Variation in Fatty Acid Composition of the Different Acyl Lipids in Seed Oils from Four *Sesamum* Species

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Seeds from different collections of cultivated *Sesamum indicum* Linn. and three related wild species [specifically, *S. alatum* Thonn., *S. radiatum* Schum and Thonn. and *S. angustifolium* (Oliv.) Engl.] were studied for their oil content and fatty acid composition of the total lipids. The wild seeds contained less oil (*ca.* 30%) than the cultivated seeds (*ca.* 50%). Lipids from all four species were comparable in their total fatty acid composition, with palmitic (8.2–12.7%), stearic (5.6–9.1%), oleic (33.4–46.9%) and linoleic acid (33.2–48.4%) as the major acids. The total lipids from selected samples were fractionated by thin-layer chromatography into five fractions: triacylglycerols (TAG; 80.3–88.9%), diacylglycerols (DAG; 6.5–10.4%), free fatty acids (FFA; 1.2–5.1%), polar lipids (PL; 2.3–3.5%) and steryl esters (SE; 0.3–0.6%). Compared to the TAG, the four other fractions (*viz*, DAG, FFA, PL and SE) were generally characterized by higher percentages of saturated acids, notably palmitic and stearic acids, and lower percentages of linoleic and oleic acids in all species. Slightly higher percentages of long-chain fatty acids (20:0, 20:1, 22:0 and 24:0) were observed for lipid classes other than TAG in all four species. Based on the fatty acid composition of the total lipids and of the different acyl lipid classes, it seems that *S. radiatum* and *S. angustifolium* are more related to each other than they are to the other two species.

KEY WORDS: Diacylglycerols, fatty acids, free fatty acids, polar lipids, sesame seeds, *Sesamum*, *S. alatum*, *S. angustifolium*, *S. indicum*, *S. radiatum*, steryl esters, triacylglycerols.

Sesame oil, obtainable from the seeds of *Sesamum indicum* Linn., is among the first edible oils known and used by humans. The oil is unique because of its unusually high oxidative stability (1). The use of sesame oil as an edible oil is, however, largely limited to the areas of production because of the high cost of the seed. The combined internal consumption of sesame seed in the major producing countries (China, India, Sudan, Mexico and Burma) represented 60% of the total world production in 1987 (2). In industrialized countries, sesame oil is sold as one of the specialty gourmet oils, with unique flavor and character (3). The low yield of the crop and difficulties in mechanized harvesting, due to the uneven ripening of the capsules (4), are the main reasons behind the high price of sesame seed and oil.

The genus *Sesamum* is made up of about 35 wild species besides *S. indicum*, the only cultivated species in the world. The wild relatives are more resistant to environmental stresses than the domesticated species. In the 1980s, plant breeders and agronomists showed interest in the wild relatives to provide genes that can improve some aspects in sesame cultivation. Increased efforts in collection and investigation of different *Sesamum* species were recommended (5,6).

We found it interesting to start some investigations on the seed lipids of the wild species that grow in the Sudan, specifically *S. alatum* Thonn., *S. radiatum* Schum & Thonn. and *S. angustifolium* (Oliv.) Engl., in comparison with different pure-line and mixed-line genotypes of the cultivated *S. indicum* Linn. In a previous communication (7), the oil contents and the fatty acid and triacylglycerol (TAG) compositions of the oils from single samples of the three wild species were reported. The wild species had lower oil percentages (29–36%) than *S. indicum* (47–55%). The fatty acid compositions and the TAG patterns of the seed oils of the wild species were basically similar to those of the cultivated species. *Sesamum radiatum* and *S. angustifolium* had slightly higher percentages of the saturated acids, especially stearic acid.

In this paper, more samples of *S. indicum* and two additional samples of each wild species were collected and studied for their total fatty acid composition to confirm or modify our previous findings and to arrive at some general conclusions on the similarities and the differences between the four species, based on more than single samples.

The composition of total fatty acids is often the only information provided in studies on seed lipids. In this study, one representative sample from each of the four species was analyzed with respect to fatty acid composition of the separated lipid classes—TAG, diacylglycerols (DAG), free fatty acids (FFA), polar lipids (PL), steryl esters (SE)—in an attempt to map the variability in their relative proportions and the fatty acid percentages in each class.

MATERIALS AND METHODS

Seeds from different cultivars of *S. indicum* Linn. and from different collections of the three related wild species, *S. alatum* Thonn., *S. radiatum* Schum & Thonn. and *S. angustifolium* (Oliv.) Engl., were collected from different locations in the Sudan (Table 1). Codes were given to the samples based on abbreviations of their local names.

All solvents and reagents used were of analytical grade (E. Merck, Darmstadt, Germany) and were used without further purification. Pre-coated Silica-gel 60 plates (20 × 20 cm, 0.25 mm layer thickness; Merck) were used for all thin-layer chromatography (TLC) separations. The TLC standard mixture, containing sterol, free fatty acid, TAG, methyl ester and SE, was from Larodan Fine Chemicals AB (Malmö, Sweden). Fatty acid methyl ester (FAME) standards and methyl heptadecanoate (17:0), used as an internal standard, were also from Larodan. BF_3 in methanol (14%) (Sigma Chemical Co., St. Louis, MO) was used to prepare the FAME. The phospholipid standards (phosphatidic acid, phosphatidylcholine, phosphatidylethanolamine, phosphatidylserine and phosphatidylinositol) were obtained in a phosphoglyceride kit from Larodan. All determinations in this paper were carried out in duplicate, and mean values are reported.

Oil extraction. Crude lipids were extracted by vigorous shaking of duplicate samples, each 5 g of seeds, in stainless-steel tubes with four steel balls and 30 mL of heptane/isopropanol (HIP; 3:1, vol/vol) for 1 h, essentially as described by Appelqvist (8). The lipid extracts were filtered through lipid-free filter paper, and the solvent was

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TABLE 1

Identification of Sesame Samples Analyzed, Their Seed Weights and Oil Contents

Species code	Variety (local name)	Locality (source)	Color of seeds	Seed weight[a] (as is, mg)	Oil content[b] (% in seed)
Sesamum indicum Linn.[a,b]					
GAS	Gabaly Aswad	Um Roaba	Black	3.5	50.7
GAB	Gabaly Abiad	Um Roaba	White	2.0	47.4
HIR	Hirihri	Um Roaba	Brown	3.6	52.3
PLM	Palarma	Agadi, Eldamazeen	White	3.0	55.1
YRO	Yrou	Agadi, Eldamazeen	Greyish-white	2.8	51.9
BAB	Bilia Abiad	Doka, Elgadarif	White	2.6	55.5
ABS	Abu Sandoog	Doka, Elgadarif	White	2.5	55.1
S. alatum[a] Thonn.					
OB-1	Camel sesame	Elobied	Brown-winged seeds	1.7	29.8
OB-2	Camel sesame	Elobied	Brown-winged seeds	1.6	29.1
UR	Camel sesame	Um Roaba	Brown-winged seeds	1.8	28.1
S. radiatum Schum & Thonn.					
RDZ	Devil sesame	Eldamazeen	Black, large seeds	1.8	30.3
RGD	Devil sesame	Elgadambalia	Black, large seeds	1.8	33.4
RDK	Devil sesame	Doka	Black, large seeds	1.7	30.8
S. angustifolium (Oliv.) Engl.					
ANG-1	Deer sesame	Elfola	Black, small seeds	1.0	29.2
ANG-2	Deer sesame	Elfola	Black, small seeds	1.0	29.7

[a]Determined by weighing 100 seeds.
[b]Percent in undried seeds. The moisture contents in the seeds were *ca.* 3.5% in *S. indicum*, *ca.* 4% in *S. alatum*, *ca.* 3% in *S. radiatum* and *ca.* 4% in *S. angustifolium*.

evaporated *in vacuo* at *ca.* 30°C. The oils were weighed to determine the oil content of the seeds and then kept in HIP solutions at −20°C for further analyses.

TLC. The total lipids from a single sample of each species were fractionated by TLC into five fractions: PL, DAG, FFA, TAG and SE. The crude lipid extracts were applied on TLC plates as 14-cm bands (*ca.* 70 mg/plate) with a Linomat-3 auto applicator (CAMAG, Muttenz, Switzerland). The TLC standard mixture was applied as a reference on one side of each plate, and the plates were developed in hexane/diethyl ether/acetic acid (HEA; 85:15:1, vol/vol/vol). The plates were covered with other glass plates, leaving the reference zone exposed to be visualized by exposure to iodine vapor. Bands corresponding to PL (R_f 0.00–0.03), DAG (R_f 0.03–0.13), FFA (R_f 0.13–0.27), TAG (R_f 0.33–0.59) and SE (R_f 0.82–0.97) were scraped and eluted (2 × 3 mL) as follows: PL ($MeOH/CHCl_3$, 2:1, vol/vol), DAG ($Et_2O/CHCl_3$, 2:1, vol/vol), FFA and TAG (Et_2O) and SE (*n*-hexane). All extractions were carried out at room temperature for a few minutes, except for the PL, which were extracted at 4°C overnight.

Part of the PL extracts, obtained as described before, were further separated by TLC with chloroform/methanol/acetic acid/water (CMAW; 170:30:20:7, by vol) as the mobile phase (9). The separated phospholipid classes were detected by iodine vapor and were matched against the authentic standards. To determine whether HIP extraction would activate the phospholipases, extracted seeds were allowed to stand in the solvent for 4 h before filtering. The filtrate was then checked by TLC (CMAW), along with the fresh extracts (1-h extraction).

Preparation and purification of FAME. Methyl heptadecanoate (17:0) was added as an internal standard to the total lipids and to each fraction at *ca.* 10% level (w/w). FAME were prepared by treating the lipids in hexane (0.5 mL) consecutively with 0.01 M NaOH in dry methanol (2 mL) and 14% BF_3 in methanol (3 mL) at 60°C (10). The FAME were then purified by TLC with HEA as the developing solvent (R_f 0.56–0.81), scraped, eluted three times with diethyl ether and stored in solvents at −20°C until injected into the gas chromatograph.

Gas chromatography. Gas chromatographic (GC) analyses of FAME were carried out in a Varian 3400 gas chromatograph (Palo Alto, CA) equipped with a split injector and a flame-ionization detector (FID). The injector temperature was 230°C and the split ratio was 50:1. Two fused silica WCOT capillary glass columns coated with CP Sil 88 (100% Cyanopropyl) of 50 m and 20 m length were connected (Chrompack International B.V., Middelburg, The Netherlands). Both columns were 0.15 mm i.d., but had 0.12 μ and 0.20 μ film thickness, respectively. The initial column temperature was 175°C for 20 min, followed by programming to 180°C at 1°C/min and further programming to 190°C at 2°C/min, with a final hold at 190°C for 14 min. Hydrogen was used as the carrier gas at a linear velocity of 18.6 cm/s. Nitrogen was used as the make-up gas at a flow rate of 30 mL/min, and the FID temperature was 260°C. Component peaks were recorded on a Varian 4290 integrating system and were identified by comparison of their retention times with those of authentic FAME standards. Peak areas were computed, and percentages of the FAME were obtained as weight percent by direct internal normalization. No correction factors were used because the response factors of the main fatty acids were close to unity.

RESULTS

The crude oils. Table 1 shows the seed weights and oil percentages, on an "as is" basis, of the seed samples studied. The crude lipid contents in the seeds of the wild species, *S. alatum* (28.1–29.8%), *S. radiatum* (28.9–33.4%)

and *S. angustifolium* (29.2–36.2%), are significantly lower than in *S. indicum* (47–55.5%).

The HIP (3:1, vol/vol)-extracted oils had the following colors at room temperature: yellow, (*S. indicum*), green (*S. alatum*), yellow-olive green (*S. radiatum*) and yellow-green yellow (*S. angustifolium*). Visible absorption spectra demonstrated carotenoids and chlorophyll as the major pigments in all oils (data not shown).

Fatty acid composition of the total lipids. Table 2 presents the fatty acid composition obtained by GC analysis of the methyl esters of the total lipids. Palmitic (8.2–12.7%), stearic (5.6–9.1%), oleic (33.4–46.9%) and linoleic (33.2–48.4%) acids were the principal fatty acids in all four species. Low percentages were recorded for other acids—palmitoleic (0.1–0.3%), *cis*-vaccenic (0.8–1.5%), linolenic (0.2–0.8%) and arachidic acid (0.5–0.8%). Eicosenoic and behenic acids occurred in all oils at *ca.* 0.1%, and trace amounts of lignoceric acid were detected.

Composition of the different acyl lipid classes. One representative sample for each species was selected for study of the percentages of the different lipid classes, namely TAG, DAG, FFA, PL and SE, and their fatty acid composition (Table 3). The major fraction in all species was TAG, representing *ca.* 89% of *S. indicum* lipids. Lipids from the seeds of the three wild species contained lower percentages of TAG (*ca.* 80–85%) and higher percentages of DAG (*ca.* 8–10%) as compared with *S. indicum* (6.5% DAG).

In all species, the fatty acid compositions of lipid classes other than TAG (DAG, FFA, PL and SE) were different from that of TAG and were generally characterized by relatively higher percentages of saturated acids, notably palmitic, and relatively lower percentages of unsaturated acids, particularly linoleic acid, in the aforementioned order. Fewer variations, but with the same trend, were observed for stearic and oleic acids. In *S. indicum*, for example, palmitic acid showed the following percentages in the different lipid classes: TAG (8.9%), DAG (12.5%), FFA (17.8%), PL (22.6%) and SE (24.4%). Linoleic acid, on the other hand, showed the following proportions: TAG (37.9%), DAG (34.3%), FFA (27.2%), PL (24.9%) and SE (21.8%). Stearic and oleic acids ranged from 6.8 and 44.1% in the TAG fraction to 11.9 and 35.8% in the SE fraction, respectively. Slightly higher percentages of long-chain fatty acids (20:0, 20:1, 22:0 and 24:0) were also observed for lipid classes other than TAG in all four species. Similar differences between the different classes were observed in the three wild species.

There was good agreement between the values for total fatty acid composition, obtained by direct analysis (Table 2) and by the sum of different percentage classes (Table 3), suggesting that the method used for the fractionation of total lipids was highly reliable.

Composition of the TAG fractions. The TAG fraction of the *S. indicum* sample (GAS) had 8.9% palmitic, 6.8% stearic, 44.1% oleic and 37.9% linoleic acid. The fatty acid composition of the TAG fraction of the *S. alatum* sample (OB-2) was comparable to that of GAS with 11.4% palmitic, 5.7% stearic, 46.4% oleic and 33.5% linoleic acid. The samples of *S. radiatum* (RDK) and *S. angustifolium* (ANG-2) had similar fatty acid percentages in their TAG fractions with respective percentages of palmitic (9.3 and 8.6%), stearic (9.1 and 6.4%), oleic (34.7 and 33.1%) and linoleic acid (44.8 and 49.4%). Palmitoleic, *cis*-vaccenic, linolenic, arachidic, eicosenoic and behenic acids occurred as minor acids (<1%) in all samples, and trace amounts of lignoceric acid were also observed.

Composition of the DAG fractions. Compared to the TAG, the DAG fraction of the three wild species displayed slightly higher percentatges of palmitic, palmitoleic, oleic and the long-chain fatty acids at the expense of linoleic acid. In *S. indicum*, these acids showed similar differences between DAG and TAG, except for oleic acid, which showed the same percentage in both fractions. *Sesamum indicum, S. alatum* and *S. angustifolium* also had slightly higher percentages of stearic acid in the DAG fraction, but *S. radiatum* was exceptional in showing a lower relative percentage for this acid.

Composition of the FFA fractions. The FFA fraction of all species had higher relative percentages of palmitic, palmitoleic, stearic and the long-chain fatty acids than did the TAG fraction. In *S. indicum* and *S. radiatum*, these were balanced by lower percentages of oleic and linoleic acids. *Sesamum alatum* and *S. angustifolium*, on the other

TABLE 2

Fatty Acid Composition of the Total Lipids from Four *Sesamum* Species

Species/sample (code)	Fatty acid percentages (%, w/w)[a]							
	16:0	16:1	18:0	18:1Δ9	18:1Δ11	18:2	18:3	20:0
S. indicum								
GAS	9.0	0.2	6.5	44.3	0.9	38.0	0.6	0.3
GAB	9.3	0.2	5.9	42.9	0.8	39.8	0.6	0.3
HIR	9.5	0.1	6.4	42.7	0.9	39.4	0.5	0.3
ABS	9.6	0.2	5.6	41.1	0.8	41.6	0.6	0.3
S. alatum								
OB-2	12.7	0.2	5.6	45.5	1.5	33.4	0.6	0.3
UR	11.5	0.2	5.8	46.9	1.2	33.2	0.6	0.4
S. radiatum								
RDZ	8.3	0.3	8.6	34.9	0.9	45.8	0.8	0.2
RDK	9.0	0.2	9.1	35.3	0.8	44.3	0.9	0.2
S. angustifolium								
ANG-1	8.2	0.2	6.6	34.3	0.8	48.1	0.8	0.8
ANG-2	8.7	0.2	6.6	33.5	0.8	48.4	0.8	0.8

[a]Fatty acids: 16:0 (palmitic), 16:1 (palmitoleic), 18:0 (stearic), 18:1Δ9 (oleic), 18:1Δ11 (*cis*-vaccenic), 18:2 (linoleic), 18:3 (linolenic), 20:0 (arachidic), 20:1 (eicosenoic), 22:0 (behenic) and 24:0 (lignoceric). All samples also contained 0.1% of 20:1, 0.1% of 22:0 and trace (less than 0.1%) of 24:0.

TABLE 3

Fatty Acid Composition of the Different Lipid Classes in Oils from Four *Sesamum* Species

Species sample (code)	Class[b] (%)	Fatty acid percentages (%, w/w)[a]									
		16:0	16:1	18:0	18:1Δ9	18:1Δ11	18:2	18:3	20:0	20:1	22:0	24:0
S. indicum (GAS)												
TAG	88.9	8.9	0.2	6.8	44.1	1.0	37.9	0.3	0.6	0.1	0.1	trace
DAG	6.5	12.5	0.7	7.0	44.1	n.d.	34.3	0.3	0.5	0.3	0.2	0.1
FFA	1.2	17.8	4.5	9.2	33.3	n.d.	27.2	0.1	5.2	n.d.	2.1	0.6
PL	2.8	22.6	2.4	11.3	36.0	n.d.	24.9	0.4	1.0	0.2	0.4	0.8
SE	0.6	24.4	3.4	11.9	35.8	n.d.	21.8	0.3	1.0	0.2	0.8	0.4
Total[c]	100	9.7	0.4	7.0	44.1	0.9	36.8	0.3	0.6	0.1	0.1	trace
S. alatum (OB-2)												
TAG	80.3	11.4	0.3	5.7	46.4	1.5	33.5	0.4	0.6	0.1	0.1	trace
DAG	10.3	13.5	0.6	6.4	50.3	n.d.	27.5	0.4	0.7	0.3	0.2	0.1
FFA	5.1	18.9	1.3	9.7	52.0	n.d.	16.1	0.3	1.1	0.2	0.3	0.1
PL	3.5	24.6	1.4	10.1	43.5	n.d.	17.0	1.4	1.2	0.2	n.d.	0.6
SE	0.8	22.6	2.6	9.9	43.7	n.d.	18.4	0.3	1.3	n.d.	0.6	0.6
Total	100	12.6	0.4	6.2	47.0	1.2	31.3	0.1	0.7	0.1	0.1	trace
S. radiatum (RDK)												
TAG	84.9	9.3	0.2	9.1	34.7	0.8	44.8	0.1	0.1	0.8	0.1	trace
DAG	10.4	11.0	1.0	8.6	39.7	n.d.	38.7	0.1	0.5	0.2	0.1	0.1
FFA	1.9	29.6	2.5	11.2	29.9	n.d.	23.4	0.1	1.7	0.1	0.7	0.8
PL	2.3	24.2	2.1	11.8	35.1	n.d.	21.9	0.1	0.9	0.5	n.d.	1.4
SE	0.5	26.8	11.4	10.4	18.8	n.d.	15.8	n.d.	11.7	n.d.	4.3	0.8
Total	100	10.3	0.4	9.2	35.1	0.7	43.2	0.1	0.8	0.1	0.1	trace
S. angustifolium (ANG-2)												
TAG	84.0	8.6	0.2	6.4	33.1	0.8	49.4	0.6	0.7	0.1	0.1	trace
DAG	8.3	10.6	0.7	7.1	37.9	n.d.	41.9	0.5	0.8	0.3	0.1	0.1
FFA	4.2	14.4	1.1	11.3	33.5	1.0	36.1	0.5	1.4	0.1	0.4	0.2
PL	3.2	20.7	2.5	11.4	33.4	n.d.	29.7	0.3	1.0	0.4	0.4	0.2
SE	0.3	27.0	7.6	17.8	18.9	n.d.	8.8	n.d.	13.0	0.3	5.4	1.2
Total	100	9.4	0.4	6.9	33.5	0.7	47.5	0.6	0.8	0.1	0.1	trace

[a]Trace; less than 0.1%, n.d., not detected.
[b]Class: TAG (triacylglycerols), DAG (diacylglycerols), FFA (free fatty acids), PL (polar lipids), SE (steryl esters).
[c]Total = fatty acid composition of the total lipids as calculated from the compositions of the different fractions.

hand, also showed higher percentages of oleic acid, and all were balanced by considerably lower percentages of linoleic acid. *Sesamum indicum* was different in showing a high percentage of linolenic acid, and *S. radiatum* was again exceptional in showing a comparatively high relative percentage of palmitic acid.

Composition of the PL fractions. In the PL fraction the percentages of palmitic, palmitoleic, stearic and the long-chain fatty acids also were higher compared with TAG and DAG. This was at the expense of both oleic and linoleic acids in *S. indicum* and *S. alatum*, but only at the expense of linoleic acid in *S. radiatum* and *S. angustifolium*.

The PL percentages were determined in a single sample from each species by weighing aliquots of TLC-separated fractions (HEA) on a microbalance. They represented 5.5% of the oil in the sample of *S. indicum* (GAS), 7.3% in *S. alatum* (OB2), 3.8% in *S. radiatum* (RDK) and 4.2% in *S. angustifolium* (ANG-2). Further separation of these fractions on TLC in the presence of authentic standards, with CMAW (170:30:20:7, by vol) as the mobile phase, revealed phosphatidylcholine (R_f 0.23), phosphatidylethanolamine (R_f 0.39) and phosphatidic acid (R_f 0.56) as the major components. Thin-layer chromatographic analysis (CMAW) of fresh extracts, compared to such extracts standing in contact with tissue fragments for 4 h at room temperature, strongly indicated that the HIP mixture did not activate any phospholipase action. Hence, phosphatidic acid may be indigenous in *Sesamum* seed oils. Galactolipids and other PL also seemed to be present, but only in small amounts. No trace of monoacylglycerol was seen.

Composition of the SE fractions. The SE fractions of the four species also showed higher percentages of palmitic, stearic, palmitoleic and the long-chain fatty acids, and lower percentages of oleic and linoleic acids than the TAG fractions. The two species *S. radiatum* and *S. angustifolium* were again comparable to each other and different from the other two in having low percentages of oleic (18.8 and 18.9%) and linoleic (15.8 and 8.8%) as compared to 35.8 and 43.7% oleic and 21.8 and 18.4% linoleic in *S. indicum* and *S. alatum*, respectively. The low oleic and linoleic acid percentages in *S. radiatum* and *S. angustifolium* were accompanied by notable relative increases in the percentages of palmitoleic (11.4 and 7.6%), arachidic (11.7 and 13.0%), and behenic (4.3 and 5.4%) acids. *Sesamum angustifolium* also contained a considerably higher percentage of stearic acid (17.8%) than the other three species (10.1–11.9%).

DISCUSSION

Oil content of seeds. The low oil content in the seeds from the wild species are similar to previous results in the literature. Seeds of *S. angustifolium* from Tanzania were reported to contain 28.9% oil (11). Uzo *et al.* (12) found only 13.2% oil in seeds of *S. angustifolium* and 25.5% oil in seeds of *S. radiatum* from Nigeria. This is mainly a reflection of the high fiber content in the wild seeds—*S.*

alatum (24%), *S. radiatum* (36%) and *S. angustifolium* (22%), as compared with *S. indicum* seeds (*ca.* 6%) (unpublished data). If oil contents were calculated on a fiber-free basis, they would be *ca.* 36% in *S. alatum* and *S. angustifolium* and 55% in *S. radiatum* compared with 50–59% in *S. indicum*. Tashiro *et al.* (13) found that 11 black-seeded strains of *S. indicum* from Japan were characterized by relatively low oil percentages (43.4–51.1%) compared with 15 white-seeded strains (51.8–58.8%). The reason is mainly due to the high percentages of hulls in the black-seeded strains (*ca.* 14%) compared with the white-seeded strains (*ca.* 6%). Twelve brown-seeded strains, with an average of 8% hulls, were slightly lower in their average oil contents than the white-seeded strains. This observation compares well with the low oil percentages in the seeds of the wild *Sesamum* species because these seeds are enclosed in thicker hulls than *S. indicum*. Thus, the oil content in the wild seeds would be increased if the crude fiber content could be genetically lowered, *e.g.*, by obtaining thinner seed coats.

Composition of the different acyl lipid classes. An oil with a green color is indicative of immature seed, which is also expected to be lower in TAGs but higher in PLs, DAGs and FFAs (14,15). Because seed oils from the wild species contained more chlorophyll and were lower in TAGs, but higher in DAGs, FFAs and/or PLs, the samples collected were probably mixtures of ripe and slightly unripe seeds. Immaturity of sesame seed is explainable by the uneven ripening nature of sesame capsules, where basal seed capsules may be opening while the upper part of the plant is still flowering (16).

Fatty acid composition of the total lipids. The fatty acid composition of total lipids of the four species is quite comparable and, apart from the slightly lower stearic acid percentage in the present samples of *S. angustifolium*, is in good agreement with our previous findings (7). The TAG profiles of the oils from seeds of the four species were also quite comparable (7), suggesting that no significant intra- or interspecific genetic differences in the basic fatty acid composition exist in these different species of the genus *Sesamum*.

Fatty acid composition of the different acyl lipid classes. Searching the literature in lipid chemistry revealed little data on the fatty acid composition of the various lipid classes in any sample of crude seed oil. It has been reported, however, that the phospholipid fractions from mature seeds frequently have quite different overall fatty acid composition from those of the corresponding TAG fractions (17). Senn (18) reported that the PL fractions from peanut oil had higher percentages of palmitic, stearic and lignoceric acids and lower percentages of oleic and linoleic acids than did the TAG fraction. This finding is in line with our observations on sesame seeds.

Variations in fatty acid composition of the SE and the total lipids were studied in rapeseed oil (19) and in sunflower and in poppyseed oils (20). In rapeseed oil (19), the SE fraction showed a high percentage of linoleic acid (60.3%) and a low percentage of oleic acid (24.1%) as compared with the total fatty acids (20.7% linoleic and 62.2% oleic acids). The percentages of palmitic, stearic and linolenic acids were comparable in the two fractions. The SE fractions of sunflower and poppyseed oils (20), on the other hand, had higher percentages of oleic acid (*ca.* 20%) and lower percentages of linoleic acid (*ca.* 50%) as compared with *ca.* 12% oleic and 77% linoleic acids in the total lipids. In sunflower oil, palmitic and stearic acid percentages were approximately equal in the SE fraction and the total lipids, but the SE contained great percentages of some long-chain fatty acids that were not detected in the total lipids. The SE fraction of poppyseed oil contained higher percentages of palmitic and stearic acids than did the total lipids. These data and our present results indicate no typical pattern of variation in fatty acid percentages between SE and other acyl lipids in the different oils.

Because TAGs are the predominant fractions in all oils (80.3–87.9%), the fatty acid compositions of the TAGs are quite comparable to the fatty acid compositions of the total lipids. During industrial refining, essentially all PL and FFA, but only part of the DAG and SE, are removed; and the resulting oil is mainly TAGs (21–23). Thus, the fatty acid composition of a refined oil would mainly be that of the TAG in the crude oil, with some contribution from the DAG.

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