Sal Olein and Mahua Olein for Direct Edible Use

S. Adhikari* and **J. Adhikari (Das Gupta)**
Ganesh Scientific Research Foundation, 64-65, Najafgarh Road, New Delhi 110 015, India

Vegetable butter oleins are obtained as by-products during the fractionation process employed for making cocoa butter substitutes from sal and mahua. Outlets for these olein portions would not only ensure total utilization of these nontraditional oils, but would also provide an extension of edible oil supplies. The normal analytical characteristics and fatty acid compositions of the olein portions obtained from sal and mahua fats were investigated under appropriate conditions of time and temperature. Sal olein was found to be rich in stearic (33.5–34.0%) and oleic acids (49.1–50.0), whereas mahua olein contained palmitic (18%), stearic (21%) and oleic (38%) acids. Projections from Schaal oven stability studies indicated that even without an antioxidant addition, the oleins could be stored for 4–5 months, and with 0.01% tertiary butyl hydroquinone, the storage life could be prolonged to over one year. Deep-fat frying experiments indicated that the oleins showed a slow build-up rate of total polar material and are quite suitable for such use.

India has the potential of producing 2 million tons of nontraditional oils of tree and forest origin of which about 0.1 million tons of oil is now recovered (1). Of these, the vegetable butters represent a unique class, because their fatty acid and glyceride composition make them suitable for cocoa butter equivalents after slight modification. Sal *(Shorea robusta)* and mahua *(Madhuca indica)* are fats of this class and have already gains considerable importance for this purpose (2–5); the solid stearin portion obtained by fractionation is mostly employed. The technology is used by the chocolate-manufacturing industries, and consequently, solid sal fat fractions are good foreign exchange earners today. Mahua fat is believed to be suitable as well.

Table 1 indicates the potential and present commercial availability of these two fats in India. Although the solid stearin fractions are utilized for making confectionery fats, the liquid olein portions obtained have, as yet, no specific utility. Studies on the following aspects are described in this paper, with an objective to find suitable, edible utilization of these oleins: Fatty acid composition and analytical characteristics of sal olein and mahua olein obtained under varying crystallization conditions, oxidative stability of the oleins with and without added antioxidant systems, and frying performance of the olein fractions, evaluated by perodically monitoring the analytical characteristics, particularly total polar material.

TABLE 1

Potential and Present Availability of Indian Nontraditional Oils (in thousand tons)

	Potential		Present availability	
Source	Seed	Oil	Seed	Oil
Sal	6000	720	114	97
Mahua	1000	350	100	35
Other trees of forest origin	7370	1000	260	100

MATERIALS AND METHODS

Oils. Sal and mahua fats were obtained through the courtsey of K.N. Oil Industries and Hindustan Vegetable Oils Corporation Ltd., respectively.

Processing. Sal and mahua fats (refined and bleached) were fractionated from acetone (7 ml/gm of oil) at appropriate temperatures for specific periods (6). The soluble portions obtained by filtration at the same temperatures were desolventized, and the oleins were then deodorized in a specially devised laboratory apparatus by purging steam from an autoclave at 180°C under vacuum.

Fatty acid composition. Sal and mahua oleins obtained under different conditions were converted to their methyl esters with a sodium methoxide catalyst. Fatty acid compositions were determined by GLC on a Varian 3700 gas chromatograph with dual flame ionization detector and 6 ft × 1/8 inch stainless steel column packed with 3% EEGS-X supported on Aeropak (80/100 mesh). The column, injector and FID temperatures were 180°C, 200°C and 230°C, respectively. The N_2 flow rate was 25 ml/min and the fatty acid composition was recorded by using computer data system CDS 111. Content of 9,10 epoxy stearic acid and dihydroxy stearic acid were measured by GLC according to the method accepted by the Bureau of Indian Standards (7).

Analytical evaluation. Analytical characteristics such as acid value, peroxide value, color, iodine value and unsaponifiable matter content of the olein fractions were evaluated by AOCS methods (8). The content of total polar material was determined by column chromatography (9) and foam height by the method of Fritsch *et al.* (10).

Stability determination. Stability of the olein fractions with and without antioxidants was examined by means of the Schaal Oven test, an accelerated test that simulates normal storage conditions.

Four oil samples (100 gm each) containing single antioxidant systems were examined: (a) 2 and 3 tertiary butyl 4 methoxy phenol (BHA); (b) 2,6 ditertiary butyl 4 methyl phenol (BHT); (c) n-propylester of 3,4,5 trihydroxybenzoic acid (nPG) (Sigma Chemical Company, USA); and (d) tertiary butyl hydroquinone (TBHQ) (Embanox, May and Baker Ltd., England). One sample without antioxidant was also tested. Each antioxidant was added in 0.01% proportion (on wt. of the oil) at 60°C as 10% solution in ethanol and mixed by adequate stirring to ensure complete solution (11). The samples were held in 250 ml breakers, covered with watch glasses, in an air oven maintained at 63° ± 0.5°C (12). Peroxide and acid values were periodically determined by AOCS methods (8). Onset of rancid flavor was evaluated by a group of trained panelists. Flavor intensity scoring was done by a method followed by Jackson *et al.* (13). Color of the

*To whom correspondence should be addressed.

sample was evaluated by Lovibond Tintometer. Onset of rancidity was judged by flavor and color bleach end point. It was observed in our previous studies (14) that oil samples kept in Schaal Oven test conditions darken to a reddish color as they appraoch rancidity and then bleach out to a faint greenish color very rapidly after they become rancid (as judged by off-flavor also). This observation agrees with that of earlier workers (12). Results are shown in Tables 4-6.

Deep-fat frying. Performance of the olein fractions with and without 0.01% TBHQ on extended deep-fat frying was evaluated by frying batches of potato chips under standard conditions and comparing the trend in oil deterioration against similar frying in a commercially-refined groundnut oil and palm olein.

Potatoes were peeled and sliced into elliptical chips (3.5-4 cm = 5 cm, thickness 1.0 mm) and kept under cold water until used for frying.

Oil (2.5 kg) was taken in a common iron pan or karai (Specific surface of oil = 0.30 cm^2/gm) and heated to 190°C with a thermostatic control device (2 KVA). After the heat had been turned on for 45 minutes, a 100 gm batch of potato chips was fried. Two batches were fried each hour for 6 hours each day and the process was continued for 5 days. At the end of the second day, 500 gm of fresh oil was added to maintain the frying level. Oil samples were drawn at the end of each day and kept under nitrogen in the dark until analyzed. Parallel experiments were conducted with a commercially refined groundnut oil and palm olein. The results are shown in Tables 7 and 8.

RESULTS AND DISCUSSION

Basically, the objective of this work was to assess the suitability of the olein fractions as edible oils. Fatty acid compositions (Table 2) indicate that sal oleins are always rich in stearic (33.5-34.0) and oleic acids (49.1-50.0). Increasing the temperature of fractionation resulted in a slight decrease in the iodine value of sal olein. Mahua olein contained palmitic (18%), stearic (21%), oleic (38%) and linoleic (21%) as major fatty acids. Iodine values (IV) of sal olein were 59.4-60.0, saponification values (SV) were around 198 and unsaponifiable matter content (USM) was 1.5%. For mahua olein, the IV was 76.8, SV 202.1 and USM 1.8% (Table 3).

Sal olein and mahua olein showed a Schaal oven stability of 17 and 15 days, respectively. The stability was judged on the basis of color bleach end point and onset of rancid flavor (evaluated by a taste panel). Results are shown in Tables 4-6. In our experimental setup, one day of Schaal oven storage has been found to be equivalent to approximately 10-11 days of normal storage (14) at ambient temperature. Thus the two oleins would have a stability of about 6 and 5 months at normal temperature, even without any antioxidant added. Antioxidant effectiveness increases in the order—BHA, BHT, PG and TBHQ. Schaal oven stability of sal olein containing 0.01% BHA, BHT and PG was 19, 39 and 41 days, respectively. Corresponding values for mahua olein were 17, 33 and 39 days. With 0.01% TBHQ, sal olein could be stored up to 53 days and mahua olein up to 45 days under Schaal oven conditions, corresponding to a normal temperature storage life of 530-585 days and 450-490 days, respectively. Table 4 shows that the acid value of sal olein with or without antioxidant systems increases from 0.3 (original) to 0.5 (rancid point). Peroxide values increase from nil to 22.3 (0.01% TBHQ) and to 28.0 (without antioxidant). The acid value of mahua olein rises from 0.2 to 0.6 and the peroxide value of mahua olein rises from nil to 9.1 (rancid point) without the presence of antioxidant. With 0.01% TBHQ, the peroxide value at rancid point is 7.6; with other antioxidant systems the values are in between.

Flavor of the oil samples was evaluated on a 10-point scale (10—completely bland, 1—repulsive) by trained panelists by the method of Jackson *et al.* Table 6 shows that flavor degradation of sal olein and mahua olein was

TABLE 2

Fatty Acid Composition of Sal and Mahua Olein Obtained Under Different Crystallization Conditions

Olein	Temp/time of fractionation	Yield (wt %)	Major fatty acids, % wt						9,10 Epoxy and dihydroxy stearic acid
			16:0	18:1	18:1	18:2	18:3	20:0	
Sal	10° ± 1°C/3 hrs	22	5.3	34.0	49.1	3.8	3.3	4.0	0.5
	15° ± 1°C/5 hrs	30	4.4	33.5	50.0	4.1	3.5	4.0	0.5
Mahua	4° ± 1°C/7 hrs	50	18.5	21.0	38.4	20.9	1.0	0.2	—

TABLE 3

Analytical Characteristics of Vegetable Butter Oleins

Olein	Temp/time	Slip pt. (°C)	I.V.	Sap. value	Color (Lovibond, 1/4" cell)	Unsap. (wt %)	Acid value
Sal	10° ± 1°C/3 hrs	24.0	59.4	198.8	0.3R/1.0Y	1.5	0.2
	15° ± 1°C/5 hrs	23.0	60.0	198.6	0.4R/1.1Y	1.5	0.2
Mahua	4° ± 1°C/7 hrs	16.0	76.8	202.1	0.3R/2.0Y	1.8	0.1

TABLE 4

Schaal Oven Study of Sal Olein With and Without Antioxidant Systems (Acid Value, Peroxide Value and Color)[a]

	Without antioxidant			BHA (0.01%)			BHT (0.01%)			PG (0.01%)			TBHQ (0.01%)		
Days	AV	POV	Color[b]	AV	POV	Color[b]	AV	POV	Color[b]	AV	POV	Color[b]	AV	POV	Color[b]
0	0.3	Nil	0.3R/1Y	0.3	Nil	0.3R/1Y	0.3	Nil	0.3R/1Y	0.3	Nil	0.3R/1Y	0.3	Nil	0.3R/1Y
10	0.4	14.5	0.3R/1.5Y	0.3	3.0	0.3R/1.4Y	0.3	2.0	0.3R/1.3Y	0.3	Nil	0.3R/1.2Y	0.3	Nil	0.3R/1.1Y
16	0.4	20.0	0.5R/1.6Y	0.3	9.0	0.3R/1.8Y	0.3	3.5	0.3R/1.4Y	0.3	Nil	0.3R/1.2Y	0.3	Nil	—
17	0.5*	25.2	0.2R/1.0Y	0.4	13.0	0.4R/2.1Y	0.3	5.0	0.3R/1.8Y	0.3	2.1	0.3R/1.3Y	0.3	Nil	—
18	0.5	28.0	0.2R/0.9Y	0.5	18.6	0.5R/2.2Y	0.4	6.6	0.4R/1.8Y	0.3	3.2	0.4R/1.3Y	0.3	1.1	—
19	—	—	—	0.5*	25.8	0.2R/0.8R	0.4	8.2	0.4R/1.9Y	0.4	4.3	0.4R/1.3Y	0.3	1.8	—
30	—	—	—	—	—	—	0.4	18.1	0.5R/2.1Y	0.4	15.9	0.4R/1.3Y	0.3	6.8	—
38	—	—	—	—	—	—	0.5	24.9	0.5R/2.3Y	0.4	21.0	0.5R/1.8Y	0.3	10.8	—
39	—	—	—	—	—	—	0.5*	26.2	0.2R/1.0Y	0.5	23.4	0.8R/2.0Y	0.4	11.3	0.4R/1.5Y
40	—	—	—	—	—	—	—	—	—	0.5	24.6	0.8R/2.1Y	0.4	11.9	0.4R/1.6Y
41	—	—	—	—	—	—	—	—	—	0.5*	25.5	0.2R/0.9Y	0.4	12.4	0.4R/1.6Y
49	—	—	—	—	—	—	—	—	—	—	—	—	0.5	17.4	0.4R/1.6Y
50	—	—	—	—	—	—	—	—	—	—	—	—	0.5	19.2	0.4R/1.6Y
52	—	—	—	—	—	—	—	—	—	—	—	—	0.5	20.1	0.4R/1.6Y
53	—	—	—	—	—	—	—	—	—	—	—	—	0.5*	22.3	0.2R/1.1Y

[a]Values were determined daily, only significant results shown here.

[b]Color measured in 1/4 in. cell in Lovibond Tintometer.

*Indicates points at which rancid odor and color bleach end point were observed (see text).

TABLE 5

Schaal Oven Study of Mahua Olein With and Without Antioxidant Systems (Acid Value, Peroxide Value and Color)[a]

	Without antioxidant			BHA (0.01%)			BHT (0.01%)			PG (0.01%)			TBHQ (0.01%)		
Days	AV	POV	Color[b]	AV	POV	Color[b]	AV	POV	Color[b]	AV	POV	Color[b]	AV	POV	Color[b]
0	0.2	Nil	0.3R/2.0Y	0.2	Nil	0.3R/2.0Y	0.2	Nil	0.3R/2.0Y	0.2	Nil	0.3R/2Y	0.2	Nil	0.3R/2.1Y
10	0.4	4.2	0.4R/3.0Y	0.3	1.1	0.5R/2.8Y	0.2	1.0	—	0.2	1.1	—	0.2	1.1	—
14	0.5	5.6	0.6R/3.5Y	0.4	4.5	0.6R/3.2Y	0.2	1.5	—	0.2	1.5	—	0.2	1.2	—
15	0.6*	9.1	0.3R/1.8Y	0.5	6.1	0.8R/3.6Y	0.3	2.5	—	0.2	2.6	—	—	—	—
17	0.6	15.0	0.2R/1.7Y	0.6*	8.5	0.4R/2.0Y	0.3	3.1	0.5R/2.0Y	0.3	3.2	—	—	—	—
18	0.7	—	—	0.6	9.9	0.4R/1.9Y	0.3	3.5	0.5R/2.8Y	0.3	3.4	0.4R/2.5Y			
19	—	—	—	—	—	—	0.4	4.5	0.6R/3.0Y	0.4	4.8	0.4R/2.5Y			
30	—	—	—	—	—	—	0.4	7.0	0.7R/3.5Y	0.4	7.1	0.5R/3.0Y	0.2	2.3	0.5R/2.4Y
31	—	—	—	—	—	—	0.5	7.5	0.8R/3.5Y	0.4	7.3	0.6R/3.5Y	0.3	3.2	0.6R/2.7Y
33	—	—	—	—	—	—	0.6*	8.1	0.4R/1.8Y	0.4	8.3	0.7R/4.0Y	0.3	4.6	0.6R/2.8Y
35	—	—	—	—	—	—	0.6	—	—	0.5	8.5	0.8R/4.6Y	0.4	5.2	0.7R/3.0Y
39	—	—	—	—	—	—	—	—	—	0.6*	9.5	0.4R/1.5Y	0.5	6.4	0.8R/3.8Y
45	—	—	—	—	—	—	—	—	—	0.6	10.5	—	0.5*	7.6	0.2R/1.1Y

[a]Values were determined daily, only significant results shown here.

[b]Color measured in 1/4 in. cell in Lovibond Tintometer.

*Indicates points at which rancid odor and color bleach end point were observed.

TABLE 6

Taste Panel Evaluation (Flavor Scores)[a] of Sal Olein and Mahua Olein With and Without Antioxidant Systems During Schaal Oven Study

	Sal olein					Mahua olein				
Days (63°C)	Without antioxidant	BHA (0.0%)	BHT (0.01%)	PG (0.01%)	TBHQ (0.01%)	Without antioxidant	BHA (0.01%)	BHT (0.01%)	PG (0.01%)	TBHQ (0.01%)
0	9.8	9.5	9.8	9.9	9.8	9.8	9.5	9.8	9.7	9.9
7	7.3	8.1	9.3	9.8	9.7	6.8	7.5	8.6	8.8	9.0
15	6.8	7.0	8.5	9.0	9.6	5.5*	6.0	8.2	8.4	8.6
17	5.2*	6.6	8.0	8.2	9.5	4.5	5.5*	7.9	8.2	8.4
19	4.3	5.0*	8.0	8.1	9.5	—	5.0	7.5	8.0	8.3
21	—	4.0	7.8	8.0	9.2	—	—	7.0	7.9	8.1
23	—	—	7.6	7.9	8.8	—	—	6.6	7.7	8.1
31	—	—	7.0	6.8	7.8	—	—	6.0	7.0	7.2
33	—	—	5.6*	6.6	7.5	—	—	5.5*	6.8	7.0
35	—	—	5.0	6.4	7.2	—	—	5.0	6.4	6.8
37	—	—	5.0	6.2	6.9	—	—	—	6.1	6.8
39	—	—	—	5.8	6.9	—	—	—	5.7*	6.0
41	—	—	—	5.6*	6.4	—	—	—	5.5	6.0
43	—	—	—	4.9	6.2	—	—	—	—	5.8
45	—	—	—	—	6.0	—	—	—	—	5.5*
47	—	—	—	—	6.0	—	—	—	—	5.4
49	—	—	—	—	6.0	—	—	—	—	—
51	—	—	—	—	5.5	—	—	—	—	—
53	—	—	—	—	5.4*	—	—	—	—	—
55	—	—	—	—	5.3*	—	—	—	—	—

[a]Ten-point odor grading scale by Jackson *et al.* (13) was used.

*Indicates points at which rancid odor and color bleach end point were observed.

TABLE 7

Deep Fat Frying of Potato Chips in Sal Olein and Mahua Olein

Period of frying (hr)	Acid value	Peroxide value (meq/kg)	Iodine value (Wijs)	Lovibond color (1/4" cell)	Foam height (mm)	Total polar material (%)
Sal olein						
0	0.2	Nil	60.2	0.3R/1.0Y	—	2.0
6	0.2	5.6	—	0.5R/9Y	10.0	8.1
12	0.3	8.7	—	0.9R/11Y	12.5	19.1
18	0.4	15.8	—	1.9R/19Y	20.0	21.5
24	0.4	19.1	49.8	3.5R/22Y	30.0	28.0
30	0.5	25.0	45.1	9.0R/30Y	37.5	29.0
Mahua olein						
9	0.1	Nil	63.0	0.3R/2.0Y	—	2.5
6	0.4	4.1	—	0.5R/5.8Y	10.0	10.5
12	0.4	14.1	—	1.5R/8.8Y	12.5	15.9
18	0.4	25.0	53.1	2.1/6.0Y	25.0	23.0
24	0.8	30.1	—	4.0R/25Y	35.0	31.0
30	0.8	32.1	50.0	1.5R/29.6Y	40.0	34.0
Groundnut oil (control)						
0	0.2	2.8	96.5	0.1R/0.3Y	—	1.2
6	0.5	9.2	89.5	0.3r/1.5Y	27.5	6.5
12	1.3	10.9	87.5	0.7R/4.4Y	30.0	17.2
18	1.6	8.6	77.3	1.0R/7.0Y	77.5	24.5
24	1.6	9.1	78.3	1.8R/6.0Y	70.0	26.0
30	1.9	9.7	78.2	1.9R/20Y	67.5	28.2
36	2.1	9.9	78.0	3.6R/26Y	67.5	28.1
Palm olein (control)						
0	0.2	1.0	58.9	0.1R/6.0Y	—	1.8
6	0.2	4.0	—	0.5R/6.2Y	50.0	5.5
12	0.3	5.6	50.6	0.9R/7.0Y	50.0	15.0
18	0.4	8.9	—	1.9R/18.0Y	50.0	20.9
24	0.5	10.9	48.0	3.0R/23.0Y	50.0	26.0
30	0.6	14.7	—	8.5R/29.7Y	62.5	26.9
36	0.8	23.8	45.0	10.8R/31Y	65.0	33.5

TABLE 8

Deep-fat Frying of Potato Chips in Sal Olein and Mahua Olein Containing 0.01% TBHQ

Period of frying (hr)	Acid value	Peroxide value (meq/kg)	Iodine value (Wijs)	Lovibond color (1/4" cell)	Foam height (mm)	Total polar material (%)
Sal olein						
0	0.2	Nil	60.2	0.3R/1.0Y	—	2.0
6	0.2	4.1	—	0.4R/4.0Y	10.0	6.1
12	0.3	5.9	—	0.9R/7.0Y	12.5	15.5
18	0.3	4.8	49.9	1.6R/14.0Y	20.0	20.1
24	0.4	4.7	—	3.0R/20.9Y	27.5	22.9
30	0.5	4.1	45.5	8.0R/29.1Y	35.0	26.8
Mahua olein						
0	0.1	Nil	63.0	0.3R/2.0Y	—	2.5
6	0.4	4.1	—	0.5R/5.2Y	7.5	5.3
12	0.4	5.3	—	1.5R/8.0Y	10.0	14.9
18	0.4	4.7	53.1	1.9R/5.0Y	12.5	20.0
24	0.7	4.2	—	3.8R/10Y	32.5	22.5
30	0.7	4.0	50.0	10.4R/20Y	37.5	24.4

slower when an antioxidant system was present. TBHQ was found to be most effective in this regard.

Table 7 shows the behavior of sal olein and mahua olein on prlonged deep-fat frying. A level of 25–30% total polar material has been suggested as an index of deterioration, beyond which, use of the oil medium is not desirable (15). After 18 hr of frying, sal olein and mahua olein had total polar material contents of 21.5 and 23%, respectively, against 24.5 and 20.9% in commercial refined groundnut oil and palm olein that had undergone identical frying treatments (Table 7). This is in accord with the lower levels of linoleic acid (about 4 and 11%) in these oleins than in groundnut oil (about 25%). Thus, the two oleins are likely to be more stable than groundnut oil and comparable to palm olein as frying media. Deep-fat frying performance of the oleins containing 0.01% TBHQ is shown in Table 8. As expected, oil deterioration is much slower when an antioxidant system is included. After 18 hr of frying, sal olein and mahua olein with 0.01% TBHQ had a total polar material content of 20% (cf. 24.5 and 20.9% in commercially refined groundnut and palm olein oil). As can be seen from the table, deterioration in acid value, peroxide value, color, etc., are slower when an antioxidant is added.

To sum up, the olein fractions from sal and mahua fats can be utilized for direct cooking purposes. These oleins may also have potential as ingredients for blending with accepted edible oils that have desired flavor characteristics.

ACKNOWLEDGMENTS

M. M. Chakrabarty and K. T. Achaya provided valuable advice.

REFERENCES

1. Information from the Central Forestry Commission Krishni Bhawan, Govt. of India, New Delhi, Proceedings of the National Seminar on Problems and Prospects of Non-Conventional Oils, Organized by Oil Technologist's Association of India, Nov. 1981.
2. Kane, J.G., *Fette Seifen Anstrichm. 68*:1 (1966).
3. Indian Patent No. 129348, assigned to Hindustan Lever Limited, Nov. 23, 1970.
4. Bhambhani, T.R., A.D. Shitole, and J.G. Kane, *J. Oil Technol. Assoc. India 4*:3 (1972).
5. Adhikari, S., J. Dasgupta, D.K. Bhattacharyya and M.M. Chakrabarty, *Fette Seifen Anstrichm. 81*:146 (1982).
6. Ghosh Chaudhuri, P., M.M. Chakrabarty, and D.K. Bhattacharyya, *Ibid. 85*:224 (1973).
7. Indian Standard Specification for Salseed Fat. IS: 7375-1979.
8. Official and Tentative Methods, American Oil Chemists' Society, 3rd edn., Champaign, Illinois, 1971.
9. Billek, G., G. Guhr, and J. Waibel, *J. Am. Oil Chem. Soc. 55*:728 (1978).
10. Fritsch, G., D. Egberg, and J.S. Magnuson, *Ibid. 56*:746 (1979).
11. Mounts, T.L., K. Warner, and G.R. List, *Ibid. 58*:792 (1981).
12. Cocks, L.V., and C. Van Rede, *Handbook of Oil and Fat Analysis*, Academic Press, 1966, p. 391.
13. Jackson, W.W., and D.J. Giacherio, *J. Am. Oil Chem. Soc. 54*:4558 (1977), Bailey's Industrial Oil and Fat Products, Vol. 3. Edited by T.H. Applewhite, John Wiley & Sons, New York (1985), p. 267.
14. Adhikari, S., and J. Adhikari, *Indian Food Industry 4*:155 (1985).
15. Billek, G., *Nutr. Metab. 24* (Suppl. 1): 200 (1979).

[Received January 25, 1988; accepted June 16, 1989]
[J5399]