Protein Content of Japanese Rice and Its Variation

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Cereals are not only the major source of calorie but the source of protein in the diet of the peoples of Asia and Africa. Accordingly, it is significant from the standpoint of nutrition for rice-eating people to have the protein content of rice increased.

Therefore, attempts are being made in many countries to increase the protein content of rice by breeding new variety.

On the other hand, there is a possibility to produce high protein rice by a method other than breeding, because it has been assumed that the protein content of rice is variable by the cultural condition.

Based upon this assumption, the protein content of rice and its variation have been studied and these findings are presented in the following.

Protein content of Japanese brown rice

The rice cultivated in Japan belongs to the japonica type and is cultivated as far as near latitude 45° North. The production of brown rice in 1970 was 12.53 million tons in paddy rice and 160,800 tons in upland rice. Recent investigations of the protein content of Japanese rice revealed the following results.

The protein content of nonglutinous paddy brown rice in 1968 and 1969 purchased by the Government from all over the country is shown as per cent on dry weight basis in Table 1[8].

The average values in grade No. 3 which comprises about 50 per cent of the total rice production are 8.64 per cent in both years. These values are not much different from those of the food composition tables of India

Table 1. Protein content* of Japanese paddy brown rice

Inspection grade	Range	Mean	Standard deviation	Coefficient of variation
1968	%	%	%	%
Grade No. 1 (n=42)	7.49 — 10.23	8.57	0.60	7.00
Grade No. 2 (n=45)	7.27 — 11.21	8.64	0.70	8.10
Grade No. 3 (n=46)	7.12 — 10.59	8.64	0.65	7.52
Grade No. 4 (n=46)	7.49 — 11.54	9.03	0.71	7.86
Grade No. 5 (n=44)	7.77 — 10.32	9.01	0.58	6.43
Off-grade 1st class (n=27)	8.25 — 10.47	9.50	0.55	5.79
1969				
Grade No. 3 (n=97)	7.11 — 10.54	8.64	0.79	9.14

* Dry weight basis

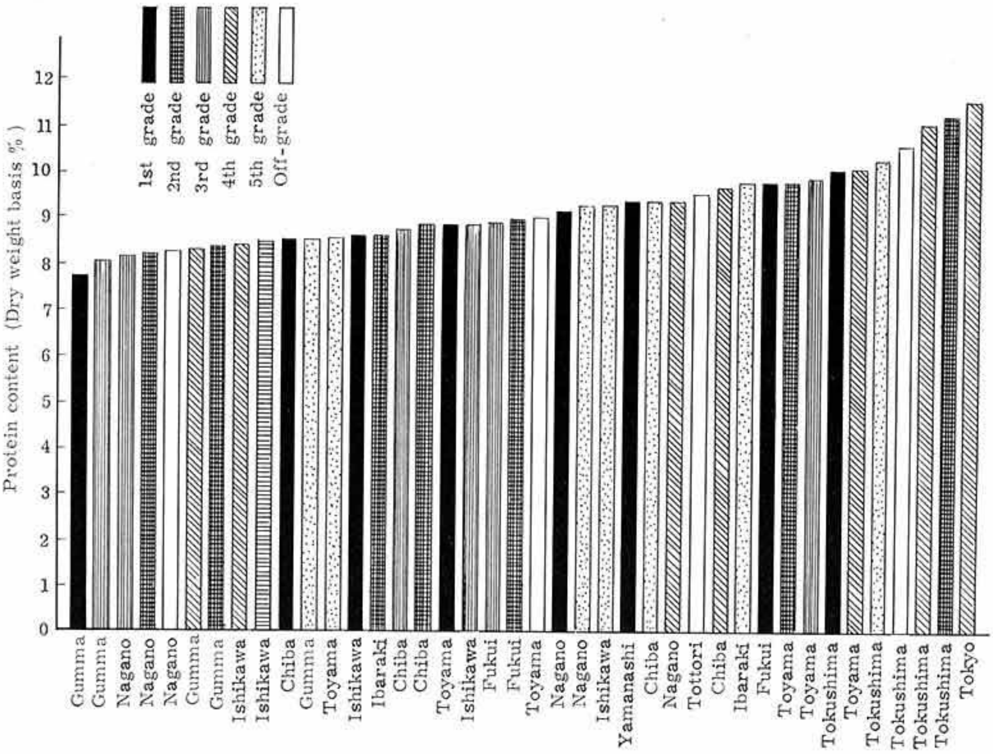

Fig. 1. Protein content of 'Honen-Wase' variety

or the United States.

However, a considerable variation in the protein content is recognized in all the grades in both the year and the variety. As an example of the variation of variety in 1968, 'Honen-wase' variety is shown in Fig. 1. The range of the value is from 7.74 per cent to 11.54 per cent and the average value of each grade is higher than that of all the samples of the same year.

On the other hand, the protein content of nonglutinous and glutinous upland brown rice purchased by the Government in 1968 from all over the country has been investigated. The results are shown in Table 2[6].

The average values show a higher content than those of nonglutinous paddy rice of the same year (Table 1) by about 40 per cent. With respect to protein content of rice, accordingly, it is reasonable to distinguish between paddy and upland rice.

Table 2. Protein content* of Japanese upland brown rice (Grade No. 3)

Sample	Range	Mean	Standard deviation	Coefficient of variation
	%	%	%	%
Nonglutinous type (n=24)	9.89 — 14.17	11.97	0.95	7.94
Glutinous type (n=23)	9.29 — 14.19	11.67	1.27	10.88
Two types (n=47)	9.29 — 14.19	11.82	1.11	9.39

* Dry weight basis

Nitrogen application and protein content of nonglutinous paddy brown rice

As described abcve, a considerable variation can be recognized in the protein content of the same variety. As cne of the factors for the variation, the influence of nitrogen application is conceived. In this case, the amount of fertilizer and the period of application pose a problem.

With respect to the relation between the protein content cf paddy brown rice and nitrogen applicaticn, it was reported that the application after heading increased the protein content by about 10 per cent in comparison to the non-application[3]. Accordingly, it is suggested that the nitrogen application after heading is one of the factors for the varialways influence the protein content by the cultivated year but the top-dressing after content.

However, this nitrogen application was not extended because of regarding it as more injurious than beneficial for rice culture.

Recently, in connection with the high-yielding paddy rice culture method, nitrogen top-dressing after the heading stage came to be recognized as effective to reduce the immature grain[2] and was begun to adopt the practice as one of the top-dressings.

As this top-dressing application suggests a possibility to increase both the yield and the protein content, the relation between the nitrogen application and the protein content of nonglutinous paddy rice has been studied at the experimental field[5].

The results revealed that the nitrogen application of basal dressing and top-dressing at the young panicle formation stage does not ation and is effective in increasing the protein heading stage does definitely increase the protein content.

As an example of the results as shown in Fig. 2, the top-dressing at the full heading

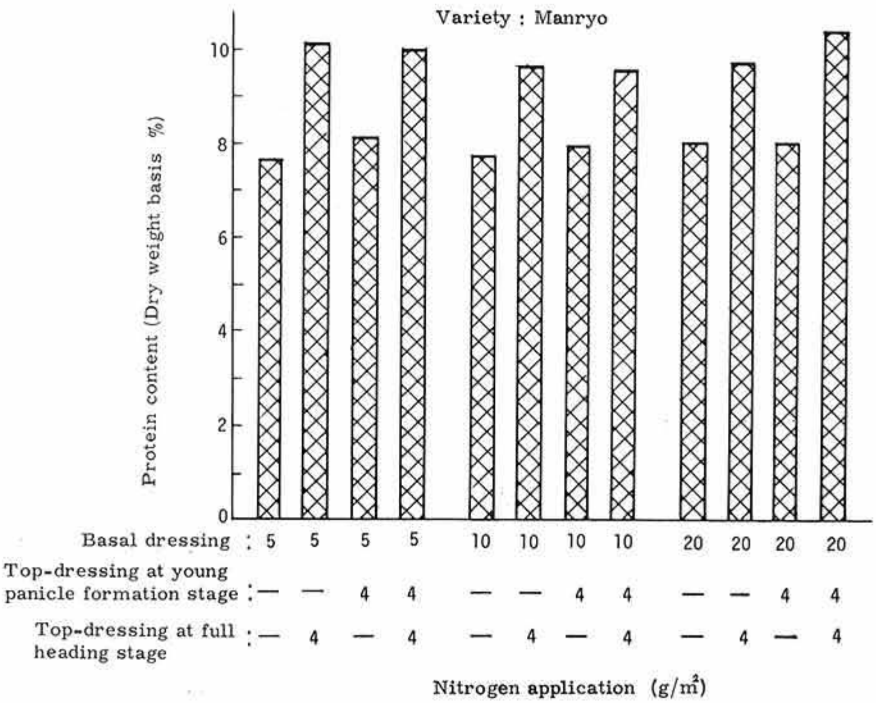

Fig. 2. Nitrogen application and protein content of brown rice

stage increased the protein content of the brown rice by about 30 per cent as compared with the application of basal dressing or basal dressing plus top-dressing at the panicle formation stage.

In regard to a given amount of top-dressing after the full heading stage, it was shown that the more the fertilizer applied, the more the protein content increased. When an identical amount of the dressing was applied in the period from the full heading stage to 30 days after it, it is more effective at the nearer stage to full heading.

From these results, it is suggested that the paddy brown rice produced by the Japanese farmer using top-dressing after the heading stage is also high in protein content.

Therefore, the influence of nitrogen application on the protein content of nonglutinous paddy brown rice in 1968 has been investigated on about 40 samples produced under high-yielding culture using the top-dressing after the heading stage at the farmers' field[7].

The average yield of the samples: 694 kg/10 a showed about 50 per cent high as compared with the same year's national average yield: 449 kg/10 a. The average protein value on dry weight basis was 9.34 per cent and eight samples showed over 10 per cent. As for the amount of nitrogen application, the basal dressing and the top-dressing at the young panicle formation stage did not influence the protein content. However, the amount of top-dressing after the heading stage showed positive correlation with the protein content (Fig. 3).

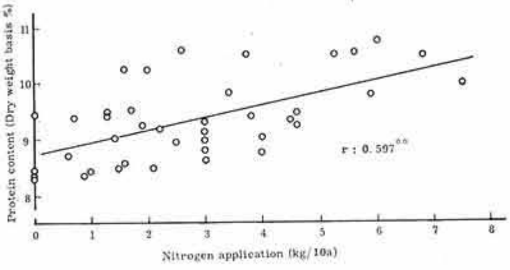

Fig. 3. Top-dressing after heading stage and protein content of paddy brown rice

Irrigation and protein content of brown rice

It has been stated that upland brown rice was higher in protein content than the paddy brown rice. However, it is not known whether the high protein content of upland brown rice is due to the cultural conditions or to the genetic factors.

If caused by cultural conditions, it is considered that irrigation affects mostly the protein content. If it is hereditary, upland rice can be used as a genetic stock for breeding many varieties of high protein rice.

Based upon such an assumption, an investigation has been carried out on the effect of irrigation to the protein content of brown rice of 20 upland rice varieties cultivated in both the upland field with intermittent irrigation for about 2.5 months from the young panicle formation stage and lowland field in 1968[9].

From the results in Fig. 4, it is recognized that all the samples obtained by upland culture manifest higher protein value than those by lowland culture. The average increasing rate of protein value by upland culture is about 40 per cent.

The same experiment has been also carried out on 20 paddy rice varieties and 14 crossed strains of paddy rice and upland rice.

The results showed the same tendency as upland rice. These results indicate that high protein value of upland rice is not hereditary but is due to the cultural condition or irrigation and the lower protein value of paddy rice among cereals is also attributed to irrigation.

In Japan, sometimes, paddy rice varieties are cultivated under upland conditions accompanied with irrigation by using sprinklers and other measures or with plastic film mulching because of its high yielding capacity and good quality as compared with upland rice varieties. The above-mentioned facts suggest that paddy rice cultivated by upland irrigation or mulching is also high in protein content.

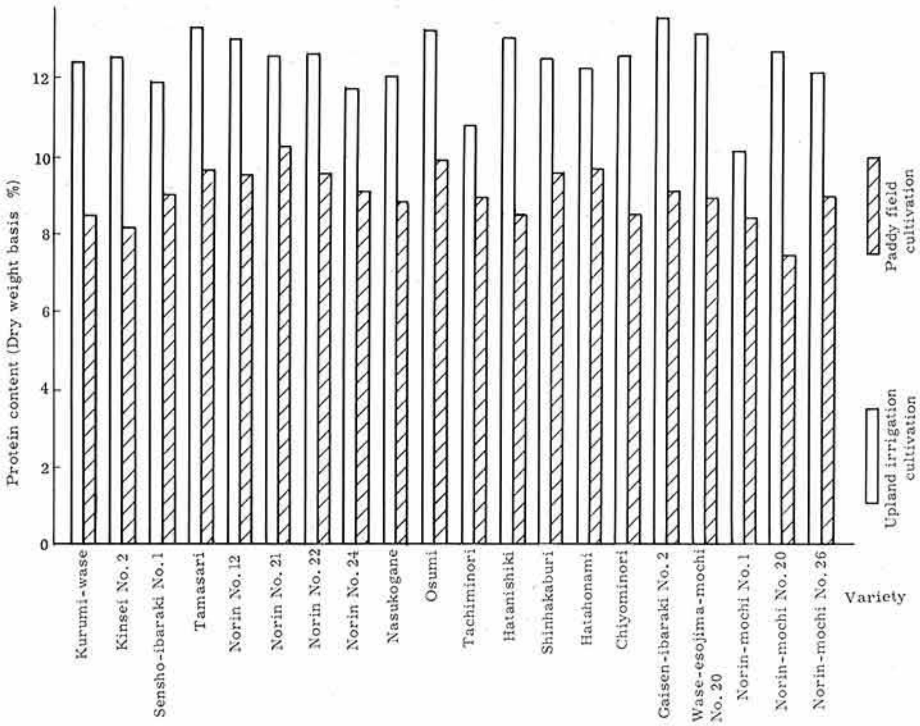

Fig. 4. Irrigation and protein content of upland brown rice

Early and late rice varieties and protein content of paddy brown rice

On the factors that influenced the protein content of rice, there is a relation between the protein content and early and late rice varieties. As an example, Kido et al.[1] studied the relation between the protein content of brown rice and heading date in the same lowland field (Fig. 5). The results indicate that the earlier the heading date, the higher the protein content.

With respect to the above-mentioned variation of protein content of 'Honen-wase' variety (Fig. 1), the following factors are suggested from this fact. The higher average values of each grade of the variety in 1968 are due to its early maturing. In the warm southwestern region of Japan, Honen-wase becomes more early maturing because of its thermosensitivity and is widely used for early season culture. Therefore, it is considered that four samples of Tokushima Prefecture in the warm southwestern region showed especially higher in Fig. 1.

Other factors influencing protein content of paddy brown rice

As the inspection grade of nonglutinuous paddy brown rice is lowered, the protein value increases as shown in Table 1. This tendency is regarded as being related to the item specified in the inspection standard. Tani et al.[11] recognized that the protein content of brown rice is negatively correlated with volume-weight, thousand-kernel-weight, specific gravity, size and hardness. The factors of those qualities are related to the maturity of rice.

On the relation between the grade of

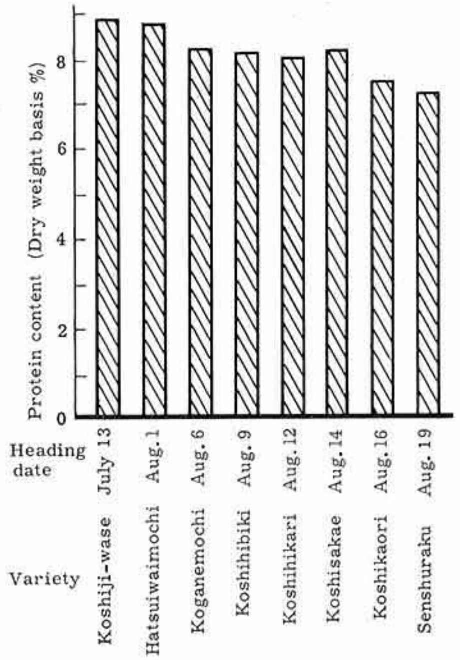

Fig. 5. Heading date and protein content of paddy brown rice

maturity and the protein content, it was shown that immatured rice contains more protein than fully ripened rice[4]. Accordingly, one of the reasons of the high protein content may be the increasing of immatured rice in lower grade.

In the case of brown rice of the japonica type, the thousand-kernel-weight is normally about 20 g. Therefore, the above-mentioned negative correlation between the thousand-kernel-weight and the protein content is the relation in normal variety of about 20 g per 1,000 kernels.

Twelve varieties, including small dwarf rice kernel, have been cultivated in the same field and the protein content of brown rice has been studied[10].

In these results, the negative correlation is also recognized between the thousand-kernel-weight and the protein content (Fig. 6). When the thousand-kernel-weight became about 25 g, however, the same correlation could nct be recognized in other experiments.

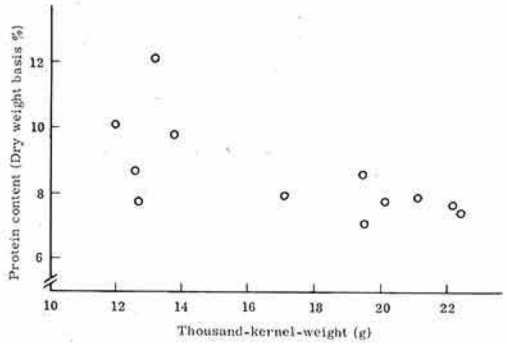

Fig. 6. Thousand-kernel-weight and protein content on paddy brown rice (12 varieties)

Japan is now being confronted with rice surplus and the improvement of quality, especially the taste, is becoming a great issue. On the other hand, the investigation on the nutrition of rice is important more than ever because rice is still the mainstay of national nutrition.

With respect to the protein content of Japanese rice and its variation, it is obvious that the cultural conditions influenced the protein content. Accordingly, the effort of rice protein fortification should be directed toward further studies by both cultural practice and genetic improvement.

References

1) Kido, M. & Yanatori, S.: Histochemical studies of protein accumulating process in rice grain. *Proc. Crop Sci. Japan*, **34**, 204–209 (1965). [In Japanese.]

2) Matsushima, S. & Wada, G.: Analysis of developmental factors determining yield and its application to yield prediction and culture improvement in lowland rice. XLVII. Studies on the mechanism of ripening (8). Relation of temperature to the rate of translocation of carbohydrates from leaves and culms to grains, and a method for increasing the percentage of ripened grains. *Proc. Crop Sci. Japan*, **27**, 6–8 (1958). [In Japanese.]

3) Ozaki, K. & Moriyama, M.: Studies on the nitrogen metabolism of rice plant. I. The protein content and quality of white rice as affected by latest nitrogen application after heading (3). *J. Sci. Soil Manu. Japan*,

23, 146–148 (1953). [In Japanese.]
4) Taira, H. & Taira, H.: Studies on amino acid contents in food crops (Part 6). Effect of the difference of transplanting and ripening stage on total and free amino acids in rice. *Eiyo To Shokuryo*, **16**, 449–452 (1964). [In Japanese.]
5) Taira, H., Matsushima, S. & Matsuzaki, A.: Analysis of yield-determining process and its application to yield-prediction and culture improvement of lowland rice. XCII. Possibility of increasing yield and nutritional value of rice protein by nitrogen dressing. *Proc. Crop Sci. Japan*, **39**, 33–40 (1970). [In Japanese.]
6) Taira, H.: Protein content of upland rice grains. *Eiyo To Shokuryo*, **23**, 94–97 (1970). [In Japanese.]
7) Taira, H.: Effect of fertilization on protein content in high yield rice. *Proc. Crop Sci. Japan*, **39**, 200–203 (1970). [In Japanese.]
8) Taira, H. & Taira, H.: Protein content of lowland nonglutinous brown rice. *Proc. Crop Sci. Japan*, **40**, 21–26 (1971). [In Japanese.]
9) Taira, H. & Taira, H.: Effect of irrigation on protein content of upland, lowland and their hybrid brown rice. *Proc. Crop. Sci. Japan*, **40** 294–298 (1971).
10) Taira, H., Hoshikawa, K. & Taira, H.: Protein content of brown rice of dwarf lowland variety, *Proc. Crop Sci. Japan*. (In press.)
11) Tani, T.: Index characters for grading the quality of rice, barley and wheat. *Shokuryo Kenkyusho Kenkyu Hokoku*, No. 9, 245–258 (1954). [In Japanese.]