Fatty Acid Composition of Indica, Sinica, Javanica, and Japonica Groups of Nonglutinous Brown Rice

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The fatty acid composition of Indica, Sinica, Javanica, and Japonica groups of nonglutinous brown rice was investigated on 15 cultivars each. Significant differences between groups were shown in all fatty acids except myristic acid. Regarding the predominant fatty acids, there were significant differences among the four groups in palmitic acid, among the four groups except between Indica and Sinica in linoleic acid, and among Japonica and other groups in oleic acid. As for the relationship between fatty acid contents, the highest and negative correlation between oleic and linoleic acid contents was shown in each of four groups. The regression line in the scatter diagram between both the fatty acids divided into three lines, i.e., Indica and Sinica, Javanica, and Japonica group lines.

For classification of rice cultivar (*Oryza sativa* L.), Indica and Japonica groups are well-known. Further, on the basis of phylogenetic remoteness, Javanica group was proposed as intermediate group between Indica and Japonica groups by Morinaga (1954) and Chang (1976). Recently, the results of isozymic and phylogenetic analyses of rice plants led to the separation of the Sinica group from the Indica group and classified rice cultivars into four groups: Indica, Sinica, Javanica, and Japonica (Nakagahra, 1978, 1986). These groups corresponded well with the cultivar groups that were classified on the basis of morphological characteristics, distribution of genetic markers, photoperiodic response, and extent of hybrid sterility (Kato, 1930; Matsuo, 1952; Morinaga and Kuriyama, 1955, 1958; Oka, 1958; Kudo, 1968).

In the previous work, it was shown that Taiwanese nonglutinous brown rice differed between Indica and Japonica groups in fatty acid composition (Taira and Chang, 1986). Therefore, further investigations were undertaken to study the fatty acid composition of Indica, Sinica, Javanica, and Japonica groups of nonglutinous brown rice.

METHODS AND MATERIALS

Mature grains of 15 nonglutinous cultivars each of Indica, Sinica, Javanica, and Japonica groups based on our classification (Nakagahra, 1978) were collected from a field experiment conducted by the National Institute of Agrobiological Resources, Japan, in 1984. The seeding and transplanting times were May 7 and June 11, respectively. The heading dates are shown in Table I. Amounts of fertilizer per hectare were N, 40 kg; P_2O_5, 50 kg; and K_2O, 50 kg as basal dressing. The grain samples were dehulled by using conventional seed-cleaning equipment and ground to pass a 0.5-mm-diameter seive. Lipid was extracted from the ground samples on a Butt-type extractor with 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 chromtograph equiped with a FID and 3 mm × 3 m glass column packed with Unisol 3000 Uniport C, 80–100 mesh (Gasukurokogyo Co., Ltd.). The column 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 by means of a Shimadzu Chromatopac C-R2A. Standard methyl ester fatty acid mixtures were separated under identical conditions to identify the compounds and to calculate the response factors of the acids. Moisture content was determined by heating the ground samples for 1 h at 135 °C, and lipid contents were reported on a dry basis of grain samples.

RESULTS AND DISCUSSION

The lipid contents and fatty acid compositions of Indica, Sinica, Javanica, and Japonica groups of brown rice are shown as mean values of duplicated data in Tables I–IV, respectively. The significant test of difference among the four groups for lipid and fatty acid contents, 1000-kernel weight, and heading date have been carried out by the analysis of variance for one-way layout. The results of the significance at the 1% and 5% levels by the F value are also shown as least significant difference (LSD) at the 5% level in Table IV.

No significant difference among the four groups was observed in lipid content. As for the fatty acid composition, there were significant differences between the groups in all fatty acids except myristic acid (14:0). Palmitic acid (16:0) content differed among the four groups, and Indica group had the highest mean value. The ratios of Indica group to Sinica, Javanica, and Japonica groups on mean value were 1.07, 1.29, and 1.16, respectively. There were significant differences among the four groups except between Indica and Sinica groups in linoleic acid (18:2) and eicosenoic acid (20:1) contents. The ratios of Indica and Sinica groups to Javanica group and to Japonica group on mean value were 0.89 and 0.89, and 0.84 and 0.85 in linoleic acid; and 0.88 and 0.92, and 0.79 and 0.82 in eicosenoic acid, respectively. Javanica group was significantly lower than three other groups in palmitoleic acid (16:1), arachidic acid (20:0), and behenic acid (22:0) contents. Japonica group, as compared with three other groups, was significantly lower in oleic acid (18:1) content and higher in lignoceric acid (24:0) content.

In regard to the fatty acid composition of Taiwanese brown rice (Taira and Chang, 1986), the Indica group, as compared with the Japonica group, gave significantly higher palmitic acid, stearic acid (18:0), and arachidic acid contents and lower linoleic acid, eicosenoic acid, and lignoceric acid contents. According to Nakagahra's classification (1978, 1986), this Taiwanese Indica group corresponds to the Sinica group in the present paper. Those significant differences between Taiwanese Indica and Japonica groups were also shown between Sinica and Japonica groups in this paper in palmitic acid, linoleic acid,

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Table I. Seed Source, Heading Date, 1000-Kernel Weight, Lipid Content, and Fatty Acid Composition of Indica Group of Brown Rice

cultivar	seed source	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
Muha	Burma	Aug 26	20.3	2.65	0.2	17.9	0.2	1.4	48.4	28.6	1.3	0.5	0.6	0.4	0.6
Dular	India	Aug 14	18.3	2.38	0.2	20.8	0.2	2.3	43.8	29.4	1.0	0.8	0.4	0.4	0.8
T 246	India	Aug 15	19.7	2.57	0.3	18.2	0.2	1.9	45.1	30.2	1.5	0.9	0.6	0.4	0.7
Jhona 349	India	Aug 17	20.1	2.47	0.2	19.7	0.2	1.8	44.4	30.2	1.2	0.7	0.6	0.4	0.7
Patna	India	Aug 17	15.5	2.57	0.3	20.0	0.3	2.0	40.2	32.3	2.0	0.9	0.6	0.5	0.9
Chinsurah boro II	India	Aug 19	19.7	2.31	0.2	19.1	0.2	2.3	42.1	32.7	1.1	0.9	0.5	0.4	0.7
Dusur	India	Aug 20	20.2	2.41	0.2	20.5	0.2	2.1	43.7	29.8	1.0	0.9	0.5	0.4	0.8
Jhona 2	India	Aug 20	20.6	2.57	0.2	19.8	0.2	1.6	45.3	29.8	1.1	0.6	0.5	0.3	0.6
Kasalath	India	Aug 20	14.1	2.60	0.2	19.7	0.2	2.0	45.5	29.0	1.0	0.8	0.5	0.4	0.7
Surjamkhi	India	Aug 20	15.5	2.40	0.2	19.4	0.2	2.4	43.4	31.2	1.0	0.8	0.4	0.4	0.6
Co 13	India	Aug 27	17.8	2.24	0.2	19.9	0.2	1.8	42.0	32.0	1.6	0.7	0.5	0.4	0.6
Pachchaiperumal	India	Sep 2	22.2	2.59	0.2	18.6	0.2	1.9	45.0	30.1	1.5	0.8	0.6	0.4	0.7
Gangala	India	Sep 10	17.6	2.75	0.2	19.2	0.3	1.6	43.3	31.5	1.5	0.7	0.6	0.4	0.6
IR 28	The Philippines	Aug 19	18.4	2.97	0.3	19.5	0.2	2.4	44.5	29.0	1.5	0.8	0.5	0.4	0.8
Dakanalo	Sri Lanka	Aug 19	21.2	2.27	0.4	21.1	0.2	1.7	42.6	30.8	1.2	0.6	0.5	0.4	0.6
mean		Aug 22	18.7	2.52	0.23	19.56	0.21	1.95	43.95	30.44	1.30	0.76	0.53	0.40	0.69
SD		7	2.3	0.19	0.06	0.89	0.04	0.31	1.91	1.27	0.29	0.12	0.07	0.04	0.10

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

Table II. Seed Source, Heading Date, 1000-Kernel Weight, Lipid Content, and Fatty Acid Composition of Sinica Group of Brown Rice

cultivar[a]	heading date	1000-kernel wt, g	lipid, % dry wt	fatty acid,[b] 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
Liu zhou bao ya zao	Aug 13	19.9	2.49	0.3	17.3	0.2	2.0	47.0	29.4	1.6	0.7	0.5	0.4	0.6
Hong jiao zhan	Aug 14	19.0	2.94	0.2	18.5	0.2	2.0	46.1	29.2	1.4	0.7	0.5	0.4	0.7
Xuan chang local	Aug 15	16.3	3.03	0.3	17.4	0.2	2.2	44.9	31.0	1.5	0.9	0.6	0.4	0.7
Xi li gu	Aug 15	21.6	2.64	0.3	18.1	0.2	1.6	44.8	31.3	1.4	0.7	0.6	0.4	0.7
Chi xian dao	Aug 16	18.2	2.96	0.3	17.4	0.2	2.0	46.0	29.7	1.9	0.8	0.6	0.4	0.7
Ai jiao nan te	Aug 18	18.9	2.47	0.2	19.5	0.2	1.7	40.4	34.0	1.6	0.7	0.5	0.4	0.7
Duan guong hua luo	Aug 18	17.9	2.55	0.2	18.1	0.2	2.0	45.8	30.1	1.3	0.8	0.6	0.4	0.6
Qing you	Aug 18	17.7	2.53	0.2	18.1	0.2	2.5	44.8	30.1	1.4	1.0	0.5	0.5	0.8
Hong mi	Aug 20	17.8	2.68	0.2	19.5	0.2	2.3	43.8	30.1	1.5	0.8	0.5	0.4	0.7
Hu nan xian	Aug 22	19.2	2.68	0.3	18.5	0.3	2.2	43.9	31.0	1.3	1.0	0.5	0.4	0.7
Wu ga hua luo	Aug 22	17.1	2.51	0.2	17.9	0.2	2.4	44.9	30.1	1.4	1.0	0.6	0.5	0.8
Dao ren qio	Aug 28	18.6	2.66	0.3	16.9	0.2	1.8	46.9	29.3	2.0	0.9	0.7	0.4	0.6
Deng pao zhai	Aug 28	17.4	2.61	0.3	19.3	0.2	1.9	42.0	32.1	1.9	0.8	0.5	0.4	0.7
Gui zhao 2	Aug 28	20.7	2.66	0.2	19.3	0.3	1.7	45.5	29.2	1.6	0.6	0.5	0.4	0.7
Xian	Aug 31	19.6	2.35	0.2	19.2	0.2	1.7	40.4	33.9	2.0	0.7	0.5	0.4	0.7
mean	Aug 20	18.7	2.65	0.25	18.33	0.21	2.00	44.48	30.70	1.59	0.81	0.55	0.41	0.69
SD	6	1.4	0.19	0.05	0.87	0.04	0.28	2.08	1.56	0.25	0.13	0.06	0.04	0.06

[a] Seed source: China. [b] Fatty acids are expressed as the ratio of number of carbons to the number of double bonds.

Table III. Seed Source, Heading Date, 1000-Kernel Weight, Lipid Content, and Fatty Acid Composition of Javanica Group of Brown Rice

cultivar	seed source	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
Bodat Mayang	Indonesia	Aug 23	27.2	2.46	0.3	13.7	0.2	2.1	45.8	34.5	1.3	0.8	0.6	0.3	0.6
Simanoek	Indonesia	Aug 23	23.9	2.65	0.4	14.6	0.2	2.1	45.2	34.1	1.1	0.6	0.6	0.3	0.8
Simedel	Indonesia	Aug 23	26.2	2.66	0.2	14.3	0.2	2.0	45.4	34.3	1.1	0.7	0.6	0.4	0.8
Siampang	Indonesia	Aug 27	25.9	2.94	0.3	15.8	0.1	2.0	45.0	33.3	1.2	0.4	0.6	0.4	0.8
Page Minyak	Indonesia	Aug 27	23.3	2.84	0.3	14.9	0.2	2.3	43.9	34.4	1.4	0.8	0.6	0.3	0.7
Masmikir	Indonesia	Aug 29	17.2	2.61	0.2	15.6	0.1	1.3	43.6	35.5	1.4	0.5	0.6	0.3	0.7
Padi kenikir putih	Indonesia	Aug 30	17.2	2.59	0.2	14.9	0.1	1.4	51.6	28.8	1.0	0.5	0.6	0.3	0.7
Ladang	Indonesia	Sep 1	26.3	2.75	0.2	15.5	0.1	1.6	43.2	35.7	1.3	0.6	0.7	0.3	0.7
Dinalaga	The Philippines	Aug 24	23.7	2.54	0.2	16.3	0.2	1.5	42.7	35.5	1.4	0.6	0.6	0.3	0.6
Basilanon	The Philippines	Aug 26	13.9	2.67	0.2	15.6	0.1	1.3	40.9	38.3	1.2	0.7	0.6	0.4	0.7
Canabongbong	The Philippines	Aug 26	21.7	2.11	0.2	14.6	0.2	1.7	42.2	37.3	1.4	0.8	0.6	0.4	0.7
Geraldine	South America	Aug 29	21.4	2.46	0.3	14.2	0.2	1.4	44.1	35.6	1.6	0.8	0.6	0.4	0.8
Tambo	South America	Aug 30	26.2	2.97	0.2	16.1	0.1	1.4	48.7	30.4	1.2	0.5	0.5	0.3	0.6
Vista	U.S.	Aug 18	17.8	2.28	0.2	15.1	0.2	1.8	44.4	34.4	1.1	0.7	0.7	0.4	0.8
Moroberekan	West Africa	Sep 4	24.3	2.99	0.2	16.8	0.1	1.5	44.5	33.4	1.2	0.5	0.5	0.4	0.7
mean		Aug 27	22.4	2.63	0.24	15.20	0.15	1.69	44.75	34.37	1.26	0.63	0.60	0.35	0.71
SD		4	4.1	0.25	0.06	0.86	0.05	0.33	2.60	2.37	0.16	0.13	0.05	0.05	0.07

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

eicosenoic acid, and lignoceric acid contents.

The numbers of fatty acids that differed between the groups were nine acids in Javanica–Japonica groups, eight acids in Sinica–Javanica groups, seven acids in Indica–Javanica groups, six acids in Indica–Japonica groups, five acids in Sinica–Japonica groups, and two acids in Indica–

Table IV. Seed Source, Heading Date, 1000-Kernel Weight, Lipid Content, and Fatty Acid Composition of Japonica Group of Brown Rice

cultivar	seed source	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
Taichung 65	China	Aug 28	22.8	2.57	0.2	16.9	0.2	1.8	41.2	35.8	1.3	0.8	0.7	0.4	0.7
Huang gu	China	Sep 1	15.5	2.32	0.2	17.6	0.2	1.9	37.9	38.2	1.4	0.7	0.5	0.4	0.9
Moritawase	Japan	Aug 6	21.9	2.54	0.4	15.7	0.2	2.2	43.5	33.6	1.4	0.9	0.7	0.5	0.9
Ginbozu	Japan	Aug 11	20.7	2.67	0.2	15.9	0.3	2.3	43.3	33.8	1.2	0.9	0.7	0.5	1.0
Shinshukaneko	Japan	Aug 11	19.1	2.65	0.2	16.4	0.2	1.9	41.1	36.0	1.4	0.8	0.7	0.4	0.9
Fujisaka 5	Japan	Aug 12	17.4	2.86	0.4	15.2	0.2	1.9	47.5	30.4	1.5	0.7	0.8	0.4	0.9
Joshu	Japan	Aug 18	18.5	2.94	0.3	16.9	0.2	1.7	39.5	37.4	1.3	0.8	0.6	0.4	0.8
Kokuryomiyako	Japan	Aug 27	23.6	2.12	0.2	16.3	0.2	1.6	41.4	36.2	1.4	0.8	0.7	0.4	0.8
Sen-ichi	Japan	Aug 31	17.3	2.27	0.2	17.2	0.2	1.9	38.6	37.7	1.5	0.8	0.6	0.4	0.9
Nakateshinsenbon	Japan	Sep 1	20.3	2.33	0.2	18.1	0.2	1.6	39.2	36.6	1.5	0.7	0.6	0.4	0.8
Araki	Japan	Sep 5	19.9	2.36	0.2	17.3	0.4	1.8	36.6	39.2	1.7	0.8	0.7	0.5	1.0
Miyako	Japan	Sep 5	20.4	2.24	0.2	17.3	0.2	1.6	38.2	37.7	1.7	0.9	0.9	0.4	1.0
Asahi	Japan	Sep 10	21.5	2.50	0.2	17.2	0.2	1.8	40.1	36.3	1.6	0.8	0.7	0.4	0.8
Shinriki	Japan	Sep 11	19.0	2.66	0.2	16.8	0.2	1.9	39.0	37.9	1.6	0.7	0.6	0.4	0.8
Omachi	Japan	Sep 12	22.9	2.56	0.2	17.0	0.2	1.7	40.1	37.1	1.4	0.6	0.6	0.4	0.7
mean		Aug 27	20.1	2.51	0.23	16.79	0.22	1.84	40.48	36.26	1.46	0.78	0.67	0.42	0.86
SD		12	2.3	0.23	0.07	0.77	0.06	0.20	2.72	2.22	0.15	0.09	0.10	0.04	0.10
LSD (5%) among gps		ns	2.0	ns	ns	0.62	0.03	0.21	1.72	1.40	0.16	0.09	0.05	0.03	0.06

[a] Fatty acids are expressed as the ratio of number of carbons to the number of double bonds. Key: LSD = least significant difference; ns = not significant.

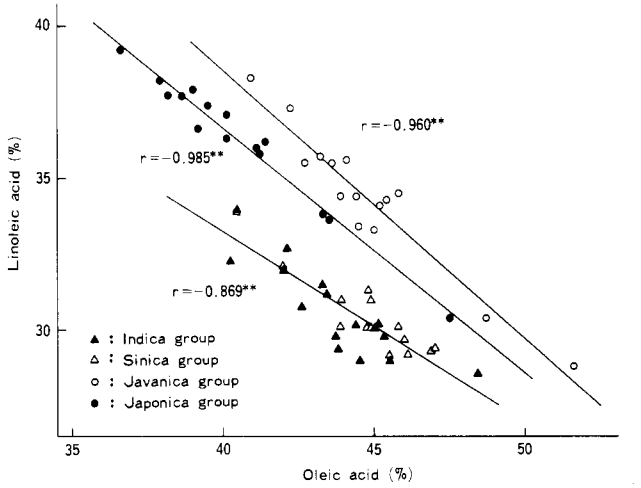

Figure 1. Relationship between oleic acid and linoleic acid contents of Indica, Sinica, Javanica, and Japonica groups: Indica and Sinica groups, $y = -0.62x + 57.8$; Javanica group, $y = -0.87x + 73.5$; Japonica group, $y = -0.80x + 68.8$.

Sinica groups.

As for the relationship between fatty acid contents, there were the highest and negative correlation coefficients between oleic acid and linoleic acid in all groups: Indica, –0.836**; Sinica, –0.939**; Javanica, –0.960**; Japonica, –0.985**. In the previous paper (Taira and Chang, 1986), the coefficients between oleic acid and linoleic acid contents in Indica and Japonica groups were also the highest and negative values. Figure 1 shows the relationship between oleic acid and linoleic acid contents of the four groups. The regression in the scatter diagram could be separated into three lines, i.e., Indica and Sinica group line, Japonica group line, and Javanica group line, because Indica and Sinica groups could not be divided into each line by the pooling test of regression equation.

On the basis of the results of the significant differences of fatty acid content and scatter diagram between oleic acid and linoleic acid contents among the four groups, it is presumed that the fatty acid composition of nonglutinous brown rice is classified at least into three groups (Indica and Sinica, Javanica, Japonica) and further that rice bran oil and milled rice may differ also in fatty acid composition among the groups because of the difference in fatty acid composition between Taiwanese Indica and Japonica groups on rice bran and milled rice (Taira, 1986).

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