Pertanika 11(3), 399-406 (1988)

The Digestion, Absorption and Utilization of Refined Palm Oil, Palm Olein and Palm Stearin in the Rat

T.K.W. NG, H.T. KHOR and Y.H. Chong
Division of Human Nutrition,
Institute for Medical Research,
50588 Kuala Lumpur

Key words : Palm oil; palm olein; palm stearin; soybean oil, digestibility; rate of absorption; utilization; food efficiency

ABSTRAK

Satu penilaian pemakanan yang dibuat pada minyak sawit, minyak sawit olein dan minyak sawit stearin dengan menggunakan tikus menunjukkan bahawa pencernaan, kadar resapan dan efisiensi pemakanan minyak sawit olein adalah lebih baik dibandingkan dengan minyak sawit dan minyak sawit stearin. Namun demikian, indeks-indeks pemakanan tersebut. bagi minyak sawit dan minyak sawit stearin tidak berbeza dengan kebanyakan nilai yang biasanya dilapor untuk minyak masak. Pencernaan dan efisiensi pemakanan minyak sawit olein hampir sama dengan indeks-indeks pemakanan tersebut untuk minyak kacang soya, iaitu 97% dan 98% bagi setiap satunya, walaupun kadar resapan minyak sawit olein adalah 10% kurang dari yang boleh didapati dengan minyak kacang soya.

ABSTRACT

A nutritional evaluation of refined, bleached and deodorised (RBD) palm oil and its fractionation products, RBD palm olein and RBD palm stearin in terms of their digestibility, rate of absorption and food efficiency in rats, shows that RBD palm olein is a better oil by these criteria than RBD palm stearin and the unfractionated RBD palm oil. Nevertheless, the nutritional indices reported for RBD palm oil and RBD palm stearin are well within the range reported for most cooking oils and fats. The digestibility and food efficiency of RBD palm olein are comparable to that of soybean oil, being 97% and 98% respectively of the values found for the latter oil, although the absorption rate of RBD palm olein is 10% less than that obtained for soybean oil.

INTRODUCTION

Edible fats and oils are generally 93–98% digestible (Langworthy, 1923; Crockett and Deuel, 1947). The digestibility of palm oil, which was reported to be 97% (Calloway *et al.*, 1956), falls within this range. On the other hand, fats with melting points above 50°C (Crockett and Deuel, 1947), those that contain higher amounts of stearic acid (Mattil and Higgins, 1945) or triglycerides that contain only saturated, long–chain fatty acids (Mattson, 1959) are less readily digested or absorbed.

Subsequent studies showed that pancreatic lipase specifically hydrolyse the fatty acids esteri-

*The information reported in this paper is contained in the Ph. D thesis of T.K.W. Ng, University of Malaya, 1987.

[1] *Department of Biochemistry, University of Malaya, 59200 Kuala Lumpur.*

[2] *Palm Oil Research Institute of Malaysia, Bandar Baru Bangi 43000 Kajang.*

fied in the I– and 3–positions of a triglyceride (Mattson *et al.,* 1952) and that a high content of palmitic acid esterified at the 2–position of a fat favours its absorption (Tomarelli *et al.,* 1968; Filer *et al.,* 1969). Generally, only a small percentage of the total palmitic acid of vegetable fats and oils is present in the 2–position of the triglyceride molecule; saturated fatty acids having a chain length of more than 18 carbons are found predominantly in the 1–and 3–positions (Bracco and Bauer, 1978).

In an earlier report (Ng, Chong and Khor, 1987), it was shown that the energy availability of RBD palm oil and RBD palm olein are comparable to that of soybean oil. Other than this communication and the very few early fat digestion and absorption studies which included unfractionated refined palm oil reported in the literature, there is practically no information available on common nutritional criteria such as digestibility, absorbability and food efficiency for Malaysian RBD palm olein and RBD palm stearin, although these relatively new processed palm oil fractions are now widely used in cooking and food processing, Thus, there is a fundamental need to establish these nutritional indices mentioned for Malaysian RBD palm oil, RBD palm olein and RBD palm stearin. The information obtained should be of value to local nutritionists and food technologists involved with product development or marketing in the palm oil industry.

MATERIALS AND METHODS

Fat Samples

The fat samples investigated (RBD palm oil, RBD palm olein and RBD palm stearin) were obtained from a production plant in Petaling Jaya. Refined soybean oil was used as the reference fat in this study and was purchased from a local supermarket. The nature and composition of these fat samples were ascertained by fatty acid analysis.

Determination of Fat Digestibility

Ninety 21–25 days old Albino–Swiss strain male rats were divided into 9 uniform groups on the basis of body weight. One group was assigned a fat–free diet (to correct for metabolic fat excreted in the faeces) while the remaining 8 groups were each provided with an experimental diet that

TABLE 1

Composition of the experimental diets

Component (g/ 100 g diet)	Fat level 0% (fat-free)	10% w/w* (21 energy %)	20% w/w* (39 energy %)
Test fat	0.0	10.0	20.0
Casein	20.0	20.8	23.1
Sucrose	20.0	20.0	20.0
Corn starch	51.0	39.9	26.8
Alphacel	4.0	4.0	4.4
AIN mineral mixture 76	3.5	3.7	4.1
AIN vitamin mixture 76	1.0	1.06	1.18
DL– methionine	0.3	0.3	0.3
Choline bitartrate	0.2	0.2	0.2
kcal per 100 g diet	370	420	467

*Diets containing equal amounts of protein, minerals, vitamins and fibre per kcal contained either 10% w/w (21 energy %) or 20% w/w (39 energy %) of each of the four fats studied (see Table 1).

Two animals were housed in each stainless steel cage equipped with a wire–mesh floor and removable aluminium tray at the bottom to facilitate the collection and record of spilled food. Food and drinking water were provided *ad libitum* while food consumption was recorded throughout the 6–week study. The animals were weighed once a week and the faeces for each dietery group were collected for 8 consecutive days at the beginning of the second, fourth and sixth weeks.

Faecal lipids were determined using the extraction procedure described by Bligh and Dyer (1959) with a slight modification: IN HCl was used in place of water in the chloroform-methanol –water mixture (1 : 2 : 0.8).

The coefficient of digestibility values of the fats studied were calculated from the following formula (Alfin–Slater and Aftergood, 1980):

$$\text{Coefficient of digestibility} = \frac{\text{Amount of fat consumed} - \left[\text{Total faecal lipid} - \text{Metabolic fat excreted in faeces}\right]}{\text{Amount of fat consumed}} \times 100$$

Determination of Rate of Absorption of Fats

At the end of the digestibility studies, the adult rats were maintained on their respective diets and used later in the absorption tests. Animals weighing about 240 g were fasted for 48 hours at the end of which their body weights were recorded. Each test animal was then very lightly anesthesized with diethyl ether and a known weight of 1.1 ml of test fat was administered via a 2 ml-syringe connected to a stomach tube. This dosage was equivalent to about 325 mg per 100 cm^2 body surface area according to the formula of Lee (1929).

For RBD palm oil and RBD palm stearin, there was a need to warm the fats slightly above their melting points and then allowed to cool as much as possible before 1.1 ml of the *liquid* samples were taken and administered orally.

At the end of the two absorption periods investigated i.e. 3 hours and 6 hours, the rats were anesthesized and the intact gastrointestinal tract (GIT) from oesophagus to rectum was removed. Fat remaining in the GIT was extracted and quantified according to the procedure described by Deuel *at al.* (1940). A correction was made fo. the quantity of diethyl ether-soluble material which was removable from the GIT of rats fasted for 48 hours but fed no fat.

As a criterion for comparing the rates of absorption of the fats investigated, the Absorption Time $(AT)_{50}$ was employed i.e. the time after which 50% of the administered fat has disappeared from the GIT (Thomasson, 1956).

Statistical Techniques

The standard deviation (SD) was used to measure the variation of a particular determination or parameter.

Where appropriate, the one-way analysis of variance (ANOVA) was used to compute for differences in weight gain, food consumption, food efficiency, digestibility and rate of fat absorption among the various experimental groups, using $\propto = 0.05$ as the level of significance (Welkowitz *et al.*, 1976).

In order to investigate whether two independent factors eg. type of fat and fat level, operate jointly, the F value for interaction was determined using the two-way ANOVA.

RESULTS AND DISCUSSION

Growth and Food Efficiency

The amount of food consumed, growth of the experimental animals and food efficiency of the diets used after 6 weeks are summarised in Table 2. On the whole, the experimental diets were well accepted and animals on the same level of dietary fat consumed approximately equal amounts of food irrespective of the type of fat. However, significantly more of a 10%-fat diet (21 energy %) was consumed compared to a 20% fat diet (39 energy %) for each dietary fat except for the case of RBD palm stearin.

Growth of the experimental animals, as reflected by weight gain, was comparable in *all* the dietary groups provided with 21 energy % fat. When the dietary fat level was approximately doubled to 39 energy %, the animals fed the three palm fats still exhibited comparable growth. However, at this higher dietary fat level, only the palm olein-fed animals showed growth that was similar to that of the soybean oil-fed animals, while growth of the animals fed the other two

TABLE 2

Weight gain, food consumption and food efficiency in male rats fed the experimental diets for 6 weeks (Mean ± SD)

Fat	Dietary level (%)	Initial weight[1] (g)	Weight gain[2] (g/rat)	Food consumed[3] (g/rat)	Food efficiency[4]	Wt gain per 1,000 kcal (g)
Soybean oil	10[a]	37.7	154.1 ±10.26	387 ±17.4	0.398 ±0.016	94.8 ±3.81
	20[b]	37.8	169.1 ± 8.97	351 ± 7.0	0.482 ±0.011	103.2 ±2.27
Palm olein	10	37.9	145.9 ±13.23	383 ±18.5	0.381 ±0.018	90.7 ±4.24
	20	37.8	165.0 ±13.01	352 ±11.6	0.468 ±0.008	100.2 ±1.81
Palm oil	10	37.8	146.2 ±10.05	387 ±21.5	0.378 ±0.006	90.0 ±1.56
	20	37.7	159.5 ± 5.40	350 ±10.1	0.453 ±0.011	97.0 ±2.34
Palm stearin	10	37.7	146.1 ±18.75	384 ±22.5	0.380 ±0.011	90.6 ±2.73
	20	37.8	157.9 ± 9.88	377 ±10.5	0.419 ±0.008	89.7 ±1.76
LDS (5%)[5]		n.s.[6]	8.75	20.5	0.0158	3.38

[1,2] Mean of 10 rats per experimental group [3] Calculated from 5 pairs of rats per group

[4] Food efficiency = Weight gain in grams per gram of food consumed; F value for interaction of fat type and fat level significant by two-way ANOVA for $\alpha = 0.05$

[5] Least significant difference by one-way ANOVA for $\alpha = 0.05$ [6] Not significant

[a] Equivalent to 21 energy % [b] Equivalent to 39 energy %

palm fats was now significantly lower than that obtained with the reference fat mentioned.

The food efficiency, defined as weight gained in grams per gram of food consumed, found for the 39 energy %-fat diets was significantly higher than that obtained for the diets containing the same fat at 21 energy %. While this result was not unexpected, the higher food efficiency obtained with a 39 energy %-fat diet was apparently due to a more efficient utilization of food at this higher level of dietary fat rather than to the greater energy intake attributed to 39 energy %-fat diets *per se.* This effect of dietary fat level on efficiency of utilization of food can be ascertained by the provision of isocaloric feeding. Alternatively, as was done in the present analysis, the influence on weight again by differences in energy intake between animal groups can be excluded to a large extent by expressing the efficiency of utilization of food as weight gain per 1,000 kcal intake. When this was done, the efficiency of utilization of food generally remained significantly higher with the 39 energy %-fat diets than with the 21 energy %-fat diets.

As shown in Table 2, the F value for interaction of fat type and fat level in the 4 x 2 factorial design was found to be significant ($\alpha = 0.05$) for food efficiency. This means that the effect of fat type on growth varied when the dietary fat level was changed. Thus, at 21 energy %-fat level, the diets containing each of the three palm fats had

TABLE 3

Digestibility of the various fats studied[1]

Fat	Dietary level (%)	Coefficient of Digestibility (%)[2] Analysis by One–way Anova	Analysis by Two–way Anova[3]
Soybean oil	10[a]	98.8 ± 0.13[c]	98.8
	20[b]	98.8 ± 0.21	
RBD palm olein	10	96.0 ± 0.24	96.4
	20	96.8 ± 0.50	
RBD palm oil	10	95.5 ± 0.46	95.8
	20	96.1 ±0.21	
PBD palm stearin	10	93.7 ± 0.51	94.2
	20	94.7 ± 0.36	
LSD $_{(5\%)}$		0.61	0.43

1 Data obtained from 5 pairs of male rats per experimental group

2 Mean for three periods

3 F value for interaction of fat type and fat level is not significant at $\alpha = 0.05$

a Equivalent to 21 energy % b Equivalent to 39 energy %

c SD

similar food efficiency values but on doubling the dietary fat level to 39 energy %, the food efficiency of the RBD palm olein diet, while not different from either the soybean oil or RBD palm oil diet, was significantly higher than for the RBD palm stearin diet. These findings agree with the report of Barki (1950) that different fats may have different optimum levels of intake and that comparing the nutritional value of fats based on only one dietary fat level may be inappropriate.

Fat Digestibility

The coefficient of digestibility values for each of the fats used were closely similar for the three periods (scond, fourth and sixth weeks) investigated. No apparent trend was observed for the digestibility of a fat in relation to the age of the animals after an initial orientation period of a week. The mean digestibility values found for these three periods were calculated for each fat and the results are presented in Table 3.

Table 3 shows that on the whole, slightly higher digestibility values were obtained with the diets containing the higher level (39 energy %) of fat except for the case of soybean oil. Similar observations were recorded by Hoagland and Snider (1943) in feeding tests with rats using purified diets containing 5% w/w and 15% w/w of fat.

Although the coefficient of digestibility values obtained for the individual refined palm oil fractions differed significantly ($\alpha = 0.05$), these values nevertheless fall within the range reported for most edible fats and oils as shown in Table 4.

TABLE 4

Digestibility of Malaysian refined palm oil compared with some common edible oils[a]

Fat/oil	Coefficient of digestibility (%)
Soybean oil	98.8
Corn oil	98.3[b]
Cottonseed oil	97.0
Coconut oil	96.5[b]
RBD palm olein	96.4
RBD palm oil	95.8
RBD palm stearin	94.2
Hydrogenated soybean oil	91.7
Butterfat	90.7[b]

[a]Values presented are those obtained by the authors unless otherwise stated

[b]Data of Hoagland and Snider (1943), using diets containing 15% w/w of fat

TABLE 5

Absorption of the test fats following the administration of 1.1 ml to fasting male rats

	Fat	Wt of Animal[1] (g)	Body surface Area[2] (cm^2)	Fat Absorbed[3] % of fat fed Absorbed	Fat Absorbed[3] Mg per 100 cm^2 per hour	
3–Hour Absorption	Soybean oil	226.0 ± 6.59	324.1 ± 5.27	41.5 ± 5.85	42.7 ± 5.96)	37.1*
	Palm olein	227.5 ± 4.17	325.4 ± 3.37	38.0 ± 5.24	38.6 ± 5.37)	
	Palm oil	225.6 ± 2.38.	323.9 ± 2.10	36.5 ± 4.57	36.8 ± 4.45)	
	Palm stearin	226.0 ± 3.62	324.1 ± 3.04	30.2 ± 3.89	30.5 ± 3.73)	
6 Hour Absorption	Soybean oil	225.5 ± 4.50	323.6 ± 3.92	66.6 ± 6.88	34.4 ± 3.87)	31.1*
	Palm olein	227.2 ± 4.13	325.4 ± 3.54	61.5 ± 7.20	34.4 ± 3.87)	
	Palm oil	225.5 ± 3.85	323.8 ± 3.24	60.0 ± 8.76	30.3 ± 4.57)	
	Palm stearin	224.5 ± 1.41	322.8 ± 1.03	57.9 ± 5.89	29.3 ± 3.03)	
	$LSD_{(5\%)}$				3.17	

[1,2]Mean ± SD for 8 animals per experimental group

[3]Corrected for the quantity of ether-soluble material removable from the GIT of rats after a 48-hour fast but fed no oil

*Significantly different by two-way ANOVA for $\alpha = 0.05$

Rate of Fat Absorption

The absorption of the test fats following the administration of a known weight of 1.1 ml sample to fasting male rats are shown in Table 5.

The absorption rates of the fats over the first 3 hours (mean of 37. l mg per 100 cm^2 per hour) were consistently higher than the rates for the 6–hour periods (mean of 31.3 mg per 100 cm^2 per hour). This was expected and might be explained by the relatively faster rate of absorption of the shorter–chain fatty acids or unsaturated fatty acid components intially and later, the remaining longer-chain saturated fatty acids were not as readily absorbed or utilised (Deuel *et al.*, 1940.

From Table 5, it can be seen that the rate of absorption of soybean oil was significantly higher than for RBD palm olein, although their growth-promoting effects were comparable at either 21 energy % or 39 energy % dietary fat level. Thus, the rate of absorption of a fat need not be correlated with its growth-promoting effect or food efficiency, as was earlier suggested by other investigators (Thomasson, 1956; Gottenbos and Vles, 1983). Nevertheless, absorbability of a fat reflects its value as an energy substrate and a source of the fat-soluble vitamins, and is therefore a useful nutritional criterion.

Using a fat dosage of about 325 mg per 100 cm^2 body surface area, the percentage of fat administered remaining in the GIT after 3 hours and 6 hours, and the corresponding AT_{50} values are shown in Table 6.

For a particular fat dosage employed, a lower AT_{50} value represents a faster rate of absorption. Under the present experimental conditions, the AT_{50} values of the fats studied ranged from 241 minutes for soybean oil to 309 minutes for RBD palm stearin. Using a higher fat dosage of 400 mg per 100 cm^2 body surface area, Thomasson (1956) reported AT_{50} values of 359 minutes and 416 minutes for soybean oil and unfractionated palm fat respectively.

CONCLUSION

Refined palm oil and its fractionation products, palm olein and palm stearin are easily digested, well absorbed and efficiently utilised for growth.

The coefficient of digestibility values obtained for RBD palm oil, RBD palm olein, RBD palm stearin and soybean oil were 95.8%, 96.4%, 94.2% and 98.8%, respectively which all fall within the range reported for most edible fats and oils.

The relative rates of absorption found for the three refined palm oil fractions, as measured by the amount of fat absorbed after 3 hours or 6 hours and their Absorption $Time_{50}$ values, were in the order RBD palm olein > RBD palm oil > RBD palm stearin.

ACKNOWLEDGEMENTS

This study was supported by a research grant provided by the Palm Oil Research Institute of Malaysia (PORIM).

TABLE 6

AT_{50} values derived from the percentage of fat administered remaining in the GIT after 3 hours and 6 hours

Fat	Percentage of fat administered remaining in the GIT		AT_{50}*
	3 hours	6 hours	(minutes)
Soybean oil	58.5	33.4	241
RBD palm olein	62.0	38.5	272
RBD palm oil	63.5	40.0	283
RBD palm stearin	69.8	42.1	309

*Time after which 50% of the administered fat had disappeared from the GIT.

REFERENCES

ALFIN-SLATER, R.B. and L. AFTERGOOD (1980): Lipids In "Modern Nutrition in Health and Disease", Sixth Edition. Goodhart, R.S. and M.E. Shils (eds.), Lea and Febiger, Philadelphia.

BARKI, V.H., R.A. COLLINS, C.A. ELVEHJEM and E.B. HART (1950): The importance of the dietary level of fats on their nutritional evaluation. *J. Nutr.* 40: 383-392.

BLIGH, E.G. and W.J. DYER (1959): A rapid method of total lipid extraction and purification. *Canadian J. Biochem. Physiol.* 37: 911-917.

BRACCO, U. and H. BAUER (1978): Human milk lipids and problems related to their replacement *In* "Lipids and Nutrition", Annales Nestle 40, p. 55-81.

COLLAWAY, D.H., G.W. KURTZ, J.J. MCMULLEN and L.V. THOMAS (1956): The absorbability of natural and modified oils. *Food Research.* 21: 621.

CROCKETT, M.E. and H.J. Jr. DEUEL (1947): A comparison of the coefficient of digestibility and the rate of absorption of several natural and artificial fats as influenced by melting point. *J. Nutr.* 33: 187-194.

DEUEL, H.J. Jr., L. HALLMAN and A. LEONARD (1940): The comparative rate of absorption of some natural fats, *J. Nutr.* 20: 215-226.

FILER, L.J., Jr., F.H. MATTSON and S.J. FOMAN (1969) Triglyceride configuration and fat absorption by the human infant. *J. Nutr.* 99: 293-298.

GOTTENBOS, J.J. and R.O. VLES (1983): The nutritive value of palm oil *In* "Nutrition", Berger, K.G. (ed.). PORIM Occasional Paper No. 8.

HOAGLAND, R. and G.G. SNIDER (1943): Digestibility of some animal and vegetable fats. *J. Nutr.* 25: 295-302.

LANGWORTHY, C.F. (1923): The digestibility of fats. *J. Ind. Eng. Chem.* 15: 276.

LEE, M.O. (1929): Determination of the surface area of the white rat with the application to the expression of metabolic results. *Am. J. Physiol.* 89: 24-33.

MATTIL, K.F. and J.W. HIGGINS (1945): The relationship of glyceride structure to fat digestibility, I. Synthetic glycerides of stearic and oleic acids. *J. Nutr.* 29: 255-260.

MATTSON, F.H. (1959): The absorbability of stearic acid when fed as a simple or mixed triglyceride. *J. Nutr.* 69: 338-342.

MATTSON, F.H., J.H. BENEDICT, J.B. MARTIN and L.W. BECK (1952): Intermediates formed during digestion of triglycerides. *J. Nutr.* 48: 335-344.

NG, T.K.W., Y.H. CHONG and H.T. KHOR (1987): Food energy from palm oil and its fractionation products, palm olein and palm stearin. *Pertanika.* 10(3): 305-309.

THOMASSON, H.H. (1956): The biological value of oils and fats. IV. The rate of intestinal absorption. *J. Nutr.* 59: 343-352.

TOMARELLI, R.M., B.J. MEYER, J.R. WEABER and F.W. BERNHART (1968): Effect of positional distribution on the absorption of the fatty acids of human milk and infant formulas. *J. Nutr.* 95: 583-590.

WELKOWITZ, J., R.B. EWEN and J. COHEN (eds.) Introductory Statistics for the Behavioral Sciences, 2nd Edition. Academic Press, New York. pp 140-146, 1976.

(Received 10 March, 1988)