Lipid Content and Fatty Acid Composition of Buckwheat Seed

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ABSTRACT

Dehulled seed of the three most important North American cultivars of buckwheat, Mancan, Tokyo, and Manor, were analyzed for content of total, free, neutral, glyco-, and phospholipids, and each class of lipid was analyzed for fatty acid composition. The samples contained from 2.6 ± 0.2 to 3.2 ± 0.1% total lipids of which 81–85% were neutral lipids, 8–11% phospholipids, and 3–5% glycolipids. Free lipids, extracted in petroleum ether, ranged from 2.1 ± 0.1 to 2.6 ± 0.1%. The major fatty acids of all cultivars and of all classes of lipids were palmitic (16:0), oleic (18:1), and linoleic (18:2) acid. Average values of these three fatty acids in the total lipids of all buckwheat samples examined were 14.0 ± 0.8, 36.3 ± 1.9 and 37.0 ± 1.9%, respectively. The corresponding values for the free lipids were 14.8 ± 1.5, 36.5 ± 2.0, and 35.5 ± 1.9% and those for phospholipids were 9.1 ± 0.8, 44.3 ± 4.4, and 41.7 ± 2.8%, respectively. Total lipid content showed significant positive correlation with free, neutral, and glycolipid contents, and there was a highly significant negative correlation between oleic and linoleic acid contents of all lipid classes. There was, however, no statistical difference between new and old buckwheat in the content of free, neutral, glyco-, and phospholipids and in the fatty acid composition of total and free lipids.

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Buckwheat (*Fagopyrum esculentum* Moench.) is a cool climate dicotyledonous plant of the Polygonaceae family adapted to short growing season and high elevations. It is cultivated in most temperate countries for food and livestock and poultry feed. In eastern Europe, buckwheat is a basic food item in porridges and soups. In North America, it is primarily used in pancake mixes containing, in addition to buckwheat flour, flours of wheat, corn, rice, or oat and a leavening agent. In Japan, buckwheat is used mostly for manufacturing *soba* or *sobakiri* (buckwheat noodle), which is prepared at *soba* shops or at home from a mixture of buckwheat and wheat flours. The ratio of buckwheat to wheat flour varies with the type of *soba* being made and ranges from 0.3 to 0.9.

The most important quality attributes of buckwheat are color and flavor of the dehulled grain or groats (Mazza 1986). The color is light green in freshly harvested seed and reddish brown in old seed. The flavor is appetizing, buckwheat-like in freshly harvested, freshly milled buckwheat and bland with a rancid tone in old buckwheat. Although the lipids of the grain probably play a major role, the reason for the deterioration of the flavor with aging of seed and flour is unclear. Dorrell (1971) analyzed the embryo, endosperm, testa, and pericarp from seeds of three buckwheat species for total lipid content and fatty acid composition; the average content of petroleum ether extractable lipids was 8.2, 0.4, 2.0, and 0.5%, respectively. Palmitic, stearic, oleic, linoleic, linolenic, arachidic, behenic, and lignoceric acids constituted more than 93% of the total acids. Several other studies (Belova et al 1971, Lockhart and Nesheim 1978, Taira et al 1986) provided the quality of total lipids and their fatty acid composition in buckwheat seed, but none of them covered all lipid classes. Also, in 1983, two large-seeded buckwheat cultivars, Mancan and Manor, were released from this station (Campbell 1983, Campbell and Ali-Khan 1983). By 1986, these two cultivars constituted over 90% of the Canadian and U.S. buckwheat production. The lipid composition of these cultivars, however, has not been determined.

This study was undertaken to determine content and fatty acid composition of total, free, neutral, glyco-, and phospholipids of buckwheat and to study the relationships between lipid classes and fatty acid contents of the three currently most important North American buckwheat cultivars, Mancan, Manor, and Tokyo. Knowledge of the lipid and fatty acid composition of buckwheat is important for nutritional reasons and may be valuable in predicting storage stability of buckwheat seed.

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MATERIALS AND METHODS

Mancan, Manor, and Tokyo buckwheat grown in 1986 and Mancan buckwheat grown in 1984 near Morden, Manitoba, were used. The samples were cleaned to remove sand, weeds, and small or immature seeds, and dehulled by passing the seed between a horizontally mounted stationary emery stone and an adjustable rotating stone of equal size (Campbell and Chubey 1985). The material produced in 1986 was dehulled and stored at $-25 \pm 1°C$ for 1–3 weeks before being milled and analyzed. The material produced in 1984 was dehulled and stored at room temperature (20–23° C) for 25 months before being milled and analyzed.

Proximate Analyses

All samples were analyzed for moisture, protein, crude fiber, and ash by AOAC (1980) procedures. Minerals (K, Mg, Ca, Fe, Zn, Mn, and Cu) were determined by atomic absorption spectroscopy and P by a spectrophotometric method (AOAC 1980) after dry ashing. All determinations were performed in triplicate.

Extraction of Total and Free Lipids

Total lipids were extracted by the chloroform-methanol method of Folch et al (1957). Ground samples equivalent to 50 g of dry solids were blended with 200 ml of distilled water in a Waring Blendor for 3 min. The slurry was mixed thoroughly with 20 g of certified silicic acid, 325 mesh (Fisher Scientific Co., Ottawa, Ontario, Canada) and 20 g of Celite 545. The mixture was filtered through Whatman No. 1 filter paper in a Büchner funnel under reduced pressure. The sample pad was then extracted in the blender with 200 ml of 2:1 (v/v) chloroform-methanol for 3 min at room temperature and filtered as previously described. The residue was reextracted with another 200 ml of solvent, filtered, washed twice with 25 ml of solvent per washing and 25 ml of chloroform. The combined methanol-chloroform extract was quantitatively transferred to a separatory funnel and allowed to stand for 30 min. The lower lipid-containing chloroform phase was collected. The upper methanolic phase was extracted with 30 ml of chloroform and this was added to the lipid phase. The extract was left in the refrigerator overnight for complete separation. The solvent was then removed by distillation on a rotary evaporator at a reduced pressure at 40° C. The lipids were further dried in a stream of nitrogen until constant weight was obtained and stored under nitrogen at $-25 \pm 1°C$ until analyzed.

Free lipids were extracted from 20-g ground samples with petroleum ether for 8 hr in a Soxhlet extraction apparatus. The solvent was removed under vacuum and the oil dried, weighed, and stored under nitrogen.

Separation of Lipid Classes by Column Chromatography

The total lipids, extracted by the chloroform-methanol method, were fractionated into three classes by two column separations. Polar lipids were separated from nonpolar lipids by silicic acid chromatography (Hirsch and Ahrens 1958, Peng and Dugan 1965, Rouser et al 1967, Peng 1982). Prior to use, the silicic acid (Fisher Scientific Co.) was washed twice with methanol to remove fines and impurities. It was activated at 120° C overnight immediately before the column was prepared. A slurry of 15 g of silicic acid in chloroform was then prepared and poured into a 2.2-cm diameter glass column with a 200-ml reservoir flask. The silicic acid was washed with 75 ml of acetone, and a 1-cm (3.5–4 g) layer of powdered anhydrous sodium sulfate was added. The column was then washed subsequentially with 75 ml of methanol and 75 ml of chloroform. Total lipids (300 mg) were dissolved in 5 ml of chloroform and quantitatively applied to the column with a Pasteur pipette. Neutral lipids were eluted with chloroform, and the eluate was monitored by the color test with acetic anhydride and sulfuric acid (Rouser et al 1967) until negative. Polar lipids were eluted with methanol at an elution ratio of 25 ml of solvent per gram of adsorbent and a flow rate of 0.5 ml/min. Each fraction was collected in bulk; its solvent was removed and stored as previously described.

The polar fraction was redissolved in 5 ml of chloroform and transferred quantitatively onto a Florisil column (Carroll 1963, Rouser et al 1967). Glycolipids were eluted by acetone at a ratio of 40 ml/40 g of adsorbent with the same flow rate as before, and phospholipids were recovered by methanol at 25 ml/g adsorbent (Peng 1974).

Gas Liquid Chromatography of Fatty Acids

The fatty acid composition of total, free, neutral, glyco-, and phospholipids was determined quantitatively by gas chromatography of the methyl esters in a Varian model 3400 gas chromatograph, equipped with a flame ionization detector. A capillary glass column (30 m × 0.25 mm i.d.), packed with J & D Durabond-225 fused silica (Chromatographic Specialties Inc., Brockville, Ontario) was used for the separation of methyl esters. The operating conditions were: injection port temperature, 250° C; detector temperature, 250° C; column temperature 200° C for 10 min and then programmed at 1° C/min to 220° C and holding at this temperature for 10 min; carrier gas flow rate 1 ml He/min; injection volume 2 μl; and range setting of detector attenuation, 10^{-11} amp/mV. Methyl esters of fatty acids were prepared by the boron-trifluoride-methanol method of Metcalfe et al (1966). Identification of the fatty acids on the chromatogram was made by comparing the retention times of the buckwheat methyl esters with those of known mixtures of methyl esters run on the same column under the same conditions. The fatty acid compositions were expressed as area percentage of the total area from all methyl esters. All lipid extractions and analyses were done in triplicate and average results are reported.

Statistical Analysis

Mean separation by Duncan's multiple range (5% level) and correlation coefficients were calculated using a VAX computer and ACTS statistical programs (Agrinet, Agriculture Canada, Ottawa) following established statistical procedures (Steel and Torrie 1980).

RESULTS AND DISCUSSION

Proximate Composition

The buckwheat samples used in this study had moisture contents of 10 to 17%. These values are higher than the value required to minimize quality deterioration of stored buckwheat (Mazza and Campbell 1985, Mazza 1986) but are well within the range practiced by the industry. Table I shows the proximate composition and selected mineral profiles of Mancan, Manor, and Tokyo buckwheat groats (dry basis). Protein contents of Mancan and Manor groats were higher than the values of Tokyo and those reported by Marshall and Pomeranz (1982). This indicates that the two new cultivars contain more protein than the other cultivar. Crude fiber values of dehulled buckwheat varied from 1.2 to 1.6%, which is 40–50% higher than the value reported by Marshall and

TABLE I
Proximate Composition and Selected Mineral Profile of Three Dehulled Buckwheat Cultivars (dwb)

	Cultivar		
Assay	Mancan $\bar{x} \pm$ SD	Manor $\bar{x} \pm$ SD	Tokyo $\bar{x} \pm$ SD
Moisture, %	16.2 ± 0.9	10.1 ± 0.2	10.9 ± 0.1
Protein,[a] %	14.2 ± 0.6	14.6 ± 0.3	11.9 ± 0.4
Crude Fiber, %	1.57 ± 0.30	1.21 ± 0.03	1.57 ± 0.10
Ash, %	1.85 ± 0.01	1.66 ± 0.01	1.39 ± 0.01
K, %	0.440 ± 0.005	0.419 ± 0.009	0.407 ± 0.005
P, %	0.359 ± 0.018	0.347 ± 0.003	0.262 ± 0.016
Mg, %	0.214 ± 0.002	0.201 ± 0.012	0.195 ± 0.010
Ca, ppm	180.5 ± 7.4	180.5 ± 10.6	220.5 ± 6.5
Fe, ppm	24.8 ± 1.8	21.4 ± 0.3	21.2 ± 0.9
Zn, ppm	23.4 ± 0.4	22.0 ± 1.6	22.8 ± 1.1
Mn, ppm	10.2 ± 0.2	10.0 ± 0.5	10.2 ± 0.4
Cu, ppm	4.6 ± 0.3	3.7 ± 0.1	4.3 ± 0.2

[a] N × 6.25.

TABLE II
Lipids of Dehulled Buckwheat Seed (% dwb)

Cultivar	Total Lipids[a]	Free Lipids[b]	Neutral Lipids[c]	Polar Lipids	
				Glycolipids[d]	Phospholipids[e]
Mancan[f]	3.2 a[g]	2.6 a	2.6 a	0.15 a	0.33 a
Mancan[h]	2.9 b	2.4 a	2.4 a	0.13 a	0.22 a
Manor	2.6 c	2.2 ab	2.2 b	0.09 b	0.27 a
Tokyo	2.9 ab	2.1 b	2.5 a	0.13 a	0.32 a

[a] Chloroform-methanol determined by the Folch et al (1975) method.
[b] Soxhlet, petroleum ether for 8 hr.
[c] Silicic acid column, chloroform extract.
[d] Florisil column, acetone extract.
[e] Florisil column, methanol extract.
[f] Fresh seed.
[g] Within each column means followed by the same letter are not significantly different ($P \leq 0.05$) using Duncan's multiple range test.
[h] Seed stored for 25 months at room temperature.

TABLE III
Significant Correlation Coefficients Among Lipid Classes of Dehulled Mancan, Manor, and Tokyo Buckwheat

Lipid Class	Total Lipids	Free Lipids	Neutral Lipids	Glycolipids
Free lipids	0.546*[a]			
Neutral lipids	0.941****	...		
Glycolipids	0.786***	0.561*	0.709***	
Phospholipids	...	−0.604**	...	...

[a] * $P \leq 0.10$; ** $P \leq 0.05$; *** $P \leq 0.01$; **** $P \leq 0.001$.

Pomeranz (1982). Ash contents of groats in this study fell within the range of 1.4 to 1.9% reported by Farrell (1976) and Marshall and Pomeranz (1982). All cultivars contained considerable amounts of minerals, especially potassium, phosphorous, and magnesium. Phosphorus contents of Mancan and Manor samples were higher than those of Tokyo buckwheat, but the calcium contents were higher in Tokyo samples (Table I).

Lipid Composition

The total lipids extractable with chloroform-methanol ranged from 2.6 to 3.2% (dry basis) and were significantly higher for Mancan and Tokyo than for Manor (Table II). Free lipids ranged from 2.1 to 2.6% (dry basis) and their concentration was highest in fresh Mancan and lowest in Tokyo buckwheat.

Separation by column chromatography of the total lipids showed that in fresh and old Mancan, Manor, and Tokyo samples there were significantly more neutral lipids than polar lipids (glyco- and phospholipids). Neutral lipids ranged from 81 to 85% of the total lipids and glycolipids and phospholipids from 3 to 5% and from 8 to 10% of the total lipids, respectively. In comparison to cereals such as wheat, rye, and oats, buckwheat contains amounts of total lipids similar to wheat and rye (Zeringue and Feuge 1980) and about 50% of the total lipid content of oats (Sahasrabudhe 1979). Notwithstanding quantitative similarity among wheat, rye, and buckwheat, however, the neutral lipid fraction in wheat and rye constitutes only 35% of total lipids (Zeringue and Feuge 1980). On the other hand, the neutral lipid fraction in oats is similar to that of buckwheat (Sahasrabudhe 1979). Correlation coefficients between the lipid classes of buckwheat are presented in Table III. Total lipid content showed significant positive correlation with free lipid, neutral lipid, and glycolipid contents. The relations of total lipid content (X) with neutral lipids content (Y_1) and glycolipids content (Y_2) were expressed by the following regression equations: $Y_1 = 0.330 + 0.728X$ and $Y_2 = -0.113 + 0.083X$.

Fatty Acid Composition

Table IV presents the data for fresh and old Mancan and fresh Manor and Tokyo on the fatty acid composition of total lipids, free lipids, neutral lipids, glycolipids, and phospholipids. As can be noted, the major fatty acids of all cultivars and of all classes of lipids examined were palmitic (16:0), oleic (18:1), and linoleic (18:2). Stearic acid (18:0) occurred in the range of up to 2.1% while linolenic (18:3) and arachidic (20:0) were in a range of 1.3 to 4.2 and 0.1 to 1.7%, respectively. The other long-chain fatty acids identified were 20:1, 22:0, and 24:0, which ranged from 0.2 to 3.7%. Average values for palmitic, oleic, and linoleic acids in the total lipids of the four types of buckwheat examined were 14.0 ± 0.8, 36.3 ± 1.9 and 37.0 ± 1.9%, respectively. The corresponding values for the free lipids were 14.8 ± 1.5, 36.5 ± 2.0, and 35.5 ± 1.9%, and those for neutral lipids were 14.5 ± 1.1, 35.6 ± 2.1, and 36.4 ± 1.8%, respectively. Glycolipids and phospholipids contained 13.8 ± 1.8 and 9.1 ± 0.8% palmitic acid, 29.5 ± 2.2 and 44.3 ± 4.4% oleic acid, and 40.4 ± 3.3 and 41.7 ± 2.8% linoleic acid, respectively.

There were significant differences between the cultivars in oleic and linoleic contents of total lipids, free lipids, and phospholipids, but there was no cultivar difference for palmitic acid of total lipids, free lipids, and phospholipids or for linolenic acid of glycolipids. There was no statistical difference for all fatty acids of total and free lipids of fresh and stored Mancan, indicating that the fatty acid composition of buckwheat seed does not change significantly with prolonged storage. The total lipid content showed significant positive correlation with palmitic acid ($r = 0.504$, $P \leq 0.10$) and significant negative correlation with linoleic acid contents ($r = -0.707$, $P \leq 0.01$) (Table V). From the relationship between fatty acid contents of total lipids, there were significant positive correlations between stearic and oleic acids ($r = 0.683$, $P \leq 0.05$), linoleic and linolenic acids ($r = 0.680$, $P \leq 0.10$), arachidic and behenic acids ($r = 0.841$, $P \leq 0.001$), arachidic and lignoceric acids ($r = 0.673$, $P \leq 0.05$), and behenic and lignoceric acids ($r = 0.831$, $P \leq 0.001$); there were significantly negative correlations between palmitic and behenic acids ($r = -0.553$, $P \leq 0.10$), oleic and linoleic acids ($r = -0.797$, $P \leq 0.01$), and oleic and linolenic acids ($r = -0.734$, $P \leq 0.01$).

The free lipid content showed significant positive correlation with oleic acid ($r = 0.566$, $P \leq 0.10$), the glycolipids content showed significant positive correlation with lignoceric acid ($r = 0.666$, $P \leq 0.01$), and the phospholipid content showed a significant negative correlation with palmitic acid ($r = -0.604$, $P \leq 0.05$) and a significant positive correlation with oleic acid ($r = 0.703$, $P \leq 0.05$), linoleic acid ($r = 0.556$, $P \leq 0.10$), and linolenic acid ($r = 0.679$, $P \leq 0.05$). As to relationships between the fatty acids of free lipids, there were significant negative correlations between palmitic and arachidic acids ($r = -0.601$, $P \leq 0.05$), palmitic and eicosenoic acids ($r = -0.544$, $P \leq 0.10$), palmitic and behenic acids ($r = -0.600$, $P \leq 0.05$), palmitic and lignoceric acids ($r = -0.837$, $P \leq 0.01$), stearic and linoleic acids ($r = -0.551$, $P \leq 0.10$), oleic and linoleic acids ($r = -0.719$, $P \leq 0.01$), and significant positive correlations between oleic and arachidic acids ($r = 0.559$, $P \leq 0.10$), arachidic and eicosenoic acids ($r = 0.510$, $P \leq 0.10$), and arachidic and behenic acids ($r = 0.613$, $P \leq 0.05$). The correlation coefficients between the fatty acids of neutral lipids, glycolipids, and phospholipids were similar to those between the fatty acids of total lipids and free lipids (Table V).

TABLE IV
Fatty Acids of Lipids of Dehulled Buckwheat Seed (% total area)

Cultivar	Lipid Class	Fatty Acids								
		16:0	18:0	18:1	18:2	18:3	20:0	20:1	22:0	24:0
Mancan (new)	Total lipids	14.5 a[a]	1.9 abc	38.2 de	34.6 hi	2.3 cde	1.4 cd	2.9 b	1.4 cd	0.9 b
	Free lipids	14.9 a	2.1 ab	38.2 de	33.7 i	2.3 cde	1.6 ab	3.4 ab	1.6 bcd	0.8 b
	Neutral lipids	15.0 a	2.1 a	37.3 def	34.4 hi	2.4 cde	1.5 abc	3.4 ab	1.7 bc	1.1 b
	Glycolipids	13.5 ab	1.9 abc	32.1 ij	39.3 bcd	4.1 a	0.7 e	1.4 c	1.0 e	0.8 b
	Phospholipids	9.1 c	0.6 g	48.9 a	38.2 c–f	1.4 fg	0.1 h	0.6 d	0.2 f	0.2 c
Mancan (old)	Total lipids	13.7 ab	1.8 abc	37.4 def	36.3 d–i	2.6 bcd	1.4 bcd	3.1 ab	1.6 bcd	1.1 b
	Free lipids	15.0 a	1.9 abc	37.6 def	34.9 ghi	2.5 bcd	1.4 bcd	3.1 ab	1.4 d	1.0 b
	Neutral lipids	13.2 ab	2.0 abc	37.5 def	35.3 f–i	2.2 def	1.7 a	3.6 ab	2.1 a	1.4 a
	Glycolipids	13.9 ab	1.6 cde	30.5 j	37.9 c–g	2.3 de	0.2 gh	0.9 cd	0.8 e	1.0 b
	Phospholipids	9.6 c	0.0 h	46.1 b	40.3 bc	1.3 g	0.1 h	0.7 d	0.3 f	0.4 c
Manor	Total lipids	13.4 ab	1.8 bc	35.7 efg	38.7 cde	2.8 bcd	1.4 cd	3.6 ab	1.6 bcd	0.9 b
	Free lipids	14.4 a	2.0 abc	36.6 def	35.8 3–i	2.6 bcd	1.6 abc	3.5 ab	1.8 b	0.9 b
	Neutral lipids	14.4 ab	1.3 ef	35.0 fgh	37.4 c–h	2.8 bcd	1.5 bcd	3.2 ab	1.6 bcd	1.0 b
	Glycolipids	15.5 a	1.7 cd	28.2 k	42.0 ab	4.2 a	0.5 f	0.7 d	1.0 e	0.3 c
	Phospholipids	9.1 c	0.0 h	43.1 c	43.5 a	1.6 efg	0.1 h	0.4 d	0.3 f	0.3 c
Tokyo	Total lipids	14.6 a	1.4 def	33.9 ghi	38.6 cde	3.0 bcd	1.3 d	3.6 ab	1.4 bcd	0.9 b
	Free lipids	14.9 a	2.0 abc	33.4 ghi	37.6 c–h	3.3 b	1.3 cd	3.7 a	1.4 bcd	0.9 b
	Neutral lipids	15.3 a	1.8 abc	32.7 hij	38.3 c–f	3.2 bc	1.4 cd	3.7 a	1.6 bcd	1.0 b
	Glycolipids	12.1 b	1.2 f	27.3 k	42.2 ab	3.3 b	0.4 fg	0.7 d	0.7 e	1.0 b
	Phospholipids	8.5 c	0.3 g	39.2 d	44.8 a	2.2 def	0.1 h	0.7 d	0.2 f	0.3 c

[a] Within each column means followed by the same letter are not significantly different ($P \leq 0.05$) using Duncan's multiple range test.

TABLE V
Significant Correlation Coefficients Among Lipids and Fatty Acids of Dehulled Mancan, Manor, and Tokyo Buckwheat

Lipids	16:0	18:0	18:1	18:2	18:3	20:0	20:1	22:0	24:0
Total lipids	0.504*[a]	...	...	−0.707***	...	...	...	...	...
16:0		...	...	...	...	...	...	−0.553*	...
18:0			0.683**	...	...	...	...	...	...
18:1				−0.797***	−0.734***	...	...	...	...
18:2					0.680*	...	...	...	...
18:3						...	...	...	...
20:0							...	0.841***	0.673**
20:1								...	...
22:0									0.831***
Free lipids	...	...	0.556*	...	...	...	...	...	...
16:0		...	...	...	...	−0.601**	−0.544*	−0.600**	−0.837****
18:0			...	−0.551*	...	0.540*	...	...	...
18:1				−0.791***	−0.779***	0.559*	...	...	...
18:2					...	...	...	...	...
18:3						...	...	...	...
20:0							0.510*	0.613**	...
20:1								...	...
22:0									...
Neutral lipids	...	...	...	...	...	...	...	...	...
16:0		...	...	...	...	−0.657**	...	−0.788***	−0.802***
18:0			...	...	...	...	...	...	...
18:1				−0.854****	−0.951****	0.782***	...	0.653**	0.582**
18:2					0.900****	−0.691***	...	−0.500*	...
18:3						−0.851****	...	−0.711***	−0.633**
20:0							0.248	0.940****	0.900****
20:1								...	...
22:0									0.971****
Glycolipids	...	...	...	...	...	...	...	...	0.666***
16:0			...	...	...	...	...	...	...
18:0			0.558*	−0.688**	...	0.544*	0.519*	...	...
18:1				−0.503*	...	...	...	...	...
18:2					...	...	...	...	...
18:3						0.497*	...	...	−0.686**
20:0							0.699**	...	...
20:1								...	...
22:0									−0.534*
Phospholipids	−0.604**	...	0.703**	0.556*	0.679**	...	...	...	...
16:0		...	...	...	...	0.564*	...	...	...
18:0			...	...	...	...	...	...	−0.614**
18:1				−0.859****	−0.889****	0.556*	...	...	...
18:2					0.676**	−0.727***	...	...	...
18:3						...	...	...	...
20:0							...	...	...
20:1								...	...
22:0									...

[a] * $P \leq 0.10$; ** $P \leq 0.05$; *** $P \leq 0.01$; **** $P \leq 0.001$.

CONCLUSIONS

For all buckwheat lipid classes there was a significant negative correlation between oleic acid and linoleic acid that ranged from −0.503 ($P \leq 0.10$) for glycolipids to −0.859 ($P \leq 0.001$) for phospholipids. Linoleic acid is highly unsaturated and is more subject to oxidation than oleic acid. Therefore, lower contents of linoleic acid and higher contents of oleic acid should improve the keeping quality of buckwheat grain and products. The significant differences between the cultivars in oleic and linoleic acid contents of total, free, and phospholipids suggest that breeding and selection of buckwheat with lower linoleic acid content and improved storage stability should be possible.

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