Nutrition of Rice Bran Oil in Relation to its Purification

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A comparative nutritive study was made to show that the extent of purification markedly influences the nutritive characteristics of rice bran oil. The coefficient of digestibility was 93.8% when rice bran oil that had been purified by degumming, deacidifying, bleaching and deodorizing was fed to rats; whereas it was 94.8% when extremely pure rice bran oil, which was achieved by including an additional dewaxing step, was used. Rice bran oil without deodorization, but purified by other treatments, showed a 96.2% coefficient of digestibility, which is somewhat lower than that of groundnut oil. However, after a feeding experiment over three months, the highly purified rice bran oil showed better results than the other two purified samples of rice bran oil, and was sometimes better than groundnut oil in terms of total lipid, triglyceride and especially in cholesterol content in serum, liver and heart tissues.

KEY WORDS: Cholesterol, groundnut oil, methyl ester, phospholipid, rice bran oil, total lipid, triglyceride.

Rice bran oil is used as an edible oil in Japan, China, India and other rice-producing countries. It is considered to be a good edible oil because it contains about 80% unsaturated fatty acids with a fairly high content of linoleic acid (1). In Japan, rice bran oil is more popularly known as heart oil as it keeps cholesterol level in serum relatively low due to its linoleic acid, tocopherol and oryzanol content. In India, the availability of rice bran oil is increasing primarily for direct consumption after proper purification. Rice bran oil has an appreciable amount of wax (2), which needs to be removed to obtain a clear, edible oil. Therefore, purification includes degumming, dewaxing, deacidifying, bleaching and deodorizing steps. Depending on the extent of purification, the quality of rice bran oil may vary in its nutritional quality. It has been reported that non-triglyceride constituents influence the nutritional quality of vegetable oils (3,4), but no detailed information on the nutritional aspects, including lipid profiles of serum and other tissues, is available for rice bran oil.

The present study aims at investigating the coefficient of digestibility of rice bran oil, food efficiency ratio and lipid profiles, as well as fatty acid composition of serum, liver, heart and kidney tissues in relation to the mode of purification of rice bran oil. Purified groundnut oil was used as the standard for comparison.

EXPERIMENTAL PROCEDURES

Crude rice bran oil was supplied by K.N. Oil Industries (Raipur, Madhya Pradesh, India) and groundnut oil was a proprietary brand (Postman, Bombay, India) which had been refined, bleached and deodorized. Rice bran oil was purified by combining various purification steps to get three rice bran oils of different purities. The oils used in this experiment were as follows: i) Degummed, deacidified, bleached and deodorized rice bran oil (RBO^1, unsaponifiable matter 4.5%, wax 3.5%); ii) degummed, dewaxed, deacidified, bleached and deodorized rice bran oil (RBO^2, unsaponifiable matter 1.1%, wax trace); iii) degummed, dewaxed, deacidified and only bleached rice bran oil (RBO^3, unsaponifiable matter 1.6%, wax trace); and iv) deacidified, bleached and deodorized groundnut oil (unsaponifiable matter 0.5%).

RBO^2 is clearly the most purified oil among the three and it differs from RBO^1 in the amount of wax (trace *vs.* 3.5%) and from RBO^3, which presumably contains some quantity of tocopherol and oryzanol, due to its undeodorized state.

Degumming. Degumming of rice bran oil was carried out by agitating the oil with phosphoric acid (G.R., E. Merck, Darmstadt, Germany, 85%, w/w, added at 0.1% of the oil) at 70°C for 30 min. The gums were removed by centrifugation at 6,000 rpm in a laboratory centrifuge.

Dewaxing. Miscella dewaxing was adopted for the degummed rice bran oil. The method involved chilling of 60% (w/v) degummed rice bran oil in food-grade normal hexane (A.R. quality, BDH, Poole, U.K.). The miscella was kept in a closed, wide-mouth flask at 5°C for 10 hr. The crystallized wax was removed very rapidly by filtration under suction. The wax content in the oil was measured by crystallizing the oil from cold acetone (5 mL/g) at 5°C.

Deacidification. Deacidification of rice bran oil was also done in the solvent phase. Neutralization was carried out with 20% excess alkali over the theoretical. The miscella was mixed with caustic lye solution by stirring for 20 min at room temperature. The soap stock was removed by centrifugation at 4000 rpm, and the refined miscella was washed thoroughly with cold water to get soap-free oil.

Bleaching. This process was also carried out in solvent phase. The refined soap-free miscella was bleached in a round-bottom glass flask with 2.5% activated Tonsil earth optimum and 0.25% activated charcoal (E. Merck) by magnetic stirring at room temperature for 45 min. The miscella was filtered and the oil was recovered from the solvent by distillation at atmospheric pressure and then under high vacuum (755 mm Hg) at 95°C.

Deodorization. Deodorization of the rice bran oil was accomplished in a laboratory Pyrex glass deodorizer fitted with a high-vacuum pump and an inlet for superheated steam. The oil was deaerated in the deodorizer by high vacuum before heating the oil and injecting the steam generated in a Pyrex glass vessel. Then the oil was heated in presence of steam at 200° ± 5°C for two hours under vacuum (755 mm Hg). The distillate was collected in the receiver during the process. The oil was then allowed to cool and was taken out from the deodorizer after cooling. The oil was flashed with nitrogen and stored in a refrigerator until used.

As the chemicals used were of high purity and all equipment was made of glass, the RBO preparations can be

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assumed to be free of any contaminants that might influence nutritional effects.

The unsaponifiable matter of rice bran oil and groundnut oil was estimated according to the standard AOCS method (5). Male albino rats of the Charles Foster strain were kept in individual cages and fed the experimental diet and fresh water *ad libitum* daily. Daily food consumption and weekly body weight gain were recorded. Two separate experiments were conducted to find out the coefficient of digestibility and the nutritional status of the differently purified rice bran oils and purified groundnut oil.

Experiment 1: Determination of coefficient of digestibility of oil. Rats with body weight of 150–155 g were divided into five groups—Four groups for four experimental oils and one group for glucose (71%) diet to determine the metabolic lipid. After allowing the rats two days for orientation, they were kept for 10 days on the experimental diets having the composition of casein, 18%; glucose, 61%; yeast, 1%; liver extract, 3%; salt mixture, 7% (6); and experimental oil, 10%. Every day the exact amount of food consumption was recorded and the extracted faeces were dried and collected. After 10 days, the faeces for each group was pulled together, powdered and extracted with petroleum ether (b.p. 60–80°C) for a few hours. The faecal fat remaining as soap was recovered by hydrolyzing the faeces through warming with dilute HCl (1:4), being left overnight, and again extracting with petroleum ether for complete extraction of fat. The coefficient of digestibility was calculated according to the standard method (7) after correction for metabolic lipid.

Experiment 2: Evaluation of nutritional characteristics of oil. Male rats of the Charles Foster strain were divided into four groups, each consisting of six rats having 105–110 g body weight, and they were fed experimental diets composed of casein (fat- and vitamin-free), 18%; starch, 55%; cellulose, 3%; salt mixture, 4% (8); one multivitamin capsule per Kg of diet; and experimental oil, 20%. Rats were maintained on these diets *ad libitum* for 12 weeks. Rats were sacrificed under anesthesia, blood was collected from cardiac puncture, and tissues (liver, heart and kidney) were isolated and stored properly for analysis. The total lipids from serum and other tissues were extracted with chloroform/methanol mixture and gravimetrically estimated (9). Individual lipid components, such as total and free cholesterol and phospholipids, were estimated colorimetrically according to standard methods (10,11). For the determination of triglyceride a known quantity of total lipid was fractionated into pure triglyceride bands by thin-layer chromatography on 20 × 20-cm plates coated with silica gel G (0.5 mm thickness), and by eluting with hexane and diethyl ether (80:20, v/v) as the solvent system. Triglyceride was extracted from the band by chloroform, followed by centrifugation (three times). The combined chloroform was removed by nitrogen chasing. Glyceride glycerol was estimated by standard colorimetric procedure (12). To determine the fatty acid composition of total lipid of serum or tissues, methyl esters were prepared according to the standard method (13) and then analyzed with a Pye Unicam gas-liquid chromatograph (GLC) (Pye Unicam, Cambridge, U.K.) equipped with a hydrogen flame ionization detector. A stainless steel column (2 meter × 1/8 inch) packed with 15% diethylene glycol succinate on chromosorb WHP (100–120 mesh) was used. The oven, injection port and flame ionization detector temperatures were kept at 190, 230, and 240°C, respectively. Nitrogen flow rate was 30 mL/min.

RESULTS AND DISCUSSION

The fatty acid composition of the two dietary oils from groundnut and rice bran are presented in Table 1. Here the rice bran oil refers to the most purified sample, *i.e.*, degummed, dewaxed, deacidified, bleached and deodorized rice bran oil. Under the GLC conditions adopted in the present study, the RBO preparations (RBO^1, RBO^2 and RBO^3) did not show any significant differences in fatty acid composition. The composition given in Table 1 agrees with the composition of RBO reported in the literature (1). No unidentified fatty acids could be detected in RBO. The two oils are close in their content of total saturated and unsaturated fatty acids, except that long-chain fatty acids occur only in groundnut oil.

The coefficient of digestibility for groundnut oil and three rice bran oil preparations, along with the amount of metabolic lipid, are shown in Table 2. Metabolic lipid for the rats was 216 mg for 10 days when the rats were raised without any dietary oil in the diet. To ensure accurate extraction and isolation of fat from rat excreta, the excreta from three rats of the same group were pooled. The digestibility coefficients were calculated with standard error of mean on the basis of determination of metabolic fat and fat excreted after dietary fat ingestion. Therefore, the data more broadly represent the average of three separate sets of determinations, because each group had three rats for each dietary oil. The coefficient of digestibility of the oils has been calculated by the standard formula (7). The experimentally determined metabolic lipid and the calculated values from the formula used in the digestibility coefficient determination agree well with each other.

After comparing Student's *t*-test (14) data between the groups of rice bran oil (Table 3), it is evident that the process of purification exerts a remarkable effect on the coefficient of digestibility, and there is also a significant difference between groundnut oil and rice bran oil with different degrees of purity. A multiple comparison test, *e.g.*,

TABLE 1

Fatty Acid Composition of the Dietary Oils

	Fatty acid composition (% w/w)									
Dietary oil	$C_{16:0}$	$C_{16:1}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$	$C_{20:0}$	$C_{20:1}$	$C_{22:0}$	$C_{24:0}$
Groundnut	11.6	1.6	6.2	43.1	29.2	1.1	1.3	1.9	1.9	2.1
Rice bran	20.7	—	2.9	45.2	30.4	0.8	—	—	—	—

TABLE 2

Metabolic Lipid and Coefficient of Digestibility of the Dietary Oils Fed Rats at 10% Level

	Metabolic lipid	Dietary oil group[a]			
		G	RBO^1	RBO^2	RBO^3
No. of rats	9	9	9	9	9
Av. wt. of rats (g)	152.3	151.6	150.0	150.5	150.8
Av. wt. gain (g)	23.4	38.5	38.0	38.7	42.1
Av. food eaten (g/rat for 10 days)	113.5	134.2	133.0	131.3	128.4
Av. fat intake (g/rat for 10 days)	0.0	13.4	13.3	13.1	12.8
Av. fat excreted (mg/rat for 10 days)	216.0	453.1	1038.2	899.0	700.9
Metabolic lipid (g for 10 days)	0.216	—	—	—	—
Coefficient of digestibility (%)	—	98.2 ± 0.3[b]	93.8 ± 0.2	94.8 ± 0.1	96.2 ± 0.4

[a]G, groundnut oil; RBO oils are rice bran oils at different levels of purification.

[b]Standard error of mean of three groups of rats, each consisting of three rats for each oil.

TABLE 3

Comparative Statistical Significance of Coefficient of Digestibility Values After Student's *t*-Test as per Table 2

Dietary oil group	Statistical significance
G[a] *vs.* RBO^1	S[b]
G *vs.* RBO^2	S
G *vs.* RBO^3	S
RBO^1 *vs.* RBO^2	S
RBO^1 *vs.* RBO^3	S
RBO^2 *vs.* RBO^3	S

[a]G, groundnut oil.

[b]S, significant ($P \leq 0.05$).

Tukey's test (15), at 5% level also reveals a significant difference in the coefficient of digestibility of groundnut and rice bran oils.

Food intake and corresponding body weight gain of rats fed groundnut oil and rice bran oil of three different grades of purity for twelve weeks are given in Table 4, and the statistical significance of the values after Student's *t*-test between two groups at a time is displayed in Table 5. It is observed that after 12 weeks, there is no significant difference in weight gain and food consumption of rats fed the two dewaxed rice bran (RBO^2 and RBO^3) and groundnut oils. However, it is interesting that throughout the experiment, rice bran oil containing wax (RBO^1) causes significantly less food consumption and less weight gain of rats when compared to groundnut oil. Therefore, it can be assumed that wax has some definite role in consumption of food and weight gain in rats.

The food efficiency ratios (FER, weight gain/food intake) of diets containing the dietary oils at a 20% level are presented in Tables 6 and 7. After the first week of the experiment the most purified rice bran oil (RBO^2) has the highest FER value when compared to the other two, and it is even significantly higher than that of purified groundnut oil. But at the end of the fourth week, there is a sharp decrease in the FER value of RBO^2, and the value has become lower than that of groundnut oil. From then until the end of the experiment, there is no significant difference in FER values between RBO^2 and groundnut oil. But it is important to mention that from the beginning until the fourth week of the experiment, rice bran oil containing wax (RBO^1) has significantly lower FER values than groundnut oil, although a significant difference does not exist at the end of the experiment. Tukey's test at a 5% level also shows significant differences in FER values of the oils up to the eighth week, but no differences exist after the twelfth week of the experiment. So, rice bran oil needs proper purification to be utilized in the body like purified groundnut oil.

It is evident from the lipid spectrum of the serum (Tables 8 and 9) of rats that the total lipid content of serum of rats raised on rice bran oil is invariably less than that of groundnut oil, and the amount is remarkable less for the highly purified rice bran oil (RBO^2). This also holds true when the individual lipid classes are compared. Among the three rice bran oil samples, RBO^1 shows the highest amounts of total lipid and especially of total cholesterol. Thus, wax in the dietary oil RBO^1 appears to have some role in increasing the cholesterol level in rat serum. A plausible explanation is that waxes that are fatty alcohol in nature are oxidatively converted into saturated fatty acids which, in turn, enhance cholesterol synthesis in the body. The difference in cholesterol levels between groundnut oil and purified rice bran oil samples is difficult to explain, but it could be due to differences in content and nature of some of the minor nontriglyceride components, such as β-sitosterol. The cholesterol-lowering effect is not prominent for RBO^1, possibly due to counter action by wax molecules. Tukey's test (5% level) shows that there is significant difference in serum lipid, triglyceride and total cholesterol values for the oils, but not in free cholesterol and phospholipid content.

The lipid profiles of liver (Table 10) indicate that rice bran oil with wax (RBO^1) produces the highest amount of triglyceride. Thus it appears that wax also influences the triglyceride level in rat liver. The most purified rice bran oil (RBO^2) produces cholesterol at significantly lower levels than does groundnut oil; whereas this is not observed for RBO^1 and RBO^3. It is clear that dewaxing and deodorization are both necessary for rice bran oil to obtain significant lowering of the cholesterol level in lever as compared to groundnut oil. After Tukey's test (5% level) it is found that significant differences exist in liver phospholipid and total cholesterol values (Table 11).

The lipid spectrum of heart (Table 12) also supports the theory that only the most purified rice bran oil (RBO^2) causes significantly less accumulation of total lipid, triglyceride and cholesterol in heart as compared to groundnut oil. Tukey's test (5% level) shows that significant differences exist in heart total lipid, triglyceride, total cholesterol and phospholipid values for three rice bran oils and groundnut oil (Table 13).

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TABLE 4

Mean Body Weight Gain and Mean Food Intake of Rats Fed Dietary Oils at 20% Level

Dietary oil group	Mean body weight gain (g) in week				Mean food intake (g) in week			
	1	4	8	12	1	4	8	12
G[a]	33.2 ± 1.0[b]	109.6 ± 3.8	153.7 ± 5.4	208.2 ± 6.2	62.8 ± 1.3	257.4 ± 4.7	558.4 ± 11.1	930.8 ± 14.7
RBO[1]	27.4 ± 0.4	86.2 ± 4.4	136.5 ± 5.3	173.8 ± 4.4	59.7 ± 1.1	230.6 ± 7.7	510.0 ± 7.6	839.6 ± 7.1
RBO[2]	34.7 ± 0.7	89.6 ± 5.2	141.5 ± 12.6	201.9 ± 12.6	62.4 ± 1.3	235.8 ± 7.0	510.0 ± 18.5	874.0 ± 23.2
RBO[3]	33.2 ± 2.5	86.7 ± 2.8	137.0 ± 5.4	186.0 ± 10.3	62.2 ± 0.6	251.4 ± 2.8	541.0 ± 8.3	901.0 ± 5.3

[a]G, groundnut oil. [b]Standard error of mean of six rats.

TABLE 5

Comparative Statistical Significance of Weight Gain and Food Intake Values After Student's *t*-Test

Dietary oil group	Statistical significance in weeks			
	1	4	8	12
G[a] *vs.* RBO[1]				
Weight gain	S[b]	S	S	S
Food intake	NS[c]	S	S	S
G *vs.* RBO[2]				
Weight gain	NS	S	NS	NS
Food intake	NS	S	S	NS
G *vs.* RBO[3]				
Weight gain	NS	S	NS	NS
Food intake	NS	NS	NS	NS
RBO[1] *vs.* RBO[2]				
Weight gain	S	NS	NS	NS
Food intake	NS	NS	NS	NS
RBO[1] *vs.* RBO[3]				
Weight gain	S	NS	NS	NS
Food intake	NS	S	S	S
RBO[2] *vs.* RBO[3]				
Weight gain	NS	NS	NS	NS
Food intake	NS	NS	NS	NS

[a]G, groundnut oil. [b]Significant, ($P \leq 0.05$). [c]Nonsignificant, ($P > 0.05$).

TABLE 6

Food Efficiency Ratio of Diets Containing Dietary Oils at 20% Level

Dietary oil group	Food efficiency ratio in week			
	1	4	8	12
G[a]	0.53 ± 0.008[b]	0.43 ± 0.008	0.27 ± 0.010	0.22 ± 0.004
RBO[1]	0.46 ± 0.004	0.37 ± 0.010	0.27 ± 0.009	0.21 ± 0.008
RBO[2]	0.56 ± 0.007	0.38 ± 0.018	0.28 ± 0.015	0.23 ± 0.010
RBO[3]	0.53 ± 0.040	0.34 ± 0.010	0.25 ± 0.010	0.21 ± 0.010

[a]G, groundnut oil. [b]Standard error of mean of six rats.

TABLE 7

Comparative Statistical Significance of Food Efficiency Ratio Values After Student's *t*-Test as per Table 6[a]

Dietary oil group	Statistical significance in weeks			
	1	4	8	12
G *vs.* RBO[1]	S[b]	S	NS	NS
G *vs.* RBO[2]	S	S	NS	NS
G *vs.* RBO[3]	NS[c]	S	NS	NS
RBO[1] *vs.* RBO[2]	S	NS	NS	NS
RBO[1] *vs.* RBO[3]	NS	NS	NS	NS
RBO[2] *vs.* RBO[3]	NS	NS	NS	NS

[a]Footnotes as in Table 5.

TABLE 8

Lipid Spectrum of Serum (mg/100 mL) of Rats Fed Dietary Oils at 20% Level[a]

Dietary oil group	Total lipid	Triglyceride	Phospholipid	Total cholesterol	Free cholesterol
G	577.1 ± 49.1[b]	99.7 ± 4.2	108.7 ± 6.1	146.4 ± 4.4	36.3 ± 3.0
RBO^1	561.6 ± 44.2	75.4 ± 4.8	122.6 ± 5.8	143.6 ± 6.0	30.7 ± 3.7
RBO^2	382.3 ± 47.2	60.6 ± 3.9	106.5 ± 6.7	100.9 ± 5.7	27.2 ± 2.5
RBO^3	454.0 ± 22.0	78.2 ± 5.0	111.1 ± 7.5	118.6 ± 5.3	29.1 ± 2.2

[a]Footnotes as in Table 6.

TABLE 9

Comparative Statistical Significance of Serum Lipid Values After Student's *t*-Test as per Table 8

Dietary oil group	Statistical significance in lipids[a]				
	TL	TG	PL	TC	FC
G[d] *vs.* RBO^1	NS[b]	S	NS	NS	NS
G *vs.* RBO^2	S[c]	S	NS	S	S
G *vs.* RBO^3	S	S	NS	S	NS
RBO^1 *vs.* RBO^2	S	S	NS	S	NS
RBO^1 *vs.* RBO^3	NS	NS	NS	S	NS
RBO^2 *vs.* RBO^3	NS	S	NS	S	NS

[a]TL, Total lipid; TG, triglyceride; PL, phospholipid; TC, total cholesterol; FC, free cholesterol.
[b]S, significant ($P \leq 0.05$).
[c]NS, Nonsignificant ($P > 0.05$).
[d]G, groundnut oil.

TABLE 10

Lipid Spectrum of Liver (mg/g) of Rats Fed Dietary Oils at 20% Level[a]

Dietary oil group	Total lipid	Triglyceride	Phospholipid	Total cholesterol	Free cholesterol
G	52.2 ± 3.2	5.4 ± 0.5	22.8 ± 0.8	11.2 ± 0.6	3.5 ± 0.2
RBO^1	61.3 ± 5.4	8.3 ± 0.9	27.4 ± 1.2	10.8 ± 0.9	3.7 ± 0.3
RBO^2	57.5 ± 3.8	5.3 ± 0.7	25.5 ± 1.1	8.1 ± 0.6	3.4 ± 0.1
RBO^3	55.8 ± 3.3	5.4 ± 0.5	22.7 ± 0.7	10.0 ± 0.7	3.0 ± 0.2

[a]Footnotes as in Table 6.

TABLE 11

Comparative Statistical Significance of Liver Lipid Values After Student's *t*-Test as per Table 10[a]

Dietary oil group	Statistical significance in liver lipids				
	TL	TG	PL	TC	FC
G *vs.* RBO^1	NS	S	S	NS	NS
G *vs.* RBO^2	NS	NS	NS	S	NS
G *vs.* RBO^3	NS	NS	NS	NS	NS
RBO^1 *vs.* RBO^2	NS	S	NS	S	NS
RBO^1 *vs.* RBO^3	NS	S	S	NS	NS
RBO^2 *vs.* RBO^3	NS	NS	NS	NS	NS

[a]Footnotes as in Table 9.

TABLE 12

Lipid Spectrum of Heart (mg/g) of Rats Fed Dietary Oils at 20% Level[a]

Dietary oil group	Total lipid	Triglyceride	Phospholipid	Total cholesterol	Free cholesterol
G	39.7 ± 3.1	2.1 ± 0.2	24.7 ± 1.3	6.0 ± 0.3	2.6 ± 0.2
RBO^1	38.8 ± 1.8	1.9 ± 0.2	27.6 ± 0.8	6.7 ± 0.2	2.7 ± 0.2
RBO^2	29.5 ± 2.8	1.5 ± 0.1	21.6 ± 1.4	4.8 ± 0.3	2.4 ± 0.2
RBO^3	39.5 ± 3.0	1.6 ± 0.05	23.5 ± 0.8	5.8 ± 0.2	2.6 ± 0.2

[a]Footnotes as in Table 6.

TABLE 13

Comparative Statistical Significance of Heart Lipid Values After Student's *t*-Test as per Table 12[a]

Dietary oil group	Statistical significance in lipids				
	TL	TG	PL	TC	FC
G *vs.* RBO^1	NS	NS	NS	NS	NS
G *vs.* RBO^2	S	S	NS	S	NS
G *vs.* RBO^3	NS	S	NS	NS	NS
RBO^1 *vs.* RBO^2	S	NS	S	S	NS
RBO^1 *vs.* RBO^3	NS	NS	S	S	NS
RBO^2 *vs.* RBO^3	S	NS	NS	S	NS

[a]Footnotes as in Table 9.

TABLE 14

Lipid Spectrum of Kidney (mg/g) of Rats Fed Dietary Oils at 20% Level[a]

Dietary oil group	Total lipid	Triglyceride	Phospholipid	Total cholesterol	Free cholesterol
G	36.4 ± 2.9	3.8 ± 0.4	24.5 ± 1.9	9.1 ± 0.6	4.8 ± 0.4
RBO^1	44.9 ± 2.0	3.8 ± 0.2	28.1 ± 2.0	11.5 ± 0.3	6.6 ± 0.3
RBO^2	38.5 ± 1.1	2.4 ± 0.3	25.2 ± 2.0	10.4 ± 0.3	6.2 ± 0.5
RBO^3	39.2 ± 3.3	3.2 ± 0.8	24.1 ± 2.5	10.9 ± 0.2	5.8 ± 0.5

[a]Footnotes as in Table 6.

TABLE 15

Comparative Statistical Significance of Kidney Lipid Values After Student's *t*-Test as per Table 14[a]

Dietary oil group	Statistical significance in lipids				
	TL	TG	PL	TC	FC
G *vs.* RBO^1	S	NS	NS	S	S
G *vs.* RBO^2	NS	S	NS	NS	NS
G *vs.* RBO^3	NS	NS	NS	S	NS
RBO^1 *vs.* RBO^2	S	S	NS	S	NS
RBO^1 *vs.* RBO^3	NS	NS	NS	NS	NS
RBO^2 *vs.* RBO^3	NS	NS	NS	NS	NS

[a]Footnotes as in Table 9.

triglyceride contents in heart, are an indication of atherogenic effects, then highly purified rice bran oil has superiority over groundnut oil as a dietary oil.

The lipid spectrum of rat kidney (Table 14) also shows the lowest content of triglyceride for the most purified rice bran oil, RBO^2. There is also a significant decrease in total lipid, triglyceride and total cholesterol content in the kidney lipid for RBO^2 as compared to wax-containing rice bran oil RBO^1. Tukey's test (5% level) indicates homogeneity among total lipid, triglyceride and phospholipid values, but differences exist in total and free cholesterol content of kidney lipid (Table 15).

The fatty acid compositions of serum of rats raised on dietary oils (Table 16) show that feeding of rice bran oil, irrespective of the extent of its purification, invariably results in increased incorporation of palmitic acid when compared to groundnut oil, and it is maximum for rice bran oil containing wax (RBO^1). The highly purified rice bran oil and groundnut oil incorporate nearly the same amount of arachidonic acid into serum lipid, but in liver lipids rice bran oil, irrespective of its purity, shows remarkably low levels of arachidonic acid in comparison with groundnut oil.

The fatty acid spectra of heart lipids (Table 17) indicate that they contain comparatively more saturated acids and less polyunsaturated fatty acids for all rice bran oil samples when compared to groundnut oil. Kidney lipids are rich in palmitic acid and stearic acid and contain little arachidonic acid for all rice bran oil preparations and groundnut oil.

Therefore, on the basis of the coefficient of digestibility, food efficiency ratios, lipid profiles such as triglyceride and cholesterol levels in serum, liver, heart and kidney tissues, and fatty acid profiles of serum and different tissues, it can be stated that highly purified rice bran oil is an excellent edible oil and is comparable with groundnut oil. In some respects it is better than groundnut oil, due to its specific hypolipidemic effect.

TABLE 16

Fatty Acid Composition of Serum and Liver Lipid of Rats

Dietary oil group		Fatty acid composition (% w/w)						
		$C_{16:0}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$	$C_{20:3}$	$C_{20:4}$
G[a]	Serum	18.5	6.7	25.5	18.4	2.8	4.7	23.4
	Liver	19.7	17.6	23.3	24.1	1.2	—	12.7
RBO^1	Serum	26.4	4.8	24.7	18.8	6.4	2.9	16.0
	Liver	28.3	26.6	25.4	14.2	—	—	5.4
RBO^2	Serum	20.2	5.6	23.5	20.1	4.0	2.6	24.0
	Liver	26.4	20.4	28.3	18.1	—	—	6.8
RBO^3	Serum	22.0	9.1	26.2	19.5	3.6	3.8	15.8
	Liver	28.7	22.8	26.4	15.2	1.0	—	5.9

[a]G, groundnut oil.

TABLE 17

Fatty Acid Composition of Heart and Kidney Lipid of Rats

Dietary oil group		Fatty acid composition (% w/w)						
		$C_{16:0}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$	$C_{20:4}$	$C_{20:5}$
G	Heart	19.5	17.9	26.6	24.4	1.0	10.6	—
	Kidney	28.1	22.7	25.4	16.7	1.0	4.9	1.1
RBO^1	Heart	24.7	23.1	24.4	19.1	1.9	6.7	—
	Kidney	29.1	26.8	27.9	13.0	—	3.2	—
RBO^2	Heart	23.8	22.4	24.6	19.6	2.1	6.2	1.2
	Kidney	27.4	25.2	23.1	15.1	1.1	4.8	3.2
RBO^3	Heart	24.0	20.4	23.8	21.6	1.1	9.0	—
	Kidney	29.7	27.5	25.5	12.4	—	4.8	—

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