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Chemical composition of kenaf (*Hibiscus cannabinus* L.) seed oil [1,2]

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Abstract

Seeds from nine kenaf genotypes (Cubano, Everglades 41, Everglades 71, GR2563, Guatemala 48, Indian, 178-18RS-10, Tainung #1, and Tainung #2) were evaluated for oil, fatty acid, phospholipid, and sterol content. Oil content ranged from 21.4 to 26.4% with a mean of 23.7%. Total phospholipids ranged from 3.9 to 10.3% of the oil, with a mean of 6.0%. Mean sterol percent was 0.9 and ranged from 0.6% of the total oil for 178-18RS-10 accession to 1.2% for Everglades 71. Palmitic (20.1% of the total fatty acids), oleic (29.2%), and linoleic (45.9%) were the major fatty acids, and palmitoleic (1.6%), linolenic (0.7%), and stearic (3.5%) were the minor components. Medium (C_{12}–C_{14}) and long (C_{22}–C_{24}) chain fatty acids were less than 1%. Sphingomyelin (4.42% of the total phospholipids), phosphatidyl ethanolamine (12.8%), phosphatidyl choline (21.9%), phosphatidyl serine (2.9%), phosphatidyl inositol (2.7%), lysophosphatidyl choline (5.3%), phosphatidyl glycerol (8.9%), phosphatidic acid (4.9%), and cardiolipin (3.6%) were identified in the nine genotypes. Phosphatidyl choline, phosphatidyl ethanolamine, and phosphatidyl glycerol were the dominant phospholipids. In addition, eight unidentified phospholipids were also found. β-sitosterol (72.3% of the total sterols), campsterol (9.9%), and stigmasterol (6.07%) were prevalent among kenaf genotypes. Kenaf's relatively high oil content and its similarity to cottonseed oil suggest that the seed oil may be used as a source of edible oil. The variation among genotypes indicates potential for genetic improvement in oil yield and quality.

Keywords: Kenaf (*Hibiscus cannabinus* L.); Seed oil; Fatty acids; Sterols; Phospholipids

1. Introduction

There is a great demand in the United States for renewable sources of raw materials that have nutritional and industrial potential. The economic potential of new crops is receiving increased recognition in today's U.S. agriculture systems. Several plants now grown on farms yield not only food and fiber but also an amazing variety of products with application in industry, including oils, pharmaceuticals, and pesticides (Hinman, 1986).

The bulk of fats and oils, whether for human consumption or for industrial purposes, is presently derived from plant sources. To meet the increasing demand for vegetable oils, improvements are being made with conventional crops as well as with selected plant species that have

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[1] The use of any trade name varieties and/or vendors does not imply the exclusion of other products or vendors that may also be suitable.

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the ability to produce unique, desirable fats and oils.

Kenaf (*Hibiscus cannabinus* L.) from the Malvaceae family is a valuable fiber plant native to India and Africa. Kenaf is widely cultivated in many parts of the world as a source of fiber for twine, cloth, rope, burlap, and carpet felting. It also provides fiber for pulp and paper and forage for animals (Bates, 1965; Killinger, 1967; Swingle et al., 1978). In the United States, kenaf has shown promise as a fiber crop for pulp and paper production (Miller, 1965). Kenaf seed production (270–900 kg/ha) would be both technically and economically feasible in the southernmost areas of Florida, Texas, Arizona, and California, where climatic conditions are suitable for production (Dempsey, 1975). Because of its high seed oil content (20%), Dempsey (1975) suggested that kenaf might be a profitable oil seed crop if consistent seed yields of 1200 kg/ha could be obtained. Palmitic, oleic, and linoleic acids were reported as major fatty acids in kenaf oil (Hopkins and Chisholm, 1959, 1960; Subbaram et al., 1964; Tolibave et al., 1986a; Singh, 1988). Seed oils of several species of Malvaceae were found to contain *cis*-12,13-epoxyoleic acid ranging from 1.5 to 7% of total fatty acids (Hopkins and Chisholm, 1959, 1960; Subbaram et al., 1964). Major phospholipids of kenaf oil were identified as phosphatidyl choline, phosphatidyl inositol, phosphatidyl ethanolamine, N-acyl phosphatidyl ethanolamine, N-acyllyso phosphatidyl ethanolamine and Lyso phosphatidyl choline, and Lyso PI (Tolibave et al., 1975, 1976a, b, 1977, 1986a, b, 1989, 1990; Mukhamedova et al., 1988).

The United States imports two-thirds of its newsprint at an annual cost of about $4.5 billion (Taylor and Kugler, 1992). Research and development efforts over the last 50 years have indicated that kenaf can be turned into pulp for newsprint with lower energy and bleaching requirements than southern pine. However, financial institutions have been reluctant to invest in new agro-industries such as kenaf. Alternative uses of kenaf, therefore, could facilitate kenaf production in wide areas of the United States. Kenaf research at Virginia State University is aimed at developing alternative applications for the crop. Those include kenaf as a summer forage (Bhardwaj and Webber, 1994) and kenaf seeds as a source of edible oil.

The objectives of this investigation were to evaluate the quality and quantity of kenaf seed oil, including the fatty acid patterns of selected varieties. In addition, total phospholipids and total sterols and their patterns were also determined.

2. Materials

Seeds from nine kenaf genotypes (Cubano, Everglades 41, Everglades 71, GR2563, Guatemala 48, Indian, 178-18RS-10, Tainung #1, and Tainung #2) were obtained from USDA-ARS and evaluated for oil, fatty acids, phospholipids, and sterols. All chemicals used in this investigation were analytical grade and purchased from Sigma (St. Louis, Mo.) unless otherwise stated. All solvents used in this study were HPLC grade. Seed samples (20 g) were ground in a centrifugal grinding mill (Cyclotec, Model 1093 sample meal, Tecator), and passed through a 0.5 mm pore size screen. Three samples from each genotypes were analyzed.

3. Methods

3.1. Oil extraction

One gram of grounded seed was extracted at room temperature by sonification for 1 min in 10 ml of hexane–isopropanol (3 : 2, v/v), and centrifugation at 4000 *g* for 5 min (St. John and Bell, 1989). The extraction process was repeated three times to ensure complete extraction. After centrifugation, the combined supernatant was washed twice with 15 ml of 1% $CaCl_2$ and 10% NaCl in 50% methanol (Mohamed and Rangappa, 1992a). The hexane–lipid layer was separated by centrifugation and removed, and the hexane extract was dried over anhydrous Na_2SO_4. The oil was gravimetrically determined after solvent evaporation under a stream of N_2 at room temperature.

3.2. Fatty acids

Fatty acid methyl esters (FAME) were prepared by incubation of 1 mg oil with 0.5 ml of boron trifluoride in methanol (14%, w/v) at 65°C for 30

min. After cooling to room temperature, 1 ml of hexane followed by 1 ml of H_2O saturated with NaCl were added. The mixture was shaken and then centrifuged at 3000 *g* for 3 min and the hexane layer containing the FAME was removed, dried over anhydrous Na_2SO_4, and analyzed by gas chromatography (GC). A Supelco Wax 10 capillary column (30 m×0.25 mm i.d. and 0.25 μm film thickness) and a Hewlett-Packard Model 5890A GC equipped with a flame ionization detector (FID) and mass spectrometer detector (MSD) model HP5971A was employed. The GC was connected to an HP3396A integrator for FID and a HP59970 ChemStation for MSD. Helium was used as a carrier gas at a flow rate of 52.5 ml/min with split ratio of 100:1. The oven temperature was isothermal at 200°C. The injector and detector temperatures were set at 250° and 280°C, respectively. To analyze for *cis*-12,13-epoxyoleic acid, the chromatographic run time was extended to 25 min. FAME were identified by comparison with standard FAME. Vernolic acid was used as the standard to identify *cis*-12,13-epoxyoleic acid. Quantification was made by the aid of heptadecanoic acid (17:0) as an internal standard. Fatty acid concentrations were calculated as relative weight percentage of total fatty acids. A normalization technique was used to calculate absolute response factors for identified fatty acids. The values in the tables are averages of three separate determinations.

3.3. Sterols

Sterols were extracted from saponified lipid with ether and dried under N_2, then silylated by 0.5 ml N,O-bi-(silyltrimethyl)trifluoroacetamide (BSTFA) in 1% trimethylchlorosilane (TMCS) in a capped glass vial at 80°C for 60 min. After concentration under N_2, 100 μl ethyl acetate was added. The sterol trimethylsilyl ether derivatives were analyzed using the GC specified above with an HP-1, 12.5 m×0.2 mm i.d., 0.1 μm film thickness fused-silica capillary column. Column and detector temperatures were maintained at 260° and 310°C, respectively. Helium was used as carrier gas at a flow rate of 55 ml/min with split ratio of 100:1. Sterol standards (β-sitosterol, campsterol, stigmasterol and cholesterol) were silylated as above and used for identification of unknown peaks. Quantitation was carried out by using cholesterol as an internal standard. For further confirmation, standards and samples were run on GC–MS. The reported data are the averages of three determinations.

3.4. Phospholipids

Total phospholipid was determined in kenaf seed oil as described by Hafez et al. (1989). An amount of 0.1 ml of the extracted oil was mixed with 0.2 ml chromogenic solution and the mixture was heated at 90°C for 10 min. The tubes were cooled to room temperature and 5 ml chloroform was added. Phosphatidylcholine standards ranging from 50 to 1000 μg per tube were used, and the samples treated similar to the unknowns. The chloroform layer was carefully removed and the developed color was read at 710 nm against the blank.

3.5. Separation and identification of phospholipids

Phospholipids were precipitated from kenaf seed oil (0.2 g in 2 ml $CHCl_3$) with cold acetone. The precipitate was separated by centrifugation, washed with cold acetone, and re-centrifuged at 4000 *g* for 5 min. The phospholipid fraction was dissolved in chloroform (10 μg/100 μl) and applied on 20 × 20 cm silica gel H plates using two-dimensional TLC (Rouser et al., 1970). Chloroform–methanol–concentrated ammonium hydroxide (64:25:5, v/v) and chloroform–acetone–methanol–acetic acid–water (30:40:10:10:5, v/v) were used as the first and second developing solvent systems, respectively. Qualitative and quantitative identification of developed phospholipids were carried out as described by Rouser et al. (1970), using purified phospholipids as references (sphingomyelin, phosphatidyl ethanolamine, phosphatidyl choline, phosphatidyl serine, phosphatidyl inositol, lysophosphatidyl choline, phosphatidyl glycerol, and phosphatidic acid). Iodine vapor or chromogenic reagent (Raheja et al., 1973) was used as the color-developing agents. After TLC separation of phospholipids, fractions were eluted and

quantitatively determined by chromogenic reagent as described previously.

The data from the chemical analyses were statistically analyzed using the general linear model (GLM), SAS (Barr et al., 1976) and the means were separated using the least significant differences (LSD) test at the 5% level of significance.

4. Results and discussion

The oil, total phospholipid, and total sterols data for nine kenaf genotypes are presented in Table 1. The mean oil percentage of kenaf seeds was 23.7% and ranged from 21.4 for Tainung #1 to 26.4 for Cubano. The range of oil percentage of kenaf seeds is similar to cottonseed oil (23.2 to 25.7) (Cherry and Leffler, 1984), and is higher than soybean oil (15.6 to 23.4) (Mohamed and Rangappa, 1992a, b; Mohamed et al. 1993). Kenaf oil is also characterized by a high concentration of phospholipids. The mean total phospholipid was 6.0% and ranged from 3.9% for 178-18RS-10 to 10.3% for GR2565. Kenaf seed has a higher total phospholipid than major oil seeds such as soybean (1.5 to 3.0%) and cottonseed (< 2.0%) (Gunstone et al., 1986). The mean total sterol percentage was 0.9 and ranged from 0.6 for 178-18RS-10 to 1.2 for Everglades 71. Total sterol percentage was similar to that reported for soybean and cottonseed oil (Gunstone et al., 1986; Mohamed and Rangappa, 1992a, b).

Table 1
Total lipid content of kenaf seed and phospholipid and sterol content of kenaf seed oil

Genotype	Total lipid g/100 g seed	Total phospholipid [a]	Total sterol [b] g/100 g oil
178-18RS-10	23.0	3.91	0.56
GR2565	24.6	10.29	1.09
Tainung #1	21.4	6.31	0.86
Tainung #2	23.1	5.68	0.86
Everglades 41	23.3	5.58	1.14
Everglades 71	24.4	5.56	1.18
Cubano	26.4	5.43	0.63
Guatemala 48	25.5	4.71	0.72
Indian	21.9	6.67	0.97
Mean	23.72	6.0	0.89
C.V.%	3.72	6.0	14.02
LSD (<0.05)	1.53	0.62	0.219

[a] Determined as g phosphatidyl choline/100 g oil.
[b] Determined as g cholesterol/100 g oil.

Wide variations in fatty acid composition among kenaf genotypes were found (Tables 2 and 3). Palmitic acid ($C_{16:0}$) was the dominant saturated fatty acid and ranged from 18.6% for Indian to 21.4% for GR2565. This mean was higher than that reported for $C_{16:0}$ in soybean, maize, safflower, sesame, sunflower, rape, and palm-kernel, but within the range of cottonseed and olive oil (Gunstone et al., 1986). Stearic acid ($C_{18:0}$) had a mean of 3.2% and ranged from 2.0% for Everglades 71 to 4% for Cubano. This range is also similar to that reported for cottonseed, maize, coconut, palm-kernel, and soybean. The means of $C_{14:0}$, $C_{20:0}$, $C_{22:0}$, and $C_{24:0}$ were less than 0.5%, which is similar to that of cottonseed oil. Variations in total saturated fatty acid among genotypes were small and ranged from 22.6% for Everglades 71 to 25.6% for Cubano.

Kenaf oil contains a high percentage of polyunsaturated fatty acids (PUFA) and monoenes (Table 3). Linoleic acid ($C_{18:2}$) was the predominant PUFA and ranged from 42.0% for GR2565 to 50.1% for Everglades 41, respectively, with a mean of 45.9%. This value is similar to cottonseed but lower than soybean. Oleic acid ($C_{18:1}$) ranged from 24.8% for Everglades 41 to 34.1% for Indian, respectively, with a mean of 29.2%. Linolenic acid ($C_{18:3}$) was present in minor amounts (0.4 to 1.1%). Total unsaturated fatty acids variation among genotypes was insignificant. Because kenaf oil has lower linoleic and linolenic content (45.9% and 0.7%, respectively) and higher oleic acid (29.2%) than soybean oil (53%, 7.5%, and 24.5%, respectively), it is expected to be more stable. However, a high concentration of linoleic and linolenic acids is undesirable in terms of oil stability because they are readily oxidized. The PUFA are essential fatty acids and are essential for normal growth. Furthermore, they are important for reducing cholesterol and heart disease problem (Hafez et al., 1990).

Mean *cis*-12,13-epoxyoleic acid of kenaf seed oil was 0.67% and ranged from 0.17 for Indian to 1.40% for GR2565 (Table 3). This mean was lower than that reported by Hopkins and Chisholm

Table 2
Saturated fatty acid composition of kenaf seed oil

Genotype	Fatty acid gas-chromatography area (%)							Total
	$C_{12:0}$	$C_{14:0}$	$C_{16:0}$	$C_{18:0}$	$C_{20:0}$	$C_{22:0}$	$C_{24:0}$	
178-18RS-10	0.67	0.45	19.59	3.44	0.52	0.28	0.13	25.08
GR2565	0.74	0.35	21.38	3.12	0.50	0.26	0.11	26.46
Tainung #1	0.28	0.46	19.78	3.21	0.33	0.17	0.10	24.33
Tainung #2	0.44	0.47	20.36	3.56	0.77	0.39	0.18	26.17
Everglades 41	0.86	0.33	20.05	3.26	0.52	0.29	0.12	25.43
Everglades 71	0.38	0.40	19.35	2.03	0.26	0.14	0.06	22.62
Cubano	0.38	0.79	20.88	4.02	0.29	0.19	0.07	26.62
Guatemala 48	0.72	0.30	21.09	2.36	0.66	0.34	0.15	25.62
Indian	0.24	0.63	18.61	3.61	0.52	0.28	0.12	24.01
Mean	0.52	0.45	20.12	3.18	0.49	0.26	0.12	–
C.V.%	18.60	21.88	2.93	28.79	13.29	8.33	14.21	–
LSD (<0.05)	0.164	0.173	1.020	1.584	0.110	0.006	0.005	–
Reference oil								
Cottonseed[a]	–	<0.1	17 –31	1.0–4.0	<0.7	<0.5	<0.5	
Soybean[a]	–	<0.4	7.0–14	1.4–5.5	4.0–11	<0.5	–	

[a] The data for cottonseed reported by Gunstone et al. (1986) and for soybean reported by Mohamed and Rangappa (1992a).

Table 3
Unsaturated fatty acid composition of kenaf seed oil

Genotypes	Fatty acid gas-chromatography area (%)							Total
	$C_{16:1}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$	$C_{20:1}$	$C_{22:1}$	*cis*-12,13-epoxyoleic	
178-18RS-10	1.7	28.1	47.5	0.56	0.20	0.60	0.55	79.1
GR2565	2.1	32.7	42.0	0.76	0.17	0.47	1.39	79.6
Tainung #1	1.6	28.5	47.3	0.93	0.13	0.76	0.41	79.6
Tainung #2	1.5	28.5	45.5	1.14	0.28	0.71	0.91	78.5
Everglades 41	1.6	24.8	50.1	0.59	0.27	0.70	0.26	78.3
Everglades 71	1.6	25.2	47.1	0.47	0.18	0.84	0.62	76.0
Cubano	1.6	31.3	42.6	0.43	0.32	0.83	0.76	77.8
Guatemala 48	1.6	29.8	46.7	0.47	0.10	0.66	0.94	80.3
Indian	1.3	34.1	44.1	0.81	0.28	0.69	0.17	81.5
Mean	1.6	29.2	45.9	0.69	0.21	0.70	0.67	–
C.V.%	7.39	12.39	2.44	11.54	7.65	16.05	10.35	–
LSD (<0.05)	0.205	6.265	1.940	0.134	0.017	0.190	0.023	–
Reference oil								
Cottonseed[a]	0.5–2.0	13–44	13–59	0.1– 2.1	<0.5	<0.5	–	–
Soybean[a]	<0.5	19–30	44–62	4 –11	<0.1	–	–	–

[a] The data for cottonseed oil reported by Gunstone et al. (1986) and for soybean oil from Mohamed and Rangappa (1992a).

(1959, 1960) and Subbaram et al. (1964). The lower concentration of epoxyoleic acid does not have a negative impact on the utilization of kenaf seed oil. These data also show that the fatty acid composition of kenaf oil is very similar to that of cottonseed oil. It is comparable to most common edible oils, and is an excellent oil for human consumption.

Three plant sterols were identified in selected kenaf genotypes: β-sitosterol, campsterol, and

Table 4
Sterols — identification and relative content of kenaf seed oil

Genotypes	Relative retention time					
	0.73 β-sitosterol	0.83 campsterol	1.00 stigmasterol percentage[b]	0.88 Unknown-1[a]	0.92 Unknown-2	1.16 Unknown-3
78-18RS-10	77.6	13.8	8.9	–	–	–
GR2565	78.5	12.8	6.2	–	–	1.9
Tainung #1	64.7	13.4	4.5	–	11.2	7.6
Tainung #2	72.6	6.9	6.0	4.3	7.2	4.4
Everglade 41	81.0	3.0	9.1	6.9	–	–
Everglade 71	65.8	8.5	5.2	5.3	8.2	6.3
Cubano	69.9	11.0	4.2	–	11.6	6.1
Guatemala 48	73.9	10.3	4.7	–	4.4	6.7
Indian	66.8	9.3	5.7	5.8	5.8	6.4
Mean	72.3	9.9	6.1	–	–	–
C.V.%	2.9	2.8	4.9	–	–	–
LSD (<0.05)	3.6	0.48	0.52	–	–	–
Reference oil						
Cottonseed[c]	93	3.99	0.99	–	–	2[d]
Soybean[c]	53	20	20	–	–	7[d]

[a] Unkn-1, -2, -3 are unidentified sterols at different retention times.
[b] Sterol gas-chromatography area %.
[c] The data for cottonseed oil reported by Gunstone et al. (1986) and for soybean reported by Mohamed and Rangappa (1992a).
[d] The total of unidentified sterols reported by Gunstone et al. (1986) for cottonseed and by Mohamed and Rangappa (1992a) for soybean.

stigmasterol. The ratios of identified sterols are listed in Table 4. The ratio of the mean for these identified sterols was 11.9:1.6:1 (β-sitosterol–campsterol–stigmasterol). This ratio was different than those reported for sterol in cotton (93.9:4.0:1) and soybean (2.65:1:1) (Gunstone et al., 1986; Mohamed and Rangappa, 1992a). β-sitosterol was the major phytosterol, with a mean of 72.3%, and ranged from 62.6% for Tainung #2 to 81.0% for Everglades 41, followed by campsterol (9.9%), which ranged from 3.0% for Everglades 41 to 13.8% for 178-18RS-10. Stigmasterol was the third common sterol and ranged from 4.2 to 9.1% with a mean of 6.1% (Table 4). In addition, three unidentified sterols (with RR_f cholesterol) Unknown-1 (0.88), Unknown-2 (0.92) and Unknown-3 (1.16) were detected as minor components (1.9 to 11.6%) in most, but not all of kenaf seed oils, particularly, Everglades 71, Indian, Everglades 41 and Tainung #2 varieties (Table 4). It has been established that sterols other than cholesterol are not well absorbed. In fact, certain plant sterols, e.g. β-sitosterol, are not only poorly absorbed, but also interfere with the absorption of cholesterol (Laraki et al., 1993). Plant sterol emulsions are used in reducing hypercholesterolemia (Laraki et al., 1993).

Kenaf oil was characterized by a high phospholipid content compared to most edible oils. Wide variations in phospholipids were observed among the genotypes and phospholipids (Table 5). Lysophosphatidyl choline, phosphatidyl choline, sphingomyelin, phosphatidyl serine, phosphatidyl inositol, phosphatidyl ethanolamine, phosphatidic acid, phosphatidyl glycerol, cardiolipin were identified in kenaf seed. These phospholipids ranged from 13.3 to 38.0% for PC, 8.5 to 29.67% for PE and 4.4 to 19.7% for PG and were the dominant phospholipids. The SPH, PS, PI, LPC, and PA were present at lower concentrations (Table 5). In addition, seven unidentified phospholipids were detected as minor components. Their relative retention times for the second direction (R_f/R_f of phosphatidyl choline) are given in Table 6. Iden-

Table 5
Phospholipids — identification and relative content of kenaf seed oil

Phospholipid	R_f 2nd dimension	R_f/R_f of PC	Genotypes (percentage) [a]				
			178-18RS-10	GR2563	Tainung #1	Tainung #2	Everglades 41
Lysophosphatidyl choline (LPC)	0.03	0.16	6.2	1.1	4.6	7.5	5.6
Sphingomyelin (SPH)	0.04	0.21	4.3	6.9	4.1	4.1	2.1
Phosphatidyl serine (PS)	0.17	0.89	3.6	2.6	1.2	1.0	4.6
Phosphatidyl inositol (PI)	0.18	0.95	2.8	2.9	1.6	1.3	3.1
Phosphatidyl choline (PC)	0.19	1.00	37.0	18.3	18.1	38.0	28.4
Phosphatidyl ethanolamine (PE)	0.49	2.58	17.9	29.7	8.6	8.5	11.3
Phosphatidic acid (PA)	0.71	3.74	2.9	14.1	6.3	1.0	8.7
Phosphatidyl glycerol (PG)	0.72	3.79	8.4	12.6	19.7	8.7	4.4
Cardiolipin (CL)	0.90	4.74	1.0	2.9	3.3	6.3	4.3

Phospholipid	Genotypes (percentage) [a]				Mean	C.V.%	LSD (0.05)
	Everglades 71	Cubano	Guatemala 48	Indian			
Lysophosphatidyl choline (LPC)	6.8	6.8	6.2	6.6	5.3	32.4	3.0
Sphingomyelin (SPH)	7.8	1.4	8.9	4.6	4.4	39.8	3.1
Phosphatidyl serine (PS)	3.9	3.6	1.2	6.5	2.9	64.3	3.2
Phosphatidyl inositol (PI)	5.2	2.8	1.5	4.9	2.7	67.6	3.1
Phosphatidyl choline (PC)	20.5	24.6	13.3	16.2	21.9	36.3	13.8
Phosphatidyl ethanolamine (PE)	10.7	10.7	13.4	19.1	12.8	20.4	4.5
Phosphatidic acid (PA)	1.6	8.4	2.5	4.8	4.9	35.2	3.1
Phosphatidyl glycerol (PG)	11.0	4.5	14.9	4.7	8.9	29.9	4.6
Cardiolipin (CL)	3.4	4.3	5.7	4.9	3.6	45.2	2.8

[a] Percentage was calculated as (μg of the fraction$\times$100)/(μg of the identified and unidentified fractions).

Table 6
Unidentified phospholipids and their content of kenaf seed oil

Phospholipid classes	R_f 2nd dimension	R_f/R_f of PC	Genotypes (relative percentage) [a]								
			178-18RS-10	GR2563	Tainung #1	Tainung #2	Everglades 41	Everglades 71	Cubano	Guatemala 48	Indian
Unknown 1	0.07	0.37	2.1	3.6	5.7	4.9	3.4	6.9	8.1	3.7	2.2
Unknown 2	0.11	0.58	1.3	1.6	6.4	5.8	1.5	1.3	3.7	3.4	5.5
Unknown 3	0.13	0.71	2.5	0.0	2.1	3.5	4.0	4.9	0.0	7.2	2.7
Unknown 4	0.26	1.33	1.6	1.2	0.0	2.4	1.4	1.7	0.8	0.0	3.1
Unknown 5	0.31	1.63	2.1	0.0	14.4	2.1	11.8	0.0	1.3	11.4	2.6
Unknown 6	0.67	3.35	4.4	2.5	4.0	0.0	3.7	6.1	3.3	2.3	5.7
Unknown 7	0.83	4.37	1.8	0.0	0.0	4.4	1.98	8.3	15.6	4.8	6.2

[a] Percentage was calculated as (μg of the fraction $\times$100)/(μg of the identified and unidentified fractions).

tification and characterization of unknown sterols and phospholipids are currently under investigation in our laboratory. Phosphatidyl choline and lyso phosphatidyl choline are known to be important in membrane properties such as synthesis of lipid bilayer and liposome formation. They are also useful as emulsifiers in food and pharmaceutical applications. In kenaf oil, phospholipids, particularly those with free amino group, may interact as a natural antioxidant and consequently increase oil stability and shelf life. Because of the higher phospholipid content of some kenaf geno-

types (10.3, 6.7, and 6.3% for GR2565, Indian, and Tainung #1, respectively), they may be a possible source for industries that depend on phospholipid.

The potential for mass production of oil as a byproduct of kenaf appears to be excellent. The relatively high oil content, the unique fatty acid composition that is similar to that of cottonseed oil, and the reasonable amounts of phytosterols and phospholipids suggest that kenaf oil can be used as a source of edible oil. Furthermore, the variation among genotypes indicates a potential for genetic improvement in oil yield and quality. Although kenaf is mainly used for its fiber, the data suggest that the seeds, as a byproduct, would provide oil and meal for feed and food. Such uses could significantly increase the economic value of this crop. In addition, kenaf seed can be a source of phospholipid for several industries. The variation among genotypes indicates potential for genetic improvement in yield and quality of both oil and phospholipids.

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