Physicochemical Properties of Brown Rice from Oryza Species and Hybrids

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Twenty-nine samples of brown rice (caryopsis), representing 11 wild species and two interspecific hybrids of the genus Oryza, differed significantly in protein and amylose contents and starch gelatinization temperature. Their amino acid analyses were similar, except for four amino acids. Correlation coefficients with protein content were significant and negative for lysine and positive for phenylalanine and tyrosine. All properties examined were almost identical to those of cultivated rice.

Important physicochemical properties related to cooking and eating qualities of rice (*Oryza sativa* L.) are amylose content, protein content, and gelatinization temperature of the starch (Juliano *et al.*, 1965). Recent studies have shown that varieties of rice differ significantly in these properties (Cagampang *et al.*, 1966; Juliano, 1966; Juliano *et al.*, 1964b; Reyes *et al.*, 1965), but they have not been investigated in wild rices. Selected wild species of the genus Oryza and eight hybrids derived from *O. sativa* and its related weed forms, designated as *Oryza* x *rufipogon* or *Oryza* x *nivara* (Chang, 1964), were studied for these properties to determine the range of values and whether they differ from cultivated rice. Brown rice was chosen instead of milled rice because the composition of milled rice would be affected by the degree of milling, which is difficult to control. In view of the existence of a naturally occurring mutant gene in a cereal grain which can drastically alter its amino acid composition (Mertz and Nelson, 1966), amino acid analyses were also undertaken on the samples.

MATERIALS AND METHODS

All of the grain samples were produced by the Varietal Improvement Department of the International Rice Research Institute (Philippines) during the 1964–65 dry season. They were dehulled in a McGill sheller and the brown rice was ground in a Wiley intermediate mill with a 40-mesh sieve. Total nitrogen was determined by the Kjeldahl method (Association of Official Agricultural Chemists, 1960) and converted to crude protein by multiplying by the factor 5.95. Amylose content was measured by the method of Williams *et al.* (1958). Gelatinization temperature was measured photometrically as the temperature of initial increase in transmittance at 525 mμ of a 0.5% milled rice dispersion in water. A Bausch and Lomb Spectronic 20 was modified such that the $^3/_4$-inch tube adapter may be electrically heated while the solution in the tube is being stirred continuously with a Teflon-coated stirring bar above a magnetic stirrer beneath the colorimeter.

Amino acid analyses were performed in duplicate hydrolyzates of these samples with a Beckman Model 120 amino acid analyzer (Cagampang *et al.*, 1966; Moore *et al.*, 1958).

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RESULTS AND DISCUSSION

There were significant differences in protein content, amylose content, and final gelatinization temperature among the 29 brown rice samples from wild rice (Table I). However, more samples differed in protein content than in amylose content or gelatinization temperature. Differences in amylose content of samples of the same species or hybrid were generally not significant. However, the starch of one of the *Oryza* x *rufipogon* samples was waxy. The final gelatinization temperature of samples from *O. glaberrima* and *O. breviligulata* were identical, but this property of the *O. nivara*, *O. rufipogon*, *Oryza* x *nivara*, and *Oryza* x *rufipogon* samples differed significantly. A greater proportion of these 29 samples had gelatinization temperatures above 73° C. than has been observed with cultivated rice (Juliano *et al.*, 1964a, 1964b; Reyes *et al.*, 1965; Williams *et al.*, 1958). In a study of variability of these properties in cultivated rice, more samples also showed significant differences in protein level than in amylose content and gelatinization temperature (Juliano *et al.*, 1964a). Similar values for protein, amylose, and gelatinization temperature have been reported for 11 strains of *O. glaberrima* and eight lines of *O. breviligulata* (International Rice Research Institute, 1966). No simple correlation was observed between these three properties for the 29 samples. These properties also are not linearly related in cultivated rice (Juliano *et al.*, 1965).

The range of physicochemical properties of the wild rices is within that reported for cultivated rice (Juliano, 1966; Juliano *et al.*, 1964a) (Table I). The variability was greater for protein content and final gelatinization temperature than for amylose content. On a wet weight basis, the intermediate amylose content of the nonwaxy wild rice samples had a range of 17.8 to 23.9%, which was narrower than the 9.0 to 30.0% recorded for cultivated nonwaxy rice, despite the marked differences in grain morphology of the former (Chang, 1964). This indicates a similarity in the cooking characteristics of these samples, since amylose content is the major factor related to the tenderness, cohesiveness, and gloss of cooked rice (Juliano *et al.*, 1965). Because of their protein and gelatinization temperature differences, variation in cooking time would be expected between these species. High protein content and high gelatinization temperature are positively correlated with cooking time determined at a constant ratio of rice to water (Juliano *et al.*, 1965). There was no association between amylose content of the species and their

Table I. Some Physicochemical Properties of Brown Rice from Oryza Species and Hybrids

Species/Hybrids	Source	Protein, %[a]	Amylose, %[a]	Final Gelatinization Temperature, °C.
O. alta Swallen	French Sudan	10.6	23.9	69
O. australiensis Domin	India	11.3	22.1	73
O. breviligulata A. Chev. *et* Roehr.	Africa	10.4	20.4	74
O. breviligulata A. Chev. *et* Roehr.	Africa	12.0	17.8	74.5
O. eichingeri A. Peter	Uganda	11.0	20.1	71.5
O. glaberrima Steud.	Africa	9.52	19.4	72.5
O. glaberrima Steud.	Africa	10.6	19.4	72
O. glaberrima Steud.	Africa	8.90	19.3	72.5
O. glaberrima Steud.	Africa	11.7	18.9	72
O. grandiglumis (Doell) Prod.	Taiwan	7.42	23.5	61
O. latifolia Desv.	U.S.A.	7.02	22.9	75
O. nivara Sharma *et* Shastry	India	11.5	18.4	73
O. nivara Sharma *et* Shastry	Australia	8.95	20.2	74.5
O. nivara Sharma *et* Shastry	India	9.80	20.8	77.5
O. officinalis Wall. *ex* Watt	Philippines	9.70	19.5	62
O. rufipogon Griff.	India	8.29	21.8	63
	India	9.20	20.8	69.5
	Thailand	13.8	19.0	76
	Thailand	11.4	19.8	74
	China	13.3	19.3	74.5
O. punctata Kotschy *ex* Steud.	Ghana	11.1	18.8	75.5
Oryza x *nivara* (Chang, 1964)	India	8.41	20.7	60
Oryza x *nivara* (Chang, 1964)	India	14.0	18.4	77
Oryza x *rufipogon* (Chang, 1964)	India	12.6	19.4	75
Oryza x *rufipogon* (Chang, 1964)	India	12.0	19.9	73.5
Oryza x *rufipogon* (Chang, 1964)	India	11.3	19.0	75
Oryza x *rufipogon* (Chang, 1964)	India	11.2	waxy	71
Oryza x *rufipogon* (Chang, 1964)	Cambodia	10.5	19.3	75
Oryza x *rufipogon* (Chang, 1964)	Burma	10.8	19.6	78
Standard error		0.05[b]	0.63[b]	0.65[b]
Least significant difference (0.05)		0.15	1.9	1.9
O. breviligulata A. Chev. *et* Roehr. (n = 8) (International Rice Research Institute, 1966)		11.7–15.2	22.4–26.8	Intermediate[c]
O. glaberrima Steud. (n = 11) (International Rice Research Institute, 1966)		8.34–12.1	21.1–25.7	Intermediate[c]
O. sativa L. (Juliano, 1966; Juliano *et al.*, 1964a)		4.8–13.7	9.0–30.0	55–76.5

[a] Wet weight basis. Mean moisture content was 12%.
[b] Highly significant.
[c] Estimated by the dispersibility of milled rice in alkali solution.

geographical distribution or chromosome number ($2n$ = 24 or $2n$ = 48).

The amino acid composition of the 17 samples was essentially constant, except for the arginine, lysine, phenylalanine, and tyrosine values (Table II). When correlations were computed between protein level and these acids, lysine showed a significant negative correlation coefficient, whereas phenylalanine and tyrosine had significant positive coefficients. Arginine and protein contents were not correlated. Arginine values ranged from 5.42% for *O. eichingeri* with 11.0% protein to 8.92% for *O. breviligulata* with 12.0% protein. The sample with the highest lysine content (4.48%) was from *O. latifolia* with 7.02% protein; *O. officinalis* (9.70% protein) had the lowest lysine content (3.12%). Phenylalanine levels ranged between 4.82% for *O. rufipogon* with 8.29% protein, to 6.22% for *O. punctata* (11.1% protein). The range of tyrosine values was from 2.48% for *O. latifolia* (7.02% protein) to 4.72% for *O. eichingeri* (11.0% protein). The variable cystine recovery has previously been noted for rice (Cagampang *et al.*, 1966), and presumably is due to a high carbohydrate content in the samples.

Comparison of the aminograms with that of brown rice from *O. sativa* revealed practically the same range of values for all acids (Table II). Presumably, very little difference in amino acid composition exists among the *Oryza* species and hybrids studied. The data imply that these taxa have similar ratios of protein fractions to those of cultivated rice and that their main protein fraction is also glutelin (Cagampang *et al.*, 1966). The correlation coefficients between protein and lysine of protein reported for milled rice are −0.64 for 16 varieties (Juliano *et al.*, 1964b) and −0.664 for two sets of samples of 8 varieties (Cagampang *et al.*, 1966). In both studies, tyrosine and protein contents also were highly significantly correlated in the positive direction but there was no indication of the correlation between phenylalanine and protein content which was noted in the wild rices.

Table II. Amino Acid Composition of 17 Samples of Brown Rice from Oryza Species and Hybrids, Grams per 16.8 Grams N

Acid	Range[a]	Mean	Standard Error	$r_{protein}$	*O. sativa* L. Juliano *et al.* (1964b)
Alanine	5.79–6.74	6.36	0.32		5.36–6.70
Arginine	5.42–8.92	7.46	0.44[b]	+0.378	6.49–8.98
Aspartic acid	9.38–11.6	10.1	1.91		8.90–13.24
Cystine	0–1.18	0.25	0.94		0.96–1.27
Glutamic acid	20.9–24.0	22.4	0.74		18.21–21.77
Glycine	4.52–5.40	4.99	1.40		4.35–5.80
Histidine	2.28–2.87	2.58	0.19		2.11–2.74
Isoleucine	3.94–4.65	4.39	0.22		3.60–4.33
Leucine	7.76–9.78	8.70	0.42		6.89–10.05
Lysine	3.12–4.48	3.82	0.20[c]	−0.617[b]	3.32–4.31
Methionine	1.42–2.78	2.15	0.31		2.03–2.99
Phenylalanine	4.82–6.22	5.52	0.22[c]	+0.516[c]	4.36–6.28
Proline	4.46–5.28	4.73	0.24		4.28–5.44
Serine	4.95–6.14	5.49	0.26		4.24–6.13
Threonine	3.68–4.54	3.92	0.24		3.58–4.77
Tyrosine	2.48–4.72	3.63	0.35[c]	+0.612[b]	2.40–3.79
Valine	5.37–6.82	6.04	0.41		5.06–6.18
Ammonia	2.10–3.04	2.55	0.32		1.91–2.77
Total	101.76–108.93	105.08			90.25–113.69
Protein content, %	7.42–12.0				7.32–13.59

[a] Recalculated to 95% nitrogen recovery.
[b] Highly significant.
[c] Significant.

The results indicated that the wild species of Oryza and some of their hybrids with *O. sativa* offer no advantage, in terms of physicochemical properties of the caryopsis, to existing cultivated rices in a breeding program since their properties fall within those observed for the latter. Interspecific hybrids are also subject to pollen and seed sterility (Chang, 1964).

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