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Lipid Content and Fatty Acid Composition of Brown Rice of Cultivars of the United States

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The lipid content and fatty acid composition of brown rice of U.S. cultivars were investigated on a nonwaxy group of 14 long-, 10 medium-, and 2 short-grain types and a waxy group of 2 short-grain types. No significant difference among 3 nonwaxy grain types was observed in lipid content and fatty acid composition except arachidic and behenic acids between long- and medium-grain types. The significant difference between nonwaxy and waxy groups was shown in palmitic acid content. As for the relationship between fatty acid contents, there was the highest and negative correlation between oleic and linoleic acids in the nonwaxy group. The scatter diagram between both fatty acids could not be divided into grain types in nonwaxy groups but might be divided into nonwaxy and waxy groups.

Rice cultivars in the United States are divided by grain size and shape into long-, medium-, and short-grain types. In the southern rice-growing area, long- and medium-grain types are grown. In California, medium- and short-grain types are produced. However, the short-grain type is also produced on a small acreage in the southern rice-growing area, and the first commercial-scale long-grain type was produced in California in 1982.

Rice cultivars can be classified into Indica and Japonica types. Most of the rice grown in California belongs to the Japonica type, while most of that in the southern rice-growing area belongs to the Indica type or is a hybrid derivative of two types (Leonard and Martin, 1967). As for the classification of rice cultivars, the Javanica type was proposed as intermediate between Indica and Japonica types on the basis of phylogenetic remoteness by Morinaga (1954) and Chang (1976). Recently, Sinica was further separated from Indica on the basis of results of isozymic and phylogenetic analysis of rice plant (Nakagahra, 1978, 1986). According to the classification, the cultivars called Indica in the United States belong to the Javanica type.

In previous work, it was shown that the fatty acid composition of nonstarch lipid of brown rice differed between Indica and Japonica types (Taira and Chang, 1986), among Indica, Sinica, Javanica, and Japonica types (Taira et al., 1988), and between Japonica and Indica-Japonica hybrid types (Taira and Lee, 1988). Therefore, investigations were undertaken to study the lipid content and fatty acid composition of brown rice of three grain types of U.S. cultivars.

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MATERIALS AND METHODS

Mature grains of U.S. cultivars were collected from a field experiment conducted by Hiroshima Agricultural College, Japan, in 1986. Cultivars tested: (a) California cultivar, 2 long-grain types (California Belle, L 202), 5 medium-grain types (M 101, M 201, M 202, M 302, M 401), 1 short-grain type (S 201), and 2 short-grain waxy types (Calmochi 101, Calmochi 202); (b) Southern cultivars, 12 long-grain types (Lemont, Lebonnet, Labelle, Starbonnet, Newrex, Bond, Tebonnet, Skybonnet, Newbonnet, Bonnet 73, Toro 2, Bellemont), 5 medium-grain types (Mars, Saturn, Brazos, Pecos, Nato), and 1 short-grain type (Nortai). The seeding and transplanting times were May 14 and June 21, respectively. The heading dates are shown in Table I. Amounts of fertilizer per hectare were as follows. Basal dressing: N, 56 kg; P_2O_5, 68 kg; K_2O, 52 kg. Top dressing: N, 15 kg; P_2O_5, 2 kg; K_2O, 15 kg.

The analytical methods for lipid and fatty acids were identical with those used in the previous paper (Taira and Chang, 1986).

RESULTS AND DISCUSSION

The lipid content and fatty acid composition of long-, medium-, and short-grain types of brown rice are shown as mean values of duplicated data in Table I.

The difference test for lipid and fatty acid contents has been carried out among three nonwaxy grain types by analysis of variance for one-way layout. There was no significant difference among three grain types in lipid and fatty acid contents except for significant differences between long- and medium-grain types in arachidic acid content at the 5% level and behenic acid content at the 1% level on F value. In the previous paper (Taira et al., 1988), significant differences were shown among Indica, Sinica, Javanica, and Japonica types in the fatty acid

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Table I. Heading Date, 1000-Kernel Weight, Lipid Content, and Fatty Acid Composition of Long-, Medium-, and Short-Grain Types of Brown Rice

cultivar	heading date	1000-kernel wt, g	lipid, % dry wt	fatty acid,[a] wt % of total acids										
				14:0	16:0	16:1	18:0	18:1	18:2	18:3	20:0	20:1	22:0	24:0
				Long-Grain Type										
California Belle	Aug 24	21.6	3.01	0.2	14.9	0.2	2.0	44.9	34.2	1.0	0.8	0.6	0.4	0.9
L 202	Aug 26	23.2	2.70	0.2	15.8	0.2	1.8	43.2	35.0	1.3	0.7	0.6	0.4	0.9
Labelle	Aug 26	17.9	3.15	0.2	15.8	0.2	1.6	45.7	32.9	1.1	0.7	0.6	0.4	0.8
Bond	Aug 27	21.5	3.04	0.2	15.5	0.2	1.8	44.8	34.1	1.1	0.6	0.6	0.4	0.9
Toro 2	Aug 28	25.4	2.32	0.2	16.4	0.2	1.6	42.4	35.1	1.4	0.6	0.7	0.4	1.0
Newbonnet	Aug 31	18.4	2.99	0.2	16.1	0.2	1.9	44.0	34.0	1.1	0.7	0.6	0.4	0.9
Tebonnet	Sep 2	19.3	3.08	0.2	15.6	0.2	1.8	44.3	34.5	1.0	0.7	0.6	0.4	0.8
Newrex	Sep 3	18.6	3.07	0.2	15.1	0.2	1.9	45.7	33.2	1.2	0.7	0.6	0.4	0.8
Bonnet 73	Sep 3	17.6	2.98	0.2	16.0	0.2	1.7	44.2	34.1	1.2	0.6	0.6	0.4	0.7
Skybonnet	Sep 4	19.8	2.84	0.2	16.1	0.2	1.7	42.1	36.1	1.3	0.6	0.6	0.4	0.8
Lebonnet	Sep 4	21.9	2.88	0.2	16.0	0.2	1.7	43.1	35.7	1.2	0.6	0.6	0.3	0.6
Lemont	Sep 5	22.4	2.61	0.2	16.1	0.2	1.6	41.4	37.0	1.3	0.6	0.6	0.4	0.7
Starbonnet	Sep 5	17.8	2.85	0.2	16.1	0.2	1.6	43.5	34.7	1.3	0.6	0.6	0.4	0.9
Bellemont	Sep 7	20.4	2.64	0.3	16.1	0.2	1.6	40.6	37.5	1.3	0.6	0.6	0.4	0.8
mean	Sep 1	20.4	2.87	0.21	15.83	0.20	1.74	43.56	34.86	1.20	0.65	0.61	0.39	0.82
SD	5	2.3	0.23	0.03	0.42	0	0.13	1.54	1.33	0.12	0.07	0.03	0.03	0.11
				Medium-Grain Type										
M 101	Aug 13	24.9	2.42	0.2	15.5	0.2	1.7	41.8	36.3	1.2	0.8	0.7	0.6	1.0
M 202	Aug 15	24.7	2.80	0.2	15.2	0.2	2.0	42.1	36.3	1.1	0.8	0.6	0.5	0.9
M 302	Aug 17	22.7	2.76	0.2	15.8	0.2	1.8	43.8	34.5	1.1	0.8	0.6	0.4	0.8
Pecos	Aug 18	20.8	3.24	0.2	15.2	0.2	2.0	44.8	33.9	1.0	0.8	0.6	0.4	0.9
M 201	Aug 19	23.4	2.79	0.2	14.9	0.2	2.0	41.7	37.2	1.1	0.9	0.6	0.5	0.8
Mars	Aug 24	21.0	3.01	0.2	16.4	0.2	1.8	44.3	33.0	1.3	0.7	0.6	0.5	0.9
M 401	Aug 25	26.6	2.63	0.2	15.8	0.2	1.5	43.0	35.6	1.2	0.6	0.6	0.4	0.8
Saturn	Aug 25	21.0	2.73	0.2	16.0	0.2	1.8	43.4	34.5	1.2	0.7	0.7	0.4	0.9
Brazos	Aug 26	24.1	2.52	0.1	16.4	0.2	1.5	44.1	34.1	1.2	0.6	0.7	0.4	0.7
Nato	Aug 27	20.3	2.65	0.2	15.9	0.2	1.7	45.0	33.2	1.2	0.7	0.7	0.5	0.8
mean	Aug 21	23.0	2.76	0.19	15.71	0.20	1.78	43.40	34.86	1.16	0.74	0.64	0.46	0.85
SD	5	2.1	0.24	0.03	0.51	0	0.19	1.21	1.42	0.08	0.10	0.05	0.07	0.08
				Short-Grain Type										
S 201	Aug 17	25.0	2.57	0.2	15.9	0.2	1.6	41.5	36.4	1.4	0.8	0.7	0.4	0.8
Nortai	Aug 28	22.7	2.41	0.2	16.2	0.2	1.6	43.4	34.6	1.3	0.7	0.6	0.4	0.8
mean	Aug 23	23.9	2.49	0.20	16.05	0.20	1.60	42.45	35.50	1.35	0.75	0.65	0.40	0.80
SD	8	1.6	0.11	0	0.21	0	0	1.34	1.27	0.07	0.07	0.07	0	0
				Short-Grain Type (Waxy)										
Calmochi 101	Aug 17	23.7	2.99	0.4	18.3	0.3	2.0	40.6	34.6	1.2	0.7	0.6	0.4	0.8
Calmochi 202	Aug 17	22.3	3.22	0.3	18.4	0.2	1.9	38.8	36.5	1.2	0.7	0.6	0.4	0.9
mean	Aug 17	23.0	3.11	0.35	18.35	0.25	1.95	39.70	35.55	1.20	0.70	0.60	0.40	0.85
SD	0	1.0	0.16	0.07	0.07	0.07	0.07	1.27	1.34	0	0	0	0	0.07

[a] Fatty acids are expressed as the ratio of number of carbons to the number of double bonds.

composition of nonwaxy brown rice of domestic or of Japanese and foreign cultivars. The Japonica type, however, was similar to the Javanica type rather than the Indica type in fatty acid composition such as palmitic, linoleic, and eicosenoic acids. The nonwaxy brown rice of Taiwanese cultivars also differed between Indica and Japonica types in fatty acid composition (Taira and Chang, 1986). On the fatty acid composition of nonwaxy brown rice of Korean cultivars, further, Indica–Japonica hybrid type differed with Japonica type and was similar to Indica type (Taira and Lee, 1988). As contrasted with those results, the fatty acid composition of Indica type or Indica–Japonica hybrid type could not be found in three nonwaxy grain types of U.S. cultivars.

Only two waxy cultivars were studied in the present work because there are not many waxy cultivars in the United States. With regard to the variation of lipid content and fatty acid composition of brown rice of Japonica type, the waxy type, as compared with the nonwaxy type, had more lipid content and myristic and palmitic acid contents and less arachidic acid content in Japanese cultivars (Taira et al., 1981) and had more lipid content and myristic, palmitic, and stearic acid contents and less oleic acid content in mutants from Japanese nonwaxy cultivar by γ-ray and ethylenimine treatments (Taira and Hiraiwa, 1982). The same tendency of difference between nonwaxy group (long-, medium-, and short-grain types) and waxy group (short-grain type) was observed in lipid content and fatty acid composition in this study. The significant difference between nonwaxy and waxy groups was shown in the palmitic acid content of long- and medium-grain types at the 1% level and of short-grain type at the 5% level by the Student's t-test.

Correlation coefficients of lipid content with fatty acid content and fatty acid content pair of three nonwaxy grain types are shown in Table II. The lipid content showed significant positive correlations with stearic and oleic acid contents and significant negative correlations with palmitic, linoleic, linolenic, and eicosenoic acid contents. As for the relationship between lipid and fatty acid contents, it was observed that nonwaxy brown rice of Japonica type of Japanese cultivars showed the same correlations as this study in stearic, oleic, linoleic, and linolenic acids (Taira et al., 1979b). From the relationship between fatty acid contents, there were significant positive correlations between palmitic and linolenic acids, stearic and arachidic acids, arachidic and behenic acids, and behenic and lignoceric acids and significant negative correlations between

Table II. Correlation Coefficient of Lipid Content with Fatty Acid Content and Fatty Acid Content Pair of Nonwaxy Long-, Medium-, and Short-Grain Types[a]

	14:0	16:0	16:1	18:0	18:1	18:2	18:3	20:0	20:1	22:0	24:0
lipid	0.070	–0.429*	0.000	0.567**	0.631**	–0.494*	–0.652**	0.122	–0.599**	–0.223	–0.068
14:0		–0.096	0.000	0.091	–0.357	0.365	0.123	0.000	–0.329	0.000	0.152
16:0			0.000	–0.740**	–0.183	–0.060	0.670**	–0.671**	0.274	–0.255	–0.185
16:1				0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18:0					0.249	–0.133	–0.641**	0.660**	–0.332	0.222	0.322
18:1						–0.949**	–0.512**	–0.002	–0.154	–0.177	0.005
18:2							0.307	0.062	0.009	0.109	–0.111
18:3								–0.433*	0.343	–0.050	–0.026
20:0									0.048	0.505**	0.320
20:1										0.303	0.216
22:0											0.491*

[a] Key: *, significant at the 5% level; **, significant at the 1% level.

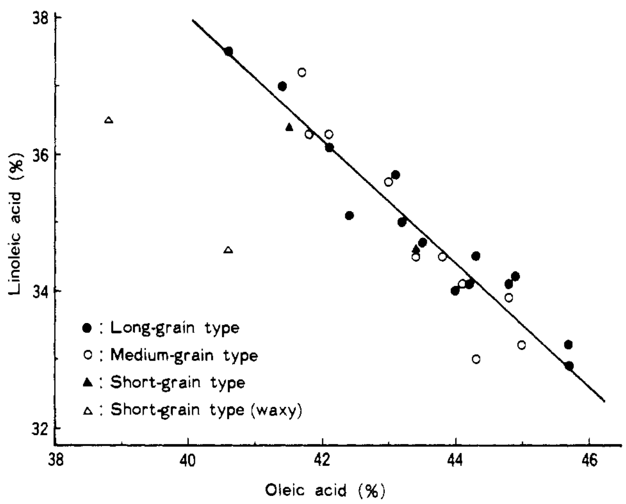

Figure 1. Relationship between oleic acid and linoleic acid contents of long-, medium-, and short-grain types. Three nonwaxy grain types: $y = -0.90x + 74.04$.

palmitic and stearic acids, oleic and linoleic acids, stearic and linolenic acids, oleic and linolenic acids, palmitic and arachidic acids, and linolenic and arachidic acids. In those correlated fatty acids, the highest value showed between oleic and linoleic acids as the dominant fatty acid of brown rice. In previous papers on nonwaxy brown rice, there were also the highest and negative correlations between oleic and linoleic acid contents in Japonica Japanese cultivars (Taira et al., 1979a,b), Indica and Japonica types of Taiwanese cultivars (Taira and Chang, 1986), Indica, Sinica, Javanica, and Japonica types of domestic or Japanese and foreign cultivars (Taira et al., 1988), and Japonica and Indica–Japonica hybrid types of Korean cultivars (Taira and Lee, 1988). Figure 1 shows the relationship between oleic and linoleic acid contents of three grain types. As for the scatter diagram of oleic and linoleic acid contents of nonwaxy brown rice in previous work, it was observed that the regression line could be divided into Indica and Japonica types (Taira and Chang, 1986), Indica and Sinica, Javanica, and Japonica types (Taira et al., 1988), and Japonica and Indica–Japonica hybrid types (Taira and Lee, 1988). In Figure 1, however, the regression line could not be divided into nonwaxy grain types. On the other hand, the regression line would be divided into nonwaxy and waxy groups based on the results of the previous papers (Taira et al., 1981; Taira and Hiraiwa, 1982).

On the basis of above-mentioned observations, it is assumed that the fatty acid composition of brown rice of U.S. cultivars in this study was affected by parental lines of Javanica or Japonica type, though containing cultivars crossed with Indica type in course of breeding. While the samples in this study were grown in Japan, the data of lipid content and fatty acid composition would be applicable to U.S.-grown samples.

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