health implications. *Palm Oil Developments No. 19*: 22-25.

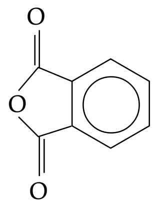
SUNDRAM, K and CHANG, K C (2000). *Trans*-fatty acids and coronary heart disease. *Palm Oil Technical Bulletin Vol. 6(1)*: 2-4.

THIAGARAJAN, T (2000). Proposed US FDA rules for *trans*-fatty acids in nutritional labelling, nutrient claims and health claims. *Palm Oil Technical Bulletin Vol. 6(1)*: 4.

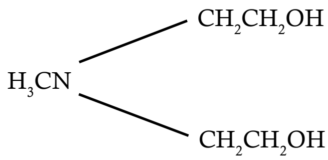
ULBERTH, F and HENNINGER, M (1996). Estimation of *trans*-fatty acids content of edible oils and fats: an overview of analytical methods. *Eur. J. Med. Res., (1995/96)*: 1, 94-99.

ERRATA

Please note the typographical errors in the structures of phthalic anhydride and N-methyl-2,2'-imino-diethanol (MDEA) on pages 8 and 12 of *Journal of Oil Palm Research Vol.13 No. 2.* The errors are regretted. The correct structures are:

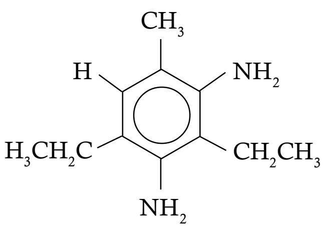


Phthalic anhydride



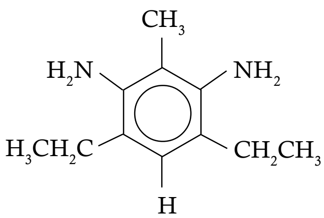
MDEA

Ethacure 100:



97.5%

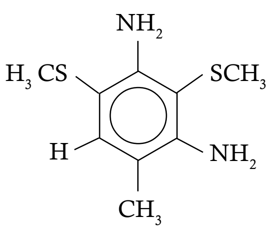
2,4-diethyltoluene-1,3-diamine



2.5%

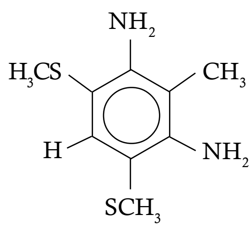
2,4-diethyltoluene-1,5-diamine

Ethacure 300:



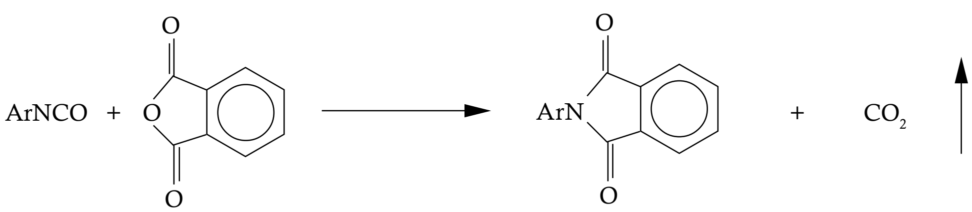
80%

1,3-benzenediamine-4-methyl-2,6-bis(methylthio)-



20%

1,3-benzenediamine-2-methyl-1-4,6-(methylthio)-



Phthalic anhydride

Imide group