Lipid Content and Fatty Acid Composition of Nonglutinous and Glutinous Varieties of Foxtail Millet

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The lipid content and fatty acid composition of foxtail millet (*Setaria italica* Beauv.) grains were determined with 31 nonglutinous and 23 glutinous varieties. The dominant fatty acid was linoleic acid (about 70% of total acids). Two types of each nonglutinous and glutinous varieties were classified based on fatty acid composition. There were 23 types A and 8 types B for nonglutinous varieties and 21 types A and 2 types B for glutinous varieties. The major differences between the two types were stearic acid and arachidic acid contents. The glutinous variety, as compared with the nonglutinous variety, was significantly higher in lipid content and palmitic acid content but lower in stearic acid content of two types. As to the distribution of lipid content and palmitic acid and stearic acid contents, there were overlapped ranges between nonglutinous and glutinous varieties.

Two types of starch properties, nonglutinous and glutinous, have been identified in the endosperm of foxtail millet (*Setaria italica* Beauv.). As to amylose content of foxtail millet starch, Taira and Miyahara (1983) have reported that 31 nonglutinous varieties showed a range of 21.9–32.3% and a mean of 27.80% and 23 glutinous varieties were divied into two groups, i.e., (a) 21 varieties of range 0.3–1.8% and mean 0.82% and (b) 2 vareities of range 3.6–4.8% and mean 4.20%. In the previous study on foxtail millet, it was determined that there were no differences in amino acid composition between the nonglutinous and glutinous varieties (Taira, 1968). For lipid content and fatty acid composition of nonglutinous and glutinous types of rice, it was reported that the glutinous type was higher in lipid content and myristic acid, palmitic acid, and stearic acid contents and lower in oleic acid content (Taira and Hiraiwa, 1982). From the results, it was suggested that nonglutinous and glutinous varieties of foxtail millet also may differ in lipid content and fatty acid composition of the grain lipid. Therefore, investigations were undertaken to study the lipid content and fatty acid composition of nonglutinous and glutinous varieties of foxtail millet.

MATERIALS AND METHODS

Mature seeds of 31 nonglutinous and 23 glutinous varieties of foxtail millet classified by the amylose content of the starch (Taira and Miyahara, 1983) were collected from a field experiment conducted by the Tohoku National Agricultural Experiment Station, Japan. The samples of the seeds were dehulled by using conventional seed-cleaning equipment and were ground to pass a 30-mesh sieve. Lipid was extracted from the ground sample on a Butt-type extractor by using diethyl ether as a solvent. Fatty Acids in the lipid were determined by gas chromatography after transesterification to their methyl ester by the boron trifluoride method as outlined by the Association of Official Analytical Chemists (1975). Esters were separated by using a Shimadzu GC-6APF chromatograph equiped with a FID by using 3 mm × 3 m glass column packed with Unisol 3000 Uniport C, 60–70 mesh (Gasukurokogyo Co., Ltd.). The coloum temperature was 240 °C, and the carrier gas was nitrogen at a flow rate of 40 mL/min. Compound retention times and areas were automatically recorded, and results were calculated by means of a Shimadzu Chromatopac C-R2A. Standard methyl ester fatty acid mixtures were separated under identical conditions to identify the compounds. Moisture content was determined by heating the samples for 1 h at 135 °C, and lipid contents were reported on a dry basis of grain samples.

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RESULTS AND DISCUSSION

The lipid contents and fatty acid compositions of the nonglutinous and glutinous varieties of foxtail millet are shown as mean values of duplicated data in Table I. Analyses of variance for lipid and fatty acid contents have been carried out. The results of significant differences by the F value are also shown in Table I.

For both nonglutinous and glutinous varieties, lipid contents were not significantly different between type A and type B, which were classified based on their fatty acid compositions.

The dominant fatty acid of foxtail millet was linoleic acid (about 70% of total acids) for both nonglutinous and glutinous varieties. According to the fatty acid profiles, however, both nonglutinous and glutinous varieties could be divided into type A and type B, i.e., 23 varieties of type A and 8 varieties of type B for nonglutinous varieties and 21 varieties of type A and 2 varieties of type B for glutinous varieties. Type A, as compared with type B, was significantly higher in stearic acid, linolenic acid, and arachidic acid contents and lower in palmitic acid, oleic acid, and linoleic acid contents for the nonglutinous varieties and also higher in stearic acid and arachidic acid contents and lower in oleic acid content for the glutinous varieties. For the nonglutinous varieties, the type A/type B ratios of the mean values of stearic acid, arachidic acid, linolenic acid, linoleic acid, palmitic acid, and oleic acid contents were 3.55, 2.02, 1.18, 0.96, 0.95, and 0.85, respectively, and for the glutinous varieties, those of stearic acid, arachidic acid, and oleic acid contents were 4.59, 2.60, and 0.77, respectively. As the results, the major differences between type A and type B of nonglutinous and glutinous varieties were identified as stearic acid and arachidic acid contents.

Compared with the nonglutinous variety, the glutinous variety was significantly higher in lipid content and palmitic acid content and lower in stearic acid content in both type A and type B and lower in oleic acid content in type A and arachidic acid content in type B. The glutinous variety/nonglutinous variety ratios of the mean values of type A and type B were 1.07 and 1.08 in lipid content, 1.16 and 1.14 in palmitic acid content, and 0.85 and 0.66 in stearic acid content, and the ratios of type A in oleic acid content and type B in arachidic acid content were 0.76 and 0.94. The lipid contents of 20 nonglutinous and 13 glu-

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Table I. Lipid Content and Fatty Acid Composition of Nonglutinous and Glutinous Foxtail Millet

variety	lipid, % of dry wt	fatty acid,[a] wt % of total acids							
		16:0	16:1	18:0	18:1	18:2	18:3	20:0	20:1
nonglutinous variety									
type A									
Kiawa 2	4.36	7.9	0.1	6.7	11.9	68.5	2.4	2.0	0.5
Ifuku	4.01	8.3	0.2	6.4	12.1	68.3	2.6	1.8	0.4
Rikuu No. 8	4.47	7.6	0.1	7.2	13.2	67.2	2.2	1.9	0.5
Shiroawa 2	4.66	8.1	0.1	6.2	12.6	67.8	2.7	1.8	0.6
Rekijohakujo	4.09	8.0	0.2	6.4	14.8	66.1	2.4	1.7	0.5
Toranoo No. 1	4.28	7.3	0.1	5.9	12.2	69.6	2.7	1.7	0.5
Taihaku	4.46	7.4	0.2	6.4	14.0	67.2	2.5	1.7	0.5
Daiseibyo	4.32	8.1	0.2	5.9	14.7	66.4	2.6	1.6	0.6
Akauchida	4.31	7.6	0.2	5.9	12.1	69.0	2.8	1.9	0.5
Kohange	4.34	7.7	0.2	6.1	15.1	65.6	2.7	2.0	0.6
Yoshitoshi	4.32	7.7	0.3	5.1	12.3	69.5	2.9	1.7	0.5
Kiawa 4	4.76	8.1	0.2	4.5	13.4	68.9	2.7	1.6	0.6
Banaka	4.54	8.2	0.2	5.2	11.9	69.2	2.8	1.8	0.7
Rikuu No. 3	4.19	7.9	0.1	5.3	11.8	69.6	2.7	1.9	0.6
Sainantorai No. 2	4.73	6.9	0.2	6.6	13.7	67.8	2.4	1.8	0.5
Keburiawa	4.63	7.8	0.2	5.3	13.7	68.0	2.7	1.8	0.5
Sokyokoku	4.47	8.1	0.1	6.1	14.7	66.0	2.7	1.7	0.5
Pekinkaikoku	4.50	8.4	0.2	5.6	14.7	65.8	3.0	1.7	0.6
Toranoo	4.55	7.2	0.2	5.8	12.5	69.0	2.7	1.9	0.6
Shiromochi 1	4.26	7.6	0.1	4.9	13.2	68.9	3.1	1.6	0.5
Kumamotokokubu No. 2	4.15	7.9	0.1	4.6	13.3	68.1	3.7	1.6	0.7
Hosoawa	4.57	7.7	0.2	3.7	13.1	70.1	3.2	1.4	0.6
Fukuokashimabara	4.02	8.0	0.1	4.0	13.9	67.7	4.1	1.5	0.6
mean	4.391	7.80	0.17	5.64	13.26	68.01	2.80	1.74	0.55
SD	0.214	0.37	0.06	0.89	1.07	1.34	0.42	0.15	0.07
type B									
Okeawa	4.55	8.1	0.2	1.4	15.2	71.5	2.2	0.9	0.5
Usujiso	4.31	7.4	0.1	1.4	16.7	71.0	2.1	0.8	0.4
Taihakuawa No. 1	4.51	7.7	0.2	1.7	15.2	71.4	2.2	1.0	0.6
Kahokuhigo	4.54	8.4	0.2	1.7	16.4	69.5	2.3	0.9	0.6
Beniawa	4.58	8.7	0.2	1.6	15.2	70.7	2.2	0.9	0.5
Mosyojo	4.67	8.2	0.2	1.7	15.8	70.6	2.2	0.9	0.5
Zenkoji	4.51	8.2	0.2	1.9	14.3	71.5	2.5	0.8	0.5
Kokubu No. 2	4.41	8.7	0.2	1.3	16.1	69.0	3.3	0.7	0.6
mean	4.510	8.18	0.19	1.59	15.61	70.65	2.38	0.86	0.53
SD	0.109	0.45	0.04	0.20	0.78	0.94	0.39	0.09	0.07
difference between types A and B	n.s.	*	n.s.	**	**	**	*	**	n.s.
glutinous variety									
type A									
Yukiyamochi	4.51	8.0	0.2	3.8	11.1	72.2	2.7	1.4	0.6
Kiawa 3	4.60	7.7	0.2	3.4	11.8	72.2	2.8	1.3	0.6
Rikuu No. 5	4.76	9.0	0.3	5.1	11.1	69.4	3.1	1.6	0.5
Shinanooawa	4.84	9.6	0.2	5.4	13.6	66.0	2.6	1.9	0.5
Jiyobeninenkoku	4.52	9.9	0.2	5.9	14.3	64.9	2.4	1.9	0.5
Rikuu No. 4	4.76	8.8	0.2	4.9	11.1	69.9	3.0	1.6	0.5
Rekijonenkoku	4.89	8.0	0.2	6.2	14.3	66.9	2.2	1.8	0.5
Rikuu No. 7	4.72	8.5	0.2	5.1	11.7	68.1	3.4	2.1	0.9
Rikuu No. 6	4.75	9.7	0.3	5.1	12.2	66.7	3.3	2.1	0.6
Kashiki	4.87	8.6	0.1	4.8	11.5	69.8	3.0	1.7	0.5
Nakateawa	4.88	8.8	0.2	5.2	12.5	68.2	3.0	1.6	0.5
Ryukai	5.09	8.7	0.1	5.3	14.6	65.9	2.9	1.9	0.6
Tsugaruwase	4.41	9.4	0.2	5.4	11.1	68.6	3.0	1.7	0.5
Mumei 1	4.86	9.0	0.2	5.1	13.5	67.2	2.8	1.7	0.5
Kiawa 1	4.18	9.8	0.2	3.4	11.2	70.0	3.3	1.5	0.6
Kozazairai	4.52	9.9	0.2	5.0	12.8	67.0	2.9	1.6	0.5
Kariwanozairai 3	4.76	9.2	0.1	3.4	11.8	70.1	3.3	1.4	0.7
Kariwanozairai 2	4.45	9.6	0.2	4.3	12.3	68.2	3.2	1.7	0.6
Okiawa	4.56	9.5	0.2	4.8	12.3	67.9	3.2	1.7	0.5
Meshiawa	4.81	8.4	0.2	4.7	13.3	68.5	2.8	1.6	0.5
Akaawa	4.80	9.6	0.2	4.9	13.6	66.3	3.3	1.7	0.5
mean	4.692	9.03	0.20	4.82	12.46	68.29	2.96	1.69	0.56
SD	0.209	0.67	0.05	0.77	1.17	1.96	0.31	0.21	0.10
type B									
Shiromochi 3	4.87	9.4	0.1	1.1	16.0	69.6	2.4	0.7	0.6
Kariwanozairai 1	4.90	9.3	0.2	1.0	16.3	69.2	2.8	0.6	0.5
mean	4.885	9.35	0.15	1.05	16.15	69.40	2.60	0.65	0.55
SD	0.021	0.07	0.07	0.07	0.21	0.28	0.28	0.07	0.07
difference between types A and B	n.s.	n.s.	n.s.	**	**	n.s.	n.s.	**	n.s.
difference between nonglutinous and glutinous varieties									
type A	**	**	n.s.	**	*	n.s.	n.s.	n.s.	n.s.
type B	**	**	n.s.	**	n.s.	n.s.	n.s.	*	n.s.

[a] In the subheadings, fatty acids are expressed as the number of carbons:number of double bonds. n.s. = not significant; (*) significant at the 5% level; (**) significant at the 1% level.

Table II. Simple Correlation Coefficients of Lipid Content with Fatty Acid Content and Fatty Acid Content Pair of Type A of Nonglutinous and Glutinous Foxtail Millets[a]

	16:0	16:1	18:0	18:1	18:2	18:3	20:0	20:1
				Nonglutinous Variety				
lipid	−0.234	0.217	0.051	0.050	0.058	−0.357	0.078	0.171
16:0		−0.057	−0.195	0.126	−0.279	0.206	−0.173	0.245
16:1			−0.058	0.116	0.012	−0.195	−0.027	−0.090
18:0				0.051	−0.445*	−0.807**	0.705**	−0.521*
18:1					−0.851**	0.050	−0.280	0.060
18:2						0.169	−0.114	0.049
18:3							−0.604**	0.481*
20:0								−0.212
				Glutinous Variety				
lipid	−0.379	−0.248	0.435*	0.485*	−0.320	−0.199	0.314	−0.080
16:0		0.186	0.137	0.099	−0.540*	0.329	0.300	−0.192
16:1			0.198	−0.184	−0.072	0.052	0.187	−0.147
18:0				0.565**	−0.768**	−0.456*	0.711**	−0.354
18:1					−0.793**	−0.536*	0.423	−0.260
18:2						0.209	−0.759**	0.218
18:3							0.090	0.465*
20:0								0.199

[a] (*) Significant at the 5% level; (**) significant at the 1% level.

tinous varieties in type A ranged from 4.18% (minimum value in glutinous varieties) to 4.76% (maximum value in nonglutinous varieties). For the fatty acid contents of type A, 16 nonglutinous and 4 glutinous varieties ranged from 7.7% (miminum value in glutinous varieties) to 8.4% (maximum value in nonglutinous varieties) in palmitic acid, and 17 nonglutinous and 13 glutinous varieties ranged from 3.7% (minimum value in nonglutinous varieties) to 6.2% (maximum value in glutinous varieties) in stearic acid.

Simple correlation coefficients between lipid and fatty acid contents and between a pair of fatty acid contents in type A varieties of nonglutinous and glutinous millets are shown in Table II. The lipid of the glutinous variety showed signifcant positive correlations with stearic acid and oleic acid. For both the nonglutinous and glutinous varieties, there were significant positive correlations between stearic acid–arachidic acid and linolenic acid–eicosenoic acid and significant negative correlations between stearic acid–linoleic acid, stearic acid–linolenic acid, and oleic acid–linoleic acid. The coefficients between oleic acid and linoleic acid showed the highest in both the nonglutinous and glutinous varieties. As to the relationship between fatty acid contents in cereals, it was reported that there were the highest and negative correlations between oleic acid and linoleic acid in rice (Taira et al., 1979), corn (Jellum, 1970), and pearl millet (Jellum and Powell, 1971).

Those results demonstrated that foxtail millet has two types of fatty acid patterns in both nonglutinous and glutinous varieties. The progenitor of foxtail millet is considered to be the common World weed, *Setaria viridis* Beauv. The fatty acid composition of weed seeds of genus *Setaria* has been reported with each sample of *S. viridis* (Daun and Tkachuk, 1976) and *Setaria glauca* Beauv. and *Setaria faberii* Herrm. (Stoller and Weber, 1970). Those fatty acid compositions have a pattern similar to that of type B. The seeds of *S. viridis* were collected from 31 prefectures of Japan in 1982 and tested for fatty acid composition in order to identify the types. All the samples showed a pattern similar to that of type B. Because of the fatty acid composition of type B in the genus, it is supposed that type B may have changed into type A after foxtail millet was derived from *S. viridis* or that type A may have changed into type B as the result of crossing with *S. viridis*.

In regard to the differences between nonglutinous and glutinous types of cereals, the glutinous varieties of both foxtail millet and rice (Taira and Hiraiwa, 1982) had a higher tendency in lipid content and palmitic acid content, while stearic acid content showed an opposite tendency. Consequently, it has been demonstrated that there exists distinct differences between nonglutinous and glutinous types of cereals in lipid content and fatty acid composition, though the variation of fatty acid composition between both types disagrees among cereals.

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LITERATURE CITED

Association of Official Analytical Chemists "Official Methods of Analysis", 12th ed.; AOAC: Washington, DC, 1975; p 497.
Daun, J. K.; Tkachuk, R. *J. Am. Oil Chem. Soc.* **1976**, *53*, 661.
Jellum, M. D. *Cereal Chem.* **1970**, *47*, 549.
Jellum, M. D.; Powell, J. B. *Agron. J.* **1971**, *63*, 29.
Stoller, E. W.; Weber, E. J. *J. Agric. Food Chem.* **1970**, *18*, 361.
Taira, H. *J. Agric. Food Chem.* **1968**, *16*, 1025.
Taira, H.; Hiraiwa, S. *Jpn. J. Crop Sci.* **1982**, *51*, 159.
Taira, H.; Miyahara, T. *Rep. Natl. Food Res. Inst. (Tokyo)* **1983**, *No. 42*, 14.
Taira, H.; Taira, H.; Maeshige, M. *Jpn. J. Crop Sci.* **1979**, *48*, 220.

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