PJN
ISSN 1680-5194

PAKISTAN JOURNAL OF NUTRITION

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

Pakistan Journal of Nutrition 2 (5): 271-278, 2003

Effect of Red Palm Oil and Refined Palm Olein on Nutrient Digestion in the Rat

D.O. Edem[1], O.U. Eka[2], I.B. Umoh[2], A.P. Udoh[1] and E.J. Akpan[1]
[1]Department of Chemistry and Biochemistry, University of Uyo, Uyo, Akwa Ibom State, Nigeria
[2]Department of Biochemistry, University of Calabar, Calabar, Nigeria

Abstract: A nutritional evaluation was carried out to determine the effects of red palm oil and refined palm olein on digestion of nutrients in animals. Four-week-old Wistar albino rats (n = 8 per group) were maintained for 28 days on standard dry rat food supplemented (10, 20 and 30% by weight) with red palm oil (RPO) and refined palm olein (REFPO). The digestion of nutrients (measured from the differences between nutrient intake and fecal nutrient) by rats fed 10% oil-supplemented diets was comparable to that of the control ($p>0.01$). There were inverse dose-effect relationships between the level of dietary fat and digestion of protein, fat, carbohydrate, calcium, potassium, sodium, magnesium, manganese and copper. In comparison with other experimental groups, animals fed 30% oil diets exhibited the lowest digestion of proximate nutrients ($p<0.01$) and minerals ($p<0.001$) in addition to exhibiting the poorest feed utilization ($p<0.01$). In general, no significant variations were observed (among the parameters measured) between RPO-fed and REFPO-fed rats, for each level of test dietary fat ($p>0.01$). The above findings suggest that consumption of palm in moderate amounts may impact growth and development through effects on nutrient retention.

Key words: Red palm oil, refined palm olein, nutrient digestion

Introduction

Oils are important nutrients and energy sources that are composed mostly of triacylglycerols. Dietary triacylglycerols are composed of fatty acids that may vary in their chain length, degree of unsaturation, isomeric orientation of double bonds and position within the triacylglycerol molecule (Hassel *et al*., 1997).

Palm oil, a triglyceride with a melting point 34.2 °C contains approximately 44% palmitic acid and is 97% digestible (Colloway *et al*., 1956). This oil, which is one of the richest sources of β-carotene, is obtained from the fleshy orange-red mesocarp of the fruits of the oil palm tree (Elaeis guineensis). Refined palm olein (REFPO) is the liquid fraction obtained from the refining, bleaching and deodorization of the crude red palm oil (RPO). This fractionation brings about enrichment with the monounsaturated oleic acid in addition to the concomitant reduction of palmitic acid, the major saturated fatty acid (MacFarlane *et al*.,1984; Chong and Ng, 1991).

Ng *et al*. (1988) reported on the digestion, absorption and utilization of palm oil and its fractionation products in the rat. However, there is a paucity of information on the effects of red palm oil and refined palm olein on nutrient retention in animals, although these oils are widely used in cooking and food processing. Thus, there is a need to establish these effects, since the information obtained could be of value in food industries.

Materials and Methods

Oil samples: Red palm oil (RPO) with a free fatty acid (FFA) content of 3% was taken from the palm oil mill at the Nigerian Institute For Oil Palm Research (NIFOR), Abak substation, Akwa Ibom State, Nigeria. Refined palm olein (REFPO), Turkey King Brand) was purchased from a municipal supermarket in Calabar, Nigeria; it had a FFA content of 0.95.

Experimental diets: The test diets were prepared (by mixing each of the oils with normal commercial rat mash) to contain 10, 20 or 30% oil. The 10% oil diet was prepared by adding 5.6g oil to 94g rat mash.16.1g oil was added to 84g rat mash to produce the 20% oil diet while the 30% oil diet consisted of 73.5g rat mash to which 26.5g oil was added. Details of the nutrient composition of the experimental diets are shown in Table 1.

Experimental animals: Fifty-six (4-weeks old) Wistar male rats were divided into 7 uniform groups on the basis of body weight. One group was assigned to the normal commercial rat mash (obtained from Bendel Feed and Flour Mill Limited, Benin City, Nigeria) group. The remaining 6 groups were each provided with a test diet, which consisted of rat mash, supplemented with 10, 20 or 30% (by weight) RPO or REFPO.

The animals were housed individually in stainless steel cages equipped with wire-mesh floors and removable plastic trays at the bottom to facilitate the collection and recording of spilled food and feces. The animal room temperature was 27± 2 °C. A light: dark cycle of 13hr: 11hr was used throughout the study. All the experimental animals were given free access to food and drinking water; while food consumption was recorded throughout

Table 1: Nutrient composition of experimental diets*

Proximate composition (%)	Control	10% RPO	20% RPO	30% RPO	10% REFPO	20% REFPO	30% REFPO
Protein	16.3±0.6	15.4±0.6	13.7±0.5	12.0±0.4	15.4±0.5	14.2±0.5	12.0±0.4
Fat	4.7±0 0	10.0±0.0	20.0±0.0	30.0±0.3	10.0±0.0	20.0±0.0	29.9±0.2
Fibre	7.9±0.5	7.5±0.4	6.7±0.4	5.9±0.4	7.4± 0.4	6.6± 0.4	5.8±0.4
Ash	7.0±0.5	6.6±0.5	6.0±0.4	5.2±0.4	6.5±0.5	5.9±0.4	5.2±0.4
Carbohydrate	64.1± 0.8	60.6±0.5	53.6±0.7	46.9±0.6	60.7±0.5	53.3±0.6	47.1±0.6
Food Energy (KJ/g)	15.2±0.1	16.5±0.1	18.8±0.2	21.2±0.0	16.6±0.1	18.9±0.2	21.1± 0.2
Mineral Composition (mg/100g)							
Calcium	825.3±0.0	776 ± 0.0	693±0.0	611±0.0	776±0.0	689±0.0	606±0.0
Magnesium	30.0±0.0	33.8±0.0	30.2±0.1	26.7±0.2	33.7±0.0	30.2±0.1	26.5±0.1
Potassium	205±0.1	193±0.1	172±0.1	152±0.1	192± 0.3	171±0.1	151±0.0
Sodium	450±0.0	423±0.1	378±0.1	331±0.1	421±0.1	374±0.7	334±0.8
Iron	168±0.1	158±0.1	141±0.1	124±0.0	157±0.1	140±0.0	123±0.0
Zinc	35.0±0.0	32.9±0.0	29.3± 0.1	25.9±0.0	32.7±0.0	29.1±0.1	25.6±0.2
Manganese	39.2±0.0	36.9±0.0	32.9±0.1	29.0±0.0	36.7±0.0	32.7±0.1	28.8±0.0
Copper (µg/100g)	331± 0.0	311± 0.0	278±0.0	245±0.0	310±0.0	276±0.6	244±0.0

Values are means of 3 determinations ± SE. Legend: RPO = red palm oil; REFPO = refined palm olein

the 4-week study. Body weights were taken weekly. Feces for the determination of proximate and mineral nutrients were collected during the last 4 days of the study. All animal management and experimental procedures were performed in strict accordance with the requirements of the National Research Council's Guide for the Care and Use of Laboratory Animals (NRC, 1985).

Determination of proximate and mineral composition of feed and feces: The recommended methods of the AOAC (1990) were adopted for the analysis of proximate nutrients. The food energy contents of the experimental diets were calculated by applying the conversion factors of 16.74, 37.67 and 16.74kJ/g respectively for the energy contents of protein, fat and carbohydrate. The mineral composition was determined as described by Horwitz (1980). One gram of each ground sample was digested in concentrated nitric acid-perchloric acid mixture (1:3). The digest was transferred to a volumetric flask and diluted to 50mL with glass distilled-deionized water (containing 5% lanthanum chloride). Aliquots of the digest were analyzed using an atomic absorption spectrophotometer (UNICAM 919, Cambridge, England) against appropriate standards. Sodium and potassium were determined by flame photometry.

Nutrient digestion: The percentage of each nutrient digested was calculated using the formula:

$$\%\text{nutrient digested} = \frac{I - F}{I} \times 100$$

where I = nutrient intake and F = amount of nutrient excreted in feces.

Statistical Analysis: Results are expressed as the means ± SE. The significance of differences between mean values was determined by Student's t-test or one-way analysis of variance (ANOVA). When ANOVA indicated significant differences, group means were compared by Student's t-test. Differences were considered significant at $p<0.01$, unless otherwise specified.

Results

Growth and Feed Efficiency: The average food intakes (AFI), body weight gains (BWG) and feed efficiency ratios (FER) for the 28-day exposure of the animals to the experimental diets are summarized in Table 2. Feed consumption (g/rat/day) of the rats fed the 10% oil-supplemented diets (11.90-12.30) were comparable to that of the control (11.87). More of a 10% fat diet (23.24 energy %) was consumed compared to a 20% fat diet. The groups fed the 30% fat diet (52.28 energy %) had the lowest AFI (5.26-5.62g/rat/day).

Growth of the experimental animals as reflected by BWG was comparable in all the dietary groups provided control diet (59.9g) and 23.24 energy % fat (61.8-68.1g). When the dietary fat level was doubled to 40.01 energy %, the animals fed the two palm fats exhibited growth with BWG of 24.8-29.8g; this was lower than those of the control and the 10% oil groups. The growth of rats fed 30% oil diets were significantly lower than those obtained with the other experimental diets ($p< 0.01$).

The FER of the groups of rats fed the 10% oil-enriched diets (0.19-0.20) were higher than those of the control (0.18) and other experimental groups (0.07-0.11). Increment of dietary fats produced decreases in FER in a dose-dependent manner.

Nutrient consumption and excretion: Information in Table 3 and 5 shows the mean protein, fat, carbohydrate (and minerals) consumed and excreted per rat daily for the various groups of experimental rats, based on the proximate and mineral composition of the experimental

Table 2: Nutritional performance of rats fed the various experimental diets*

Parameter	Dietary Group						
	Control	10%RPO	20%RPO	30%RPO	10%REFPO	20%REFPO	30%REFPO
Average food intake (g/rat/day)	11.87^{a}±0.34	11.90^{a}±0.22	9.81^{b}±0.39	5.52^{c}± 0.36	12.30^{a}± 0.23	9.41^{b}±0.30	5.26^{c}±0.12
Average daily energy intake (kJ/rat)	180.84^{a}±1.72	195.53^{a}±4.21	184.85^{a}±2.68	118.92^{b} ±5.10	209.92^{a}±6.26	177.53^{a}±4.18	107.99^{b}±4.40
Average fecal output (g/rat/day)	2.06^{a}±0.18	2.44^{ac}±0.13	1.92^{a}±0.15	1.99^{ab}±0.01	2.32^{ac} ±0.11	1.89^{ab}±0.05	1.72^{ad}±0.02
Body weight gain* (g/rat)	59.94^{a} ±2.39	61.83^{a} ±4.09	30.75^{b} ±3.38	15.34^{c}±2.05	68.08^{a}±3.37	26.31^{b}±1.43	9.93^{c}±2.50
Feed efficiency ratio	0.18^{a}±0.01	0.19^{a}±0.01	0.11^{b} ±0.01	0.10^{b}±0.01	0.20^{a}±0.01	0.10^{b}±0.01	0.07^{b}±0.02

*Values are means ±SE (n = 8). Values in same row not sharing a common letter are significantly different ($p<0.01$). Legend: RPO = red palm oil; REFPO = refined palm olein

Table 3: Consumption and fecal output of protein, fat and carbohydrate * during the 4-day collection period in rats fed red palm oil (RPO) and refined palm olein (REFPO)

Parameter	Dietary Group						
	CONTROL	10% RPO	20%RPO	30%RPO	10%REFPO	20%REFPO	30%REFPO
Protein intake (g/rat/day)	1.94 ± 0.07^{a}	1.83±0.07^{a}	1.35±0.05^{b}	0.67±0.02^{c}	1.89±0.07^{a}	1.29±0.05^{b}	0.66±0.02^{c}
Fat intake (g/rat/day)	0.56±0.00^{a}	1.19± 0.01^{b}	1.96±0.00^{c}	1.68±0.03^{d}	1.23±0.00^{b}	1.89±0.02^{c}	1.56±0.00^{d}
Carbohydrate intake (g/rat/day)	7.60±0.09^{a}	7.17±0.09^{a}	5.28±0.06^{b}	2.65±0.02^{c}	7.88±0 16^{a}	5.06±0.06^{b}	2.48±0.03^{c}
Fecal protein (g/rat/day)	0.35±0.01^{a}	0.31±0.01^{a}	0.29±0.01^{a}	0.26±0.02^{ab}	0.27±0.02^{ab}	0.32±0.01^{a}	0.20±0.01^{b}
Fecal fat (g/rat/day)	0.01±0.00^{a}	0.03±0.01^{b}	0.11±0.00^{c}	0.15±0.01^{c}	0.04±0.00^{b}	0.10±0.00^{c}	0.11±0 00^{c}
Fecal carbohydrate (g/rat/day)	1.24±0.01	1.44±0.09	1.00±0.09	1.01±0.06	1.35±0.03	1.04±0.07	1.04±0.00

* Values are means ± SE (n = 8 rats per group). Values in same row not sharing a common superscript are significantly different ($p<0.01$)

Table 4: Proximate and mineral composition of feces (mg/100g sample) from rats fed red palm oil (RPO) or refined palm olein (REFPO)*

Nutrient	Dietary Group						
	Control	10% RPO	20%RPO	30%RPO	10%REFPO	20%REFPO	30%REFPO
Protein^{+} (%)	16.92^{a}±0.29	12.84^{b}±0.29	14.88^{ab}±0.51	13.07^{abc}±0.87	11.67^{bc}±0.29	17.21^{ab}± 0.29	11.45^{c}±0.50
Fat^{+} (%)	0.50^{a}±0.06	1.23 ^{b}±0.05	5.38^{c}±0.18	7.57^{d}±0.49	1.57^{b}± 0.49	5.19^{c}±0.16	6.30^{d}±0.46
Carbohydrate^{+} (%)	60.00^{a}±0.32	59.05^{a}±3.52	54.85^{ab}±2.58	50.70^{b}±3.38	58.15^{ab}±1.33	55.10^{b}±0.53	60.29^{a}±0.27
Mineral Element^{++}							
Ca	39.50^{a}±2.47	99.00^{abc}±9.58	98.00^{b}±0.60	65.00^{c}±0.00	59.50^{a}±0.29	100.00^{b}±0.57	115.00^{bc}±5.88
Mg	11.50^{a}±0.29	12.67^{a}±0.33	24.00^{b}±0.00	29.50^{c}±0.29	10.33^{a}±0.33	24.00^{b}±0.00	29.75^{c}±0.14
K	290.00^{ad}±0.00	229.50^{b}±0.29	296.67^{a}±3.33	174.60^{c}±1.40	299.10^{ac}±0.52	286.67^{a}±3.33	160.40 ^{c}±1.00
Na	300.00^{a}±3.65	220.00^{b}±1.11	406.67^{c}±6.68	243.70^{d}±2.34	339.00^{a}±4.58	483.33^{c}±6.68	295.25^{d}±5.52
Fe	35.44^{a}±0.04	20.85^{c}±0.03	47.98^{c}±0.52	15.64^{c}±0.22	37.53^{a}±0.30	52.12^{c}±0.54	17.72^{d}±0.27
Zn	68.15^{a}±0.03	32.95^{b}±0.71	27.03^{c}±0.87	42.00^{c}±0.88	42.85^{b}±0.90	17.99^{c}±0.87	42.56^{d}±0.05
Mn	29.34^{a}±0.01	20.42^{b}±0.15	38.50^{c}±0.29	21.63^{c}±0.06	31.25^{a}±0.25	45.50^{c}±0.80	19.40^{b}±0.36
Cu (µg/100g)	444.67±33.33	200.00±0.00	307.30±0.17	187.60±0.12	225.13±0.03	309.00±0.58	193.90±0.00*

Values are means ± SE (8 rats per group). Values in same row not sharing a common superscript are significant $^{+}(p<0.01)$, $^{++}(p<0.001)$.

Table 5: Mineral intake and excretion (mg/rat/day)* of rats fed red palm oil (RPO) or refined palm olein (REFPO)

Mineral Element	Dietary Group						
Intake	CONTROL	10% RPO	20%RPO	30%RPO	10%REFPO	20%REFPO	30%REFPO
Ca	98.09±0.60^{a}	92.32±0.33^{a}	67.98±0.31^{b}	34.07±0.00^{c}	95.37±0.30	65.18±0.28^{b}	31.93± 0.00^{d}
Mg	4.28±0.03^{a}	4.03± 0.02^{a}	2.97±0.00^{b}	1.49±0.00^{c}	4.16±0.01^{a}	2.84 ±0.02^{b}	1.39± 0.03^{c}
K	24.39±0.17^{a}	22.95±0.06^{a}	16.90±0.08^{b}	8.47±0.00^{c}	23.71±0.08^{a}	16.20±0.04^{b}	7.93± 0.00^{d}
Na	53.51±0.37^{a}	50.37±0.20^{a}	37.09±0.16^{b}	18.59±0.23^{c}	52.05±0.18^{a}	35.56±0.16^{b}	17.42± 0.01^{d}
Fe	19.96±0.11^{a}	18.79±0.03^{a}	13.83±0.06^{b}	6.93±0.00^{c}	19.41±0.01^{a}	13.26±0.05^{b}	6.49± 0.00^{d}
Zn	4.16±0.02^{a}	3.90 ±0.03^{a}	2.88±0.02^{b}	1.45±0.04^{c}	4.05±0.01^{a}	2.77±0.01^{b}	1.36± 0.00^{c}
Mn	4.66±0.04^{a}	4.38 ±0.01^{a}	3.23±0.02^{b}	1.62±0.04^{c}	4.53±0.00^{a}	3.10±0.01^{b}	1.52± 0.00^{c}
Cu (µg/rat/day)	39.39±021^{a}	37.07±0.20^{a}	27.30±0.17^{b}	13.68±0.33^{c}	38.30±0.12^{a}	26.17±0.17^{b}	12.82± 0.00^{c}
Excretion							
Ca	0.81±0.01^{a}	2.42±0.02^{b}	1.88±0.01^{c}	1.29±0.00^{d}	1.28±0.01^{dc}	1.89±0.00^{c}	0.92±0.05^{a}
Mg	0.24±0.01^{a}	0.31±0.01^{a}	0.46±0.00^{b}	0.59±0.01^{c}	0.24±0.01^{a}	0.45±0.01^{b}	0.51±0.02^{bc}
K)	5.97±0.00^{a}	5.60±0.01^{b}	5.70±0.06^{ab}	3.47±0.00^{c}	6.94±0.01^{d}	5.42±0.06^{b}	2.76±0.00^{e}
Na	6.18±0.01^{a}	5.37±0.00^{b}	7.81±0.06^{c}	4.85±0.00^{d}	7.86±0.02^{c}	9.13±0.06^{e}	5.08±0.03^{f}
Fe	0.73±0.00^{a}	0.51±0.00^{b}	0.92±0.01^{c}	0.31±0.00^{d}	0.87±0.00^{c}	0.99±0.02^{c}	0.31±0.00^{d}
Zn	1.40±0.03^{a}	0.80±0.02^{b}	051±0.02^{c}	0.84±0.01^{b}	0.99±0.02^{b}	0.34±0.01^{c}	0.73±0.02^{b}
Mn	0.60±0.02^{a}	0.50±0.00^{ab}	0.74±0.01^{ac}	0.43±0.01^{abd}	0.73±0.02^{a}	0.86±0.01^{c}	0.33±0.01^{a}
Cu (µg/rat/day)	9.20±0.07^{a}	4.88±0.00^{b}	5.90±0.00^{c}	3.73±0.04^{d}	5.23±0.01^{e}	5.84±0.01^{c}	3.34± 0.02^{d}

* Means ± Standard Error (8 rats per group). Values in same row not sharing a common superscript are significant ($p<0.001$).

Table 6: Percentage digestion/apparent absorption of nutrients in rats fed red palm oil (RPO) or refined palm olein (REFPO)*

	Dietary Group						
Nutrient	CONTROL	10% RPO	20% RPO	30% RPO	10% REFPO	20% REFPO	30% REFPO
Protein^{+}	82.11± 0.29^{a}	83.15±0.84^{a}	72.62±1.33^{b}	61.45±1.59^{c}	85.85±0.14^{a}	74.77±1.38^{b}	69.95±1.87^{c}
Fat^{+}	98.21± 0.20^{a}	97.47±0.08^{a}	94.68±0.23^{b}	91.05±0.58^{c}	97.01±0.28^{a}	94.81±0.15^{b}	93.18±0.43^{c}
Carbohydrate^{+}	83.73± 0.20^{a}	79.93±0.98^{a}	81.03±1.48^{a}	59.40±0.20^{b}	83.63±0.68^{a}	79.45±0.95^{a}	58.18±0.58^{b}
Mineral Element^{++}							
Ca	99.17±0.08^{a}	97.38±0.23^{ab}	97.23±0.21^{ab}	96.21± 0.00^{b}	98.55±0.01	97.10±0.24^{a}	93.18±0.15^{b}
Mg	94.47±0.29^{a}	92.31±0.25^{a}	84.51±0.05^{b}	60.18±0.22^{c}	94.23±0.24^{a}	84.15±0.00^{b}	63.07±0.26^{c}
K	75.39±0.13^{a}	75.60±0.03^{a}	66.29±0.38^{b}	59.05±0.72^{c}	70.73±0.64^{a}	66.56±0.39^{b}	65.20±0.10^{c}
Na	88.06±0.40^{a}	89.34±0.29^{a}	78.95±0.17^{b}	73.93±0.30^{c}	84.89±0.27^{a}	74.31±0.18^{b}	70.88±0.20^{c}
Fe	96.34±0.16	97.28±0.21	93.35±0.38	95.53±0.06	95.52±0.00	92.57±0.40	95.28±0.05
Zn	66.27±0.08^{a}	79.51±0.08^{b}	81.94±0.40^{b}	42.53±0.23^{c}	75.48±0.48^{b}	87.73±0.95^{b}	46.32±0.00^{d}
Mn	87.06±0.06^{a}	88.61± 0.17^{a}	77.11±0.23^{b}	73.64±0.29^{b}	83.93±0.37^{a}	72.26±0.22^{b}	77.85±0.44^{b}
Cu	76.65±0.18^{a}	86.84±0.00^{b}	78.39±0.20^{a}	72.71±0.02^{c}	86.36±0.09^{b}	77.68±0.04^{a}	73.95±0.00^{d}

*Means ± Standard Error (8 rats per group). Values in same row with different superscripts are significantly different: $^{+}$($p<0.01$), $^{++}$($p<0.001$)

diets and feces excreted (Table 1 and 4). The average daily protein and carbohydrate intakes of rats fed 10% oil-enriched diets (1.83-1.89 g/rat/day and 7.17-7.88g/rat/day respectively) were comparable to those of the control (1.94g/rat/day and 7.60g/rat/day respectively). There were dose-dependent decreases in protein and carbohydrate consumption. The protein and carbohydrates intakes of rats eating 20% oil-enriched diets (1.29-1.35 g/rat/day and 5.06-5.28g/rat/day respectively) were intermediate between those consuming the 30% oil-enriched diets (0.51-0.67 g/rat/day and 1.98-2.65 g/rat/day, respectively) and those fed the control or 10% oil-enriched diets. Animals fed the unsupplemented rat mash (control) had the lowest fat intake (0.56g/day/rat) followed by those eating the 10% oil-containing diets (1.19-1.23g/rat/day). Animals fed the 20% oil-containing diets had the highest fat intake (1.87-1.96g/rat/day).

Rats consuming the 10% oil-supplemented diets had similar protein and carbohydrate excretion as those of the control ($p>0.01$). Though rats fed the 30% REFPO diets excreted the lowest amount of protein (0.20g/rat/day), there were small variations in the fecal protein contents of other test rats (0.26-0.32g/rat/day) when compared with the controls (0.35g/rat/day). Control rats had a fecal fat output of 0.01g/rat/day. Rats eating 10% oil diets excreted 3 to 4 times more fat than the controls; while 30% oil-fed rats excreted 11-15 times more fat than the controls ($p<0.01$).Animals given the 10% oil-enriched diets excreted more carbohydrate (1.35-1.44g/rat/day) than those provided the 20 or 30% oil diets (1.00 to 1.04g/rat/day).

The intakes of minerals (calcium, magnesium, potassium, sodium, zinc, iron, manganese and copper) by the groups of rats fed 10% oil-supplemented diets were comparable to those of the control ($p>0.01$). Intakes declined with increasing level of oil in the diet in a dose-dependent fashion. The type of dietary fat did not seem to exert much influence on the consumption of the micro elements studied.

The control rats excreted the lowest amount of fecal calcium (Ca) and magnesium (Mg). The highest Ca excretion was observed in the 10% RPO fed group (2.42mg/rat/day) followed by 1.89mg/rat/day for the 20% REFPO group. There was a direct dose-effect relationship between the amount of dietary fat and Mg excretion. The excretion of potassium decreased with increasing levels of oil in the test diets. Potassium excretion by rats fed 20% RPO-containing diets (5.70mg/rat/day) was similar to that of the control (5.97mg/rat/day).Animals consuming the 30% oil test diets excreted the least amounts of sodium (4.85-5.08mg/rat/day) and iron (0.31mg/rat/day) when compared with the other experimental rats (6.18-9.13mg/rat/day and 0.51-0.99mg/rat/day, respectively) ($p<0.001$). Zinc excretion was highest in the control rats (1.40mg/rat/day); fecal manganese values were lower in animals eating the 30% oil diets (0.33-0.43mg/rat/day) when compared with the other dietary groups studied (0.50-0.86mg/rat/day). Control rats had significantly higher fecal copper (Cu) values (9.20µg/rat/day) than the other groups studied ($p<0.001$). Excretion of Cu by groups fed RPO was generally similar to those fed REFPO.

Percentage digestion of nutrients: Table 6 shows the percentage of individual nutrients digested by the animals based on the intake and excretion of nutrients noted in Tables 3 and 5.

The protein digestion for control animals (82.11%) was comparable to that of animals in the 10% oil groups (82.66-85.85%). In sharp contrast to the dietary patterns of the control 10% oil and 20% oil-fed rats, the 30% oil fed rats had significantly low protein digestion of 61.45-69.95% ($p<0.01$). Protein digestions were proportional to dietary intake, with the 10% oil-fed animals digesting the highest and the 20% oil groups having values (72.62%-74.77%) that were intermediate between those of the 30% oil-fed and 10% oil-fed groups. The digestion of fat decreased with increasing levels of oil in the diet; the 30% oil group digested the least (91.05-93.18%).

Carbohydrate digestion by the 10 and 20% oil-supplemented groups (79.45-83.63%) showed no marked difference ($p>0.01$) from the control (83.73%), demonstrating an efficient intestinal absorption of the nutrient. The efficiency of carbohydrate digestion was lowest in the 30% oil-fed (58.18-59.40%) group compared to other groups ($p<0.01$). The values for mineral digestion/apparent absorption in the 10% oil-treated groups were comparable with those of the control except for copper and zinc ($p<0.001$). The apparent absorption/digestion of calcium in the 30% oil fed groups (93.81-96.21%) were significantly lower than those of other experimental groups ($p<0.001$). The 30% oil groups, which had the lowest intake of Mg (1.11-1.49mg/rat/day), exhibited the least apparent absorption (60.18-63.07%) of the mineral Mg. The digestion/apparent absorption of Mg decreased with increasing levels of oil in the diet in a dose-dependent fashion. The digestion/apparent absorption of potassium was higher in the groups fed the 10% oil-containing diets (70.73-75.60%) than in the groups fed the 20% oil (66.29-66.56%) and 30% oil diets (59.05-65.20%). Sodium (Na) absorption followed a similar pattern to potassium with animals fed the 10% oil diets having higher apparent absorption (84.89-89.34%) and the 30% oil fed groups exhibiting the lowest values of 70.88-73.93%. The percentage digestion/apparent absorption of iron in all test groups (92.57-97.28%) was comparable with the control value of 96.34% ($p>0.01$).Animals fed the 30% RPO-supplemented diets absorbed the least zinc (42.53%) followed by the 30%

REFPO group rats (46.32%). The apparent absorption of zinc by the groups fed 10%-20% oil-enriched diets (75.48-87.73%) were significantly higher ($p<0.001$) than those of the control (66.27%). The manganese (Mn) apparent absorption by rats eating 10% oil-supplemented diets (83.93-88.61%) was significantly higher ($p<0.001$) than those of the 20% oil and 30% oil diet groups (72.26-77.85%). The control rats exhibited a significantly lower apparent absorption ($p<0.001$) of copper (76.65%) when compared with rats fed 10% oil-enriched diets (86.36-86.84%). The copper (Cu) digestion by animals fed the 20% oil diets (77.68-78.39%) was comparable to those of the control. The group fed 30% REFPO had the lowest Cu absorption (72.71-73.95%) when compared with other experimental groups ($p<0.001$).

Discussion

The data presented on growth show that the 10% oil-supplemented diets satisfactorily supported growth, as indicated by superior BWG of the animals in these groups and the low BWG for the animals eating the 30% oil diets, irrespective of the type of dietary fat. The amount and quality of food consumed by experimental animals greatly influence growth responses (Fashakin and Unokiwedi, 1993). The accelerated growth rates of the animals fed the 10% oil-supplemented diets are most likely due to the fact that these groups consumed more food than any other test group.

Fat contributes to food palatability and also enhances satiety (Mead *et al*., 1986; Newsholme *et al*.,1993), since fatty foods remain in the stomach for longer periods of time than do foods containing protein and carbohydrate. The 10% oil diets were well accepted by the rats. When moderate amounts of fat are added to the diet, caloric consumption is more frequently increased than depressed (NRC, 1978). Growth response was however significantly lower ($p<0.01$) in animals fed the 20 and 30% diets when compared with the control. The 30% oil dietary groups had the poorest growth response. The inclusion of oils at 30% level had a negative effect on rat growth probably because of the decreased food (caloric) intake. Food intake is seemingly depressed when high amounts of fat are added to the diet. Another possible reason for the disparity in BWG between the groups fed high fat diets and those fed low fat diets may be the protein imbalance imposed through dilution of nutrients especially protein with increasing amounts of fats.

In general, the 10% oil-supplemented diets were better utilized than the other experimental diets; 20% oil diets were better utilized than the 30% oil diets. The FER of the control and 10% oil-supplemented diets were within the range of values reported in the literature (Manorama and Rukmini, 1991; Ghandi *et al*., 1997). The differences between FER values of the 20% oil and 30% oil-supplemented diets were not significant ($p<0.01$). Though the unique contributions of fat to the diet include: enhancing satiety, stimulating gastro-intestinal secretions, promoting fat-soluble vitamin absorption and regulation of glucose utilization/oxidation (Newsholme *et al*., 1993), these contributions may only be met when moderate amounts of fat are added to the diet (NRC, 1978). Thus in terms of proper utilization of diets, 10% supplemented could be regarded as maximal under the conditions of this research.

The values for protein digestion by the rats fed the 10% oil-supplemented diet (comparable to those of the control) were close to the values (86.0-87.0%) obtained by Manorama and Rukmini (1991). The 20 and 30% oil-fed groups consumed less protein that the control and 10% oil-fed groups. The high amounts of fat may have reduced the quantity of protein in these diets through dilution. This may have caused some "protein restriction" in animals fed 30% oil. Protein restriction in animals has been shown to reduce intestinal mass and villous height (Alleyne *et al*., 1978). These reductions could have been responsible for the decreases in intestinal digestion/absorption of proteins. The maximal digestion of dietary fat by the 10% oil-treated groups is consistent with reports, which demonstrate effective absorption of lipids in animals fed some dietary oils at a 10% level (Manorama and Rukmini, 1991). The 30% oil-fed groups had the lowest fat digestion followed by the 20% oil-fed groups. There are anatomical differences between humans and rats with respect to the digestion of fat. The rat has no gallbladder, cannot concentrate bile and has a nearly constant flow of undiluted bile into the duodenum (Bjornhag, 1992). Rats may, therefore be unable to emulsify large meals of fat sufficiently, which may potentially lead to a lower absorption (Wisker *et al*., 1996). Carbohydrate digestion in the groups fed 10% oil and 20% oil-supplemented diets were superior to those of the 30% oil-fed counterparts. It could be speculated that the high digestion of carbohydrate in the 20% oil-fed groups might not be unrelated to the increased demand for protein discussed. Carbohydrate possesses both anabolic (proteogenic) and protein-sparing abilities. Carbohydrate may be diverted to more efficiently meet the energy demands of the cell.

In general, the mineral absorptions of the 10% oil-fed animals were comparable to those of the control. The decreases in calcium (Ca) absorption of test rats (0.21-6.98%) were slight when compared with the control values of 99.17%. The levels of oil used in the present study could be regarded as promoting Ca retention. The low Mg absorption in the 30% oil-fed groups may not be beneficial for the catalytic activities of the kinases, which require Mg^{2+} ions. The efficiencies of absorption of sodium (Na) and potassium (K) were lowest in 30% oil and 20% oil groups compared with the control or 10% oil-fed groups. These low absorption of Na and K may

negatively impact the Na^+ - K^+ - ATPase or sodium pump system estimated to contribute between 15 and 50% to total cellular energy utilization in mammalian tissues (Lin *et al.*, 1979). The percent digestion/apparent absorption of iron in all the experimental groups studied might ensure adequate iron supplies to maintain normal erythropoietic functions and hemoglobin level. This was observed when Edem (1999) determined hemoglobin and mean corpuscular hemoglobin concentrations of rats fed various levels of palm oil containing diets. Though the apparent absorptions of zinc and copper in the 20% oil-fed rats were comparable with values in the 10% oil-fed and control rats, those of the 30% oil-fed rats were lower. Zinc is necessary for the mobilization of vitamin A from the liver in addition to maintaining normal concentrations of vitamin A in the plasma (IVACG, 1979). Copper is involved in the tryptophan dioxygenase rate-limiting step for the conversion of tryptophan to nicotinic acid nucleotides, e.g. NAD (Van Eys, 1991) that is important in vitamin A metabolism. Furthermore, copper along with zinc, manganese, iron and selenium, are components of various antioxidant enzyme systems (Johnson and Fisher, 1992). Lei (1990) reported that copper deficiency induces hypercholesterolemia in rats and other species including man. Thus, the consumption of the dietary oils at 30% levels may cause "deficiencies" of copper and zinc, which have a negative impact on the metabolism of vitamin A and cholesterol. The low manganese (Mn) absorption in animals fed the 20 and 30% oil diets when compared with the control may be a consequence of dietary intake and relative Mn excretions. These absorptions may adversely affect enzyme systems dependent on plasma Mn concentration viz. the kinases and antioxidant enzyme systems.

In conclusion, the current digestion studies have revealed that protein, fat, carbohydrate and mineral absorption in rats fed 10% oil-containing diets were comparable with the control. There were inverse dose-effect relationships between the test dietary fat levels and digestion of protein, carbohydrate, fat, potassium, magnesium, copper and manganese. The 30% oil-fed groups of rats seemed to have been dependent mainly on lipids that were highly absorbed to handle anabolic activities and protein synthesis in a bid to cope with increased protein demand. The "deficiencies" of minerals due to low dietary intake and absorption in the 30% oil-fed rats are capable of adversely affecting enzyme systems dependent on these elements. Furthermore, feed utilization was highest in the groups eating the 10% oil containing diets while the 30% oil diets were poorly utilized. Thus, moderate consumption of palm oil (red or refined) appears to support growth and normal development of animals and may possibly be protective against certain derailment in metabolism.

References

Alleyne, C.A.O., R.W. Hay, D.F. Icon, J.G. Stanfield and R.G. Whitehead, 1978. Protein-energy malnutrition, English Language Book Society, London.

AOAC, 1990. Official Methods of Analysis. Association of Official Analytical Chemists.15th ed., Arlington, VA. Methods 992.066 to 962.09.

Bjornhag, G., 1992. Anatomy of the digestive tract and transport of digesta. In: The rat as a model for man and pig in nutritional and physiological studies. Proceedings (Tungvid, M., Forshell, L. and Eggum, B. O. eds), Gramineer, Lidkoping, Sweden, pp: 1-6.

Chong, Y.H. and T.K.W. Ng, 1991. Effects of palm oil on cardiovascular risk. Med. J. Malaysia, 46: 41-50.

Colloway, D.H., G.W. Kurtz, J.J. McMullen and L.V. Thomas, 1956. The absorbability of natural and modified oils. Food Res., 21: 621.

Edem, D.O., 1999. Comparative biochemical and haematological studies on rats fed various levels of palm oil-containing diets. Ph. D. Thesis. University of Calabar, Nigeria, 283 pp.

Fashakin, J.B. and C.C. Unokiwedi, 1993. Nutritional evaluation of "warankasi" and "waragusi" prepared from cow milk partially substituted with melon milk. Nig. Food J., 11: 128-134.

Ghandi, V.M., M.J. Mulky, B. Mukerji, V.J. Iyer and K.M. Cherian, 1997. Safety evaluation of wild apricot oil. Food and Chemical Toxicology, 35: 583-587.

Hassel, C.A., E.A. Mensing and D.D. Gallacher, 1997. Dietary stearic acid reduces plasma and hepatic cholesterol concentration without increasing bile acid excretion in cholesterol-fed hamsters. J. Nutr., 127: 1148-1155.

Horwitz, W., 1980. Official Methods of Analysis of the Association of Official Analytical Chemists, AOAC, 13th ed., Washington DC, p: 31.

IVACG, 1979. International Vitamin A consultative Croup. Recent advances in the metabolism and function of vitamin A and relationship to applied nutrition. A report of the International Vitamin A Consultative Group. The Nutritional Foundation Inc. Washington DC, pp: 1-24.

Johnson, M.A. and J.G. Fisher, 1992. Is copper an antioxidant nutrient? Crit. Rev. Food Sci. Nutr., 22: 1-31.

Lei, K.Y., 1990. Plasma cholesterol response in copper deficiency. In: Role of copper in lipid metabolism (Lei, K. Y. and Carr, T. P., eds), CRC Press, Boca, Raton, Florida, pp: 1-23.

Lin, M.H. J.G.U. Tuig, D.R. Romsos, T. Akera and G.A. Leveille, 1979. Na^+, K^+ - ATPase enzyme units in lean and obese (ob/ob) thyroxine injected mice. Am. J. Physiol., 237: E265 - E272.

MacFarlane, N., A.A. Swetmen and D.G. Coursey, 1984. Comparison of traditional and industrial palm oil. Palm Oil News, 28: 11-17.

Manorama, R. and C. Rukmini, 1991. Nutritional evaluation of crude palm oil in rats. Am. J. Clin. Nutr., 53: 1031S - 1033S.

Mead, J.F., R.B. Alfin-Slater, D.R. Houston and G. Popjack, 1986. Lipids: Chemistry, Biochemistry and Nutrition, Plenum Press, New York and London, pp: 459-473.

Newsholme, E.A., P. Calder and P. Yaqoob, 1993. The regulatory, informational and immunomodulatory roles of fat fuels. Am. J. Clin. Nutr., 57 (suppl.): 738S - 751S.

Ng, T.K.W., H.T. Khor and Y.H. Chong, 1988. The digestion, absorption and utilization of refined palm oil, palm olein and palm stearin in the rat. Pertanika, 11: 399-406.

NRC, 1978. National Research Council. Nutrient requirement of laboratory animals, No. 10, (3rd ed.) National Academy of Sciences, Washington DC, pp: 56-82.

NRC, 1985. National Research Council. Guide for the care and use of laboratory animals, Publication No. 85-23 (rev). National Institutes of Health, Bethesda, MD.

Van Eys, J., 1991. Niacin. In: Handbook of Vitamins, 2nd ed. (Machlin, L. A. ed.), Marcel Dekker, New York. pp: 311-340.

Wisker, E., K.E.B. Knudsen, M. Daniel, W. Felheim and B.O. Eggum, 1996. Digestibilities of energy, protein, fat and non-starch polysaccharides in a low fibre diet and diets containing coarse or fine whole meal rye are comparable in rats and humans. J. Nutr., 126: 481 - 488.