Lipid Content and Fatty Acid Composition of Rice

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In Japan, rough rice is dehulled to brown rice after harvest and drying. The brown rice is separated by rice mill into milled rice and bran (the outer part of caryopsis that includes pericarp, seed coat, aleurone layer, and embryo). The lipid of brown rice and milled rice is not important nutritionally because of its low content, i.e. brown rice: about 2% and milled rice: about 1%. However, it is known that free fatty acids released by hydrolysis of the lipid during storage exert influences on deterioration of flavor and cooking quality of rice. As the lipid content of rice bran on the other hand is about 20%, the bran is used for raw material of rice oil. Production of rice oil in Japan occupied 98,000 t in 99,000 t of vegetable oil production using domestic raw materials in 1981. All vegetable oil production* was 1,776,000 t in 1981 and the rank, item, and production were as follows: 1) soybean oil 664,000 t, 2) rapeseed oil 510,000 t, and 3) palm oil 157,000 t. Then, rice oil was given the 4th rank. Edible oil is important as source of energy, essential fatty acids for cell structure and prostaglandin, and a vehicle for oil-soluble vitamins and for cell structure and membrane functions and also control of blood lipids. For population groups with a high incidence of atherosclerosis, obesity, and maturity-onset diabetes, it is recommended that edible fat should have a reduced saturated fatty acid content and a linoleic acid content amounting to at least one third of the total fatty acids.

The investigations of lipid content and fatty acid composition of rice and their variations presented in this paper have been carried out with the consideration for quality of rice grain and oil, and nutrition of rice oil.

* The statistics includes imported oils.

Influence of variety and cropping year

The influence of variety and cropping year on lipid content and fatty acid composition of brown rice was studied using 24 lowland non-glutinous varieties cultivated at Hiroshima Agricultural Experiment Station in 1976 and 1977[3]. The results are shown in Table 1.

Lipid content and stearic acid, oleic acid, and linoleic acid contents were significantly affected by variety and cropping year, and palmitoleic acid and linolenic acid contents were significantly affected by cropping year. As to the fatty acid composition in 1976 and for the both years (1976+1977), the daily mean temperature during ripening showed significantly positive correlations with palmitoleic acid, oleic acid, and arachidic acid contents and negative correlations with myristic acid, palmitic acid, linoleic acid, and linolenic acid contents. On the other hand, no significant correlation between daily mean temperature during ripening and fatty acid content was observed in 1977. As a reason for that, it was presumed that there was no marked difference in the temperature to which each variety was exposed during ripening in 1977 because higher temperature lasted from the middle of August to the middle of September as compared with 1976. Oleic acid content showed significantly negative correlations with linoleic acid content (Fig. 1) and linolenic acid content, and linoleic acid content showed significantly a positive correlation with linolenic acid content in 1976, 1977, and for the both years. The relation between

Table 1. Lipid content and fatty acid composition of brown rice of 24 non-glutinous varieties

	Cropping year	Range	Mean	Standard deviation	Coefficient of variation
					%
Lipid	1976	2.22– 2.72	2.340	0.127	5.2
	1977	2.25– 2.78	2.542	0.145	5.7
					%
Myristic acid	1976	0.2 – 0.5	0.31	0.06	19.4
	1977	0.2 – 0.4	0.30	0.05	16.7
Palmitic acid	1976	16.2 –18.8	17.47	0.60	3.4
	1977	16.3 –18.1	17.18	0.45	2.6
Palmitoleic acid	1976	0.2 – 0.4	0.33	0.06	18.2
	1977	0.2 – 0.5	0.38	0.08	21.1
Stearic acid	1976	1.4 – 2.1	1.69	0.21	12.4
	1977	1.6 – 2.3	1.88	0.18	9.6
Oleic acid	1976	36.4 –43.6	39.10	1.97	5.0
	1977	36.6 –43.0	40.42	1.39	3.4
Linoleic acid	1976	35.4 –41.1	38.58	1.50	3.9
	1977	35.7 –40.9	37.50	1.16	3.1
Linolenic acid	1976	1.4 – 2.4	1.72	0.28	16.3
	1977	1.2 – 2.1	1.55	0.17	11.0
Arachidic acid	1976	0.5 – 1.0	0.79	0.13	16.5
	1977	0.6 – 0.9	0.79	0.08	10.1

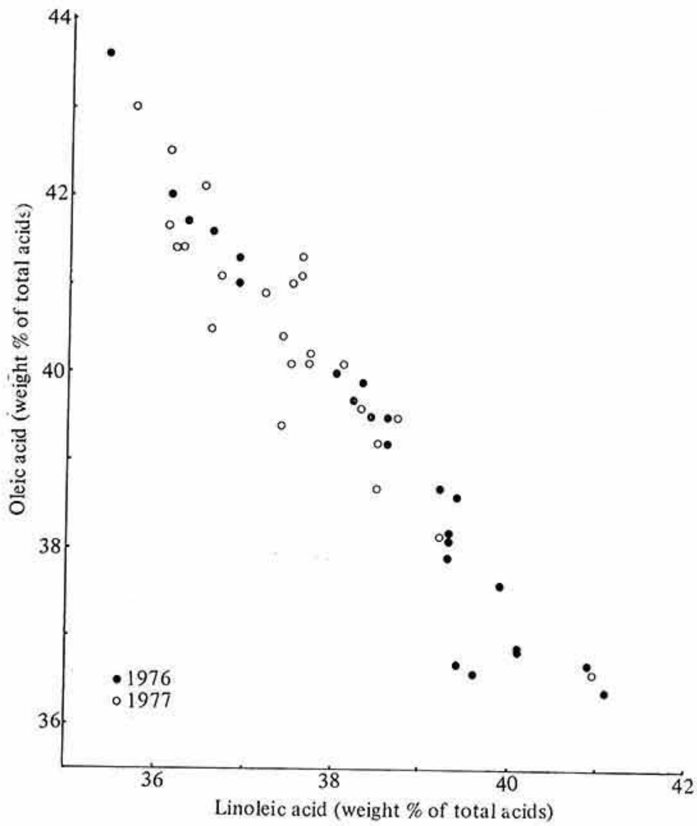

Fig. 1. Relationship between oleic acid and linoleic acid contents of brown rice

Table 2. Ripening conditions

Variety	Heading date			Date of maturity			Daily mean temperature during ripening		
	Early season culture	Normal season culture	Late season culture	Early season culture	Normal season culture	Late season culture	Early season culture	Normal season culture	Late season culture
							°C	°C	°C
Fujihikari	Jul. 7	Aug. 5	Aug. 30	Aug. 12	Sep. 14	Nov. 1	27.8	26.5	21.3
Katsurawase	Jul. 12	Aug. 10	Sep. 12	Aug. 16	Sep. 22	Nov. 13	27.8	25.7	19.1
Reimei	Jul. 11	Aug. 14	Sep. 12	Aug. 20	Oct. 1	Nov. 18	27.8	25.0	18.7
Honenwase	Jul. 17	Aug. 14	Sep. 21	Aug. 17	Sep. 27	Nov. 26	27.6	25.3	17.0
Chugoku No. 64	Jul. 20	Aug. 21	Sep. 19	Aug. 28	Oct. 2	Nov. 24	27.2	24.5	17.4
Koshihikari	Jul. 23	Aug. 19	Sep. 11	Aug. 29	Sep. 30	Nov. 13	27.1	24.7	17.8

Seeding: early season culture Mar. 28, normal season culture May 25, late season culture Jul. 4.
Transplanting: early season culture Apr. 28, normal season culture Jun. 23, late season culture Jul. 29.

Table 3. Correlation coefficients of daily mean temperature during ripening with lipid content and fatty acid content of brown rice, milled rice, and bran

	Lipid	14 : 0	16 : 0	16 : 1	18 : 0	18 : 1	18 : 2	18 : 3	20 : 0
Brown rice	0.608**	0.700**	−0.285	0.914**	0.712**	0.829**	−0.849**	−0.830**	0.760**
Milled rice	0.729**	0.859**	−0.425	0.683**	0.432	0.875**	−0.774**	−0.688**	0.065
Bran	0.230	0.560*	−0.052	0.618**	0.765**	0.605**	−0.747**	−0.720**	0.708**

* Significant at the 5% level ** Significant at the 1% level

oleic acid content (X%) and linoleic acid content (Y%) was expressed by the following regression equation from the values of both years. $Y = -0.759X + 68.21$.

Influence of cropping season

Since it was suggested that lipid content and fatty acid composition of rice were affected by daily mean temperature during ripening, the influence of cropping season on lipid content and fatty acid composition of brown rice, milled rice, and bran was investigated with six lowland non-glutinous varieties grown by early, normal, and late season cultures at Chugoku National Agricultural Experiment Station ni 1977. The ripening conditions are shown in Table 2.

1) Brown rice[4)]

As to the lipid, the earlier the cropping season, the higher the lipid content, with a significant difference among three cropping seasons.

The earlier the cropping season, it was revealed, the more the myristic acid, palmitoleic acid, stearic acid, oleic acid, and arachidic acid contents. On the other hand, the later the cropping season, the more the linoleic acid and linolenic acid contents. The significance of variation was observed among three cropping seasons on oleic acid, linoleic acid, and linolenic acid contents, and between late and normal seasons and also between late and early seasons on other fatty acid contents.

The daily mean temperature during ripening showed significantly positive correlations with lipid content and myristic acid, palmitoleic acid, stearic acid, oleic acid, and arachidic acid contents, and negative correlations with linoleic acid and linolenic acid contents (Table 3). With respect to the fatty acid composition, there was a highly negative correlation between oleic acid and linoleic acid contents.

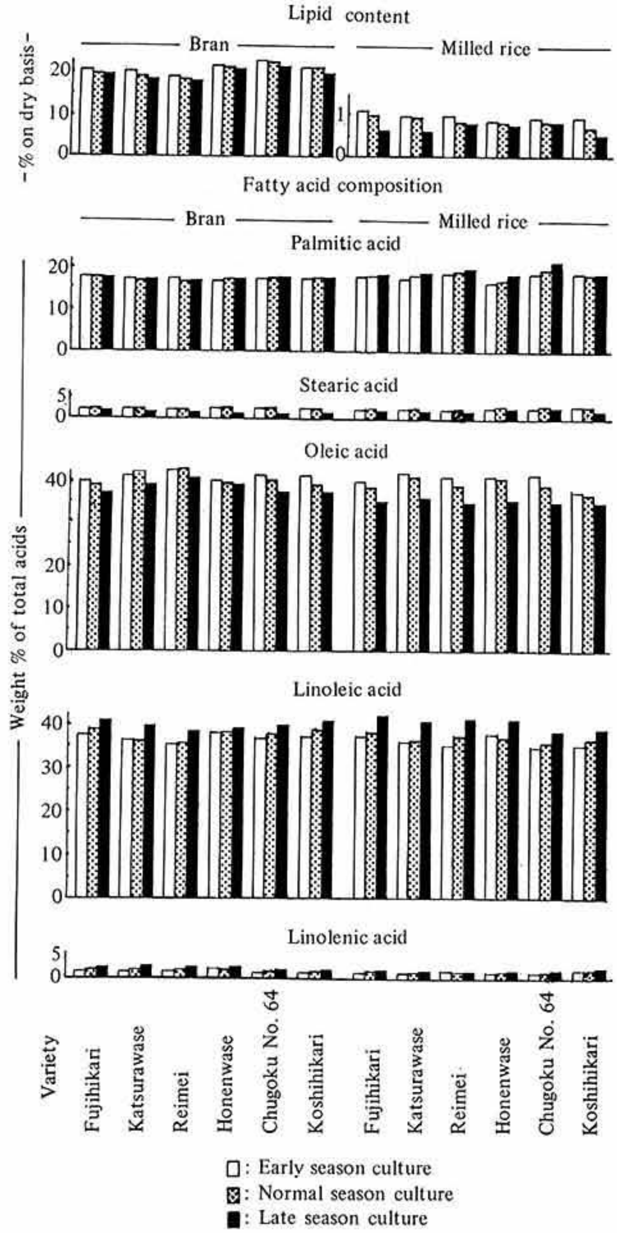

Fig. 2. Lipid content and fatty acid composition of bran and milled rice by three season cultures

From the regression equation between oleic acid and linoleic acid contents, and that between ripening temperature and these fatty acid contents shown in Table 3 and in the previous results[3]), it was estimated that the both fatty acids come to the same value, about 38.7%, at about 20 to 22°C of the daily mean temperature during ripening.

2) Milled rice and bran[6]

The results are shown in Fig. 2. The earlier the cropping season, the higher was the lipid content of bran and milled rice. The significant differences were revealed in the content in bran among three cropping seasons and that in milled rice between late and early or normal seasons.

As to the fatty acid composition, the earlier the cropping season, the more the palmitoleic acid, stearic acid, and oleic acid contents of bran and milled rice, the arachidic acid content of bran, and the myristic acid content of milled rice. On the other hand, the later the cropping season, the more the linoleic acid and linolenic acid contents of bran and milled rice, and the palmitic acid content of milled rice. A significant difference was observed among three cropping seasons for palmitic acid content of bran and oleic acid content of milled rice, and that between late and early or normal seasons was recognized for the other fatty acid contents of bran and milled rice.

The daily mean temperature during ripening showed significantly positive correlations with lipid content of milled rice and with myristic acid, palmitoleic acid, and oleic acid contents of bran and milled rice, and stearic acid and arachidic acid contents of bran, but negative correlations with linoleic acid and linolenic acid contents of bran and milled rice (Table 3). Regarding the main fatty acids of bran and milled rice, a negative correlation was shown between oleic acid and linoleic acid contents. From the regression analysis between oleic acid and linoleic acid contents and that between daily mean temperature during ripening and these fatty acid contents, it was estimated that these fatty acids showed the same contents, 38.9% in bran and 37.8% in milled rice at about 20°C to 21°C for the former and about 24°C for the latter.

From these results shown above, it is presumed that fatty acid composition of commercial rice oil shows variations. In the case of main fatty acids of the oil, linoleic acid content is generally lower than oleic acid content. In Japan, however, their contents are nearly the same or even higher linoleic acid content is found in the fatty acid composition. As a reason, it may safely be assumed from the above-mentioned results that the bran, as a by-product of rice production, was obtained mostly from the brown rice ripened at lower temperatures in mid- to late-autumn.

Influence of irrigation

In an earlier paper[1], it was reported that the upland culture, as compared with the lowland culture, gave significantly high protein content of brown rice. Based on the assumption that irrigation may also influence lipid content and fatty acid composition of rice, their difference between the lowland culture (flooded irrigation) and the upland culture with intermittent irrigation practiced nearly after the young panicle formation stage was examined with non-glutinous and glutinous brown rice of lowland, upland, and lowland-upland hybrid varieties and lines[7,8].

The difference between lowland and upland cultures was not significant in the lipid content. However, contents of six fatty acids, especially oleic acid and linoleic acid, were influenced by the culture methods. The lowland culture, as compared with the upland culture, gave significantly high oleic acid content and low linoleic acid content in both of the non-glutinous and glutinous samples of lowland, upland and hybrid rice.

Changes in the stage from dough- to over-ripening

In a previous paper[2], changes in contents of protein, lipid, ash, phosphorus, potassium, and magnesium of rice kernel occurring from dough-ripening to over-ripening were reported, showing that the lipid content varied greatly from dough-ripening to full-ripening, decreasing on dry matter basis and increasing in 1,000 kernels. After the full ripening, on the other hand, the lipid content decreased on dry matter basis and in 1,000 kernels.

Further investigations were carried out to determine the lipid content and fatty acid

Table 4. Lipid content and fatty acid composition* of rice kernel from dough ripening to over ripening

(variety: Akihikari)

Sampling date	Days after heading	Days after full-ripening	Lipid on dry matter basis	Lipid per 1000 kernels	14:0	16:0	16:1	18:0	18:1	18:2	18:3	20:0
			%	mg	weight % of total acids							
Aug. 31	22	−20	2.92	642	0.3	19.1	0.3	1.9	38.2	37.9	1.5	0.7
Sep. 10	32	−10	2.54	683	0.4	18.4	0.4	1.8	40.2	36.8	1.5	0.7
Sep. 21	43	1	2.44	681	0.4	17.6	0.4	1.7	40.5	37.0	1.6	0.7
Sep. 30	52	10	2.43	688	0.5	17.6	0.4	1.7	41.0	36.5	1.6	0.7
Oct. 10	62	20	2.44	698	0.4	17.5	0.4	1.8	41.2	36.5	1.5	0.7
Oct. 20	72	30	2.33	664	0.4	17.3	0.4	1.8	41.3	36.6	1.6	0.7
Oct. 30	82	40	2.31	626	0.4	17.2	0.4	1.8	41.3	36.5	1.6	0.8

* 14:0 myristic acid, 16:0 palmitic acid, 16:1 palmitoleic acid, 18:0 stearic acid, 18:1 oleic acid, 18:2 linoleic acid, 18:3 linolenic acid, 20:0 arachidic acid

composition of lowland non-glutinous rice kernel of three varieties and one line at intervals of 10 days from the dough-ripening (20 to 25 days before full-ripening) to over-ripening (35 to 45 days after full-ripening)[5]. Results of a variety, Akihikari, are adduced in Table 4.

From dough-ripening to full-ripening, the lipid content and the fatty acid composition varied widely. The lipid content decreased especially until 10 or 15 days before full-ripening on dry matter basis, while it increased until 3 or 15 days before full-ripening but then decreased in 1,000 kernels. As to the fatty acid composition, the myristic acid, oleic acid, and linolenic acid contents increased and the palmitic acid, stearic acid, and linoleic acid contents decreased. After the full-ripening, though the lipid content had a tendency to decrease slightly on dry matter basis and in 1,000 kernels, the fatty acid composition was little varied.

With each of three varieties and one line, the lipid content on dry matter basis showed significantly positive correlations with the palmitic acid and linoleic acid contents and a negative correlation with the oleic acid contents. The oleic acid content showed significantly negative correlations with the palmitic acid and linoleic acid contents.

Difference between non-glutinous rice and glutinous rice

In order to confirm lipid content and fatty acid composition of glutinous rice, brown rice and its milled rice of 11 glutinous mutant lines and three non-glutinous mutant lines, all of which were induced by gamma ray irradiation or ethylenimine treatment of a lowland non-glutinous variety: Nihonmasari, and those of 4 comparative glutinous varieties were investigated[9]. The results are shown in Fig. 3.

The lipid content of the glutinous lines, the comparative glutinous varieties, and one non-glutinous line was significantly higher in both brown rice and milled rice in comparison with that of the original non-glutinous variety. The value of the non-glutinous lines, however, was significantly lower than that of the glutinous lines.

As to fatty acid composition of brown rice and milled rice, the glutinous lines and the comparative glutinous varieties showed significantly higher myristic acid and palmitic acid contents than the original non-glutinous variety. The stearic acid content showed also the same tendency except brown rice of two comparative glutinous varieties and milled rice of one glutinous line and one comparative glutinous variety, but the oleic acid content was

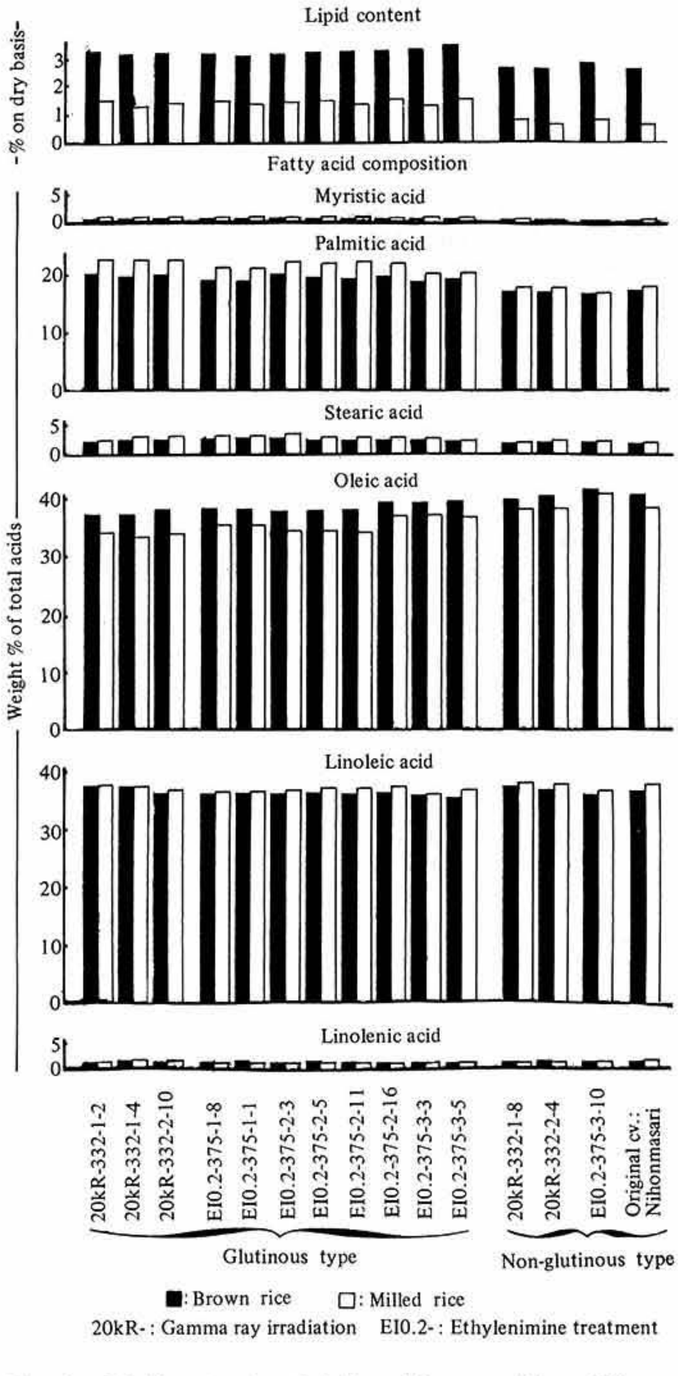

Fig. 3. Lipid content and fatty acid composition of brown rice of glutinous and non-glutinous mutants

lower. In regard to the difference between the non-glutinous lines and the original non-glutinous variety, no significance was observed in the contents of above-mentioned four fatty acids of brown rice and milled rice with some exceptions in oleic acid content. As the results, it was presumed that glutinous rice, as compared with non-glutinous rice, was higher in lipid content and in myristic acid, palmitic acid, and stearic acid contents but lower in oleic acid content as for fatty acid composition.

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