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Cooking and eating characteristics of some newly identified inter sub-specific (*indica/japonica*) rice hybrids

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ABSTRACT: Experiments were conducted to determine the cooking and eating characteristics of 17 newly identified inter sub-specific (*indica/japonica*) rice hybrids. Superior cooking performance over DRRH-1 was observed in 14 hybrids for length of cooked rice elongation, all the hybrids for kernel elongation ratio, 14 hybrids for elongation index, 11 hybrids for water uptake, and 6 hybrids for volume expansion. Among the hybrids, 2 hybrids showed low amylose content (18.8%) and 7 hybrids showed high amylose content (26–30%), while the remaining 8 hybrids showed intermediate amylose content (20–25%) which was considered the best from the cooking point of view. The amylose content of the hybrids depended on the amylose content of parents. Maximum hybrids showed intermediate gelatinization temperature (GT) and intermediate amylose content which is preferred by the consumers. High amylose grains had low GT, intermediate amylose grains had intermediate GT while low and very low amylose types had high GT.

KEYWORDS: quality characters, gelatinization temperature, amylose content

INTRODUCTION

Rice is consumed mainly as whole grains, and quality considerations are much more important than for any other food crop. Rice grain quality preference varies from country to country and region to region. For instance, in *japonica* rice eating countries, low amylose, short grain rice is preferred since after cooking it is soft and sticky. However, in *indica* rice consuming countries, long grain rice with intermediate amylose and intermediate gelatinization temperature is preferred since it is soft and fluffy after cooking.

The cooking and eating quality assumes much greater importance in the case of inter sub-specific hybrid rice, as its consumable product in the F_2 seed generation would tend to show segregation if the two parental lines differ in quality traits. Although *indica/japonica* hybrids are known to show a very high level of heterosis for grain yield, they suffer from serious problems of grain quality mainly because of the high degree of grain quality diversity of the parental lines. To overcome the problems of grain quality, the *indica/japonica* derivative lines with identical grain quality are used for development of hybrids in the present study. With the consumers becoming more concerned for the quality, emphasis on quality breeding has assumed a greater significance in the recent years. Keeping the foregoing problems in view, the present investigation was undertaken to analyse and evaluate cooking and eating characteristics of some newly identified inter sub-specific (*indica/japonica*) rice hybrids.

MATERIALS AND METHODS

The field experiment was carried out at the farm of Genetics Division and the laboratory experiment was carried out at the Agronomy Division of the Indian Agricultural Research Institute (IARI), New Delhi, from November 2003 to March 2004. For this purpose, 17 newly developed hybrids involving *indica* CMS lines and 11 *indica/japonica* derived restorer lines, showing standard heterosis of 14.47–105% over DRRH-1 with yield level of 9.09–16.25 t/ha[1] were studied for eating and cooking quality compared with two popularly cultivated hybrids, DRRH-1 and Pusa RH-10.

Length (L_0) and breadth (B_0) of milled rice were measured under a photo enlarger with a magnification of 3× on graph paper. For cooking, individual milled kernels of the hybrid sample along with checks were taken separately in long labelled test tubes and presoaked in 5 ml of tap water for 30 min. After that, the tubes were placed in a water bath maintained at boiling temperature for 8–9 min. After cooking, the tubes were taken out and cooled under running water for 2 min. Cooked kernels were taken out of the tubes and excess water was removed with blotting paper. Cooked rice length (L_1) and breadth (B_1) were measured as described before. For each of L_0, B_0, L_1, and B_1, the mean of 5 measurements was taken. The ratio of cooked kernel length to breadth (L_1/B_1), the elongation ratio (L_1/L_0), and the elongation index ($(L_1/B_1)/(L_0/B_0)$) were then calculated. Water absorption was measured as the volume of water needed to cook 1 g of rice in a specified time at a particular temperature. Samples of 1 g milled rice kernels were used for the study. The weight of each sample was recorded before and after cooking. Water absorption was calculated as a percentage. After recording the weight of uncooked samples, their volume was determined by displacement of water method using a finely graduated narrow cylinder of 5 ml capacity. After cooking, the final volume of the sample was recorded and the volume expansion was calculated as a percentage. Alkali spreading value was determined according to the procedure suggested by Zaman[2] and mean value calculated on a 7 point numerical scale[3,4]. Amylose content was determined by a rapid calorimetric procedure[5].

RESULTS AND DISCUSSION

During cooking, rice grains absorb water and increase in volume through increase in length or breadth alone or both length and breadth. Breadthwise splitting is not desirable whereas lengthwise splitting (grain elongation) on cooking without increase in girth is considered as a desirable trait in high quality premium rice such as basmati, which has an elongation of almost 100% on cooking[6,7]. Some rice shows extreme elongation on cooking, particularly in presoaked grains, whereas in most varieties the expansion is more breadthwise[8,9]. In the present study, the highest length of cooked kernel was recorded for H-10 (12.73 mm) and least for H-14 (8.84 mm) (Table 1). Except for H-14, all the hybrids showed a larger kernel length than the check Jaya (9.33 mm), and 14 hybrids showed a larger kernel length than the check DRRH-1 (9.80 mm). Hybrids H-6, H-7, H-8, H-9, H-10, and H-11 had a larger elongation than that of the basmati check hybrid PRH-10. The kernel length after cooking of hybrids ranged from 8.84 to 12.73 mm. Shobha Rani[10] reported kernel length after cooking of 9 released hybrids of India ranging from 10.2 to 12.4 mm.

The largest breadth of cooked kernel was for H-14 (3.70 mm) and lowest for H-2 (2.35 mm). All the hybrids showed a lower breadth than the check Jaya (3.78 mm). Hybrids H-13, H-14, H-15, and H-16 had a larger B_1 than the check DRRH-1 (2.90 mm) while seven hybrids had a larger B_1 than the check PRH-10 (2.84 mm) (Table 1).

The L_1/B_1 of the cooked kernel was highest for H-6 (5.07) and lowest for H-14 (2.39). Sandeep[11] found kernel length/breadth ratio after cooking of 20 new plant type genotypes which was ranged from 2.04 to 3.95. A low value indicates poor cooking quality. All the hybrids showed higher L_1/B_1 than the check DRRH-1 (3.38) while 9 hybrids showed ratios higher than the check PRH-10 (4.01).

Elongation ratio (L_1/L_0) is a measure of kernel elongation upon cooking resulting from swelling of starch granules by uptake of water[12]. Elongation ratio is a better index of quality than elongation index and proportionate change[13]. Significant association of L/B with kernel elongation has been reported[14]. In the present study, the hybrids had moderate to high degree of kernel elongation ratio. The highest elongation ratio of 1.82 was recorded for H-11 and lowest ratio of 1.51 was recorded for H-4 (Table 1). All the hybrids in our study showed a higher elongation ratio than the check DRRH-1 (1.44). Similar or higher elongation ratios than the checks Jaya (1.65) and PRH-10 (1.70) were recorded for 13 and 10 hybrids, respectively. Shobha Rani[10] found that the kernel elongation ratio of nine released hybrids in India ranged from 1.7 to 2.0.

Kumar[15] concluded that elongation index was a more reliable measure of kernel elongation. In the present study, 12 hybrids gave higher elongation index than Jaya (1.03) and PRH-10 (1.06) (Table 1). As many as 14 hybrids showed higher elongation index than the check DRRH-1 (0.94). Kernel elongation index of the hybrids ranged from 0.80 to 1.67 in the present study. Sandeep[11] reported a lower range of the kernel elongation index (1.32–1.72 in 20 new plant type genotypes). Consumers in north and north-west India prefer breadthwise swelling of the kernel after cooking, but the consumers of other regions mostly prefer lengthwise swelling[16].

Water uptake is considered an important economic attribute of rice as it gives an indirect measure of volume increase on cooking. Water uptake shows a positive and significant influence on grain elongation, while volume expansion did not influence grain elongation[17]. Earlier studies of rice in general[18] suggested the extent of variation for this character to range between 194 to 250%. Hogan and Planck[19] observed that short and medium grain varieties of the USA have higher water absorption than

Table 1 Cooking properties of inter sub-specific (*indica/japonica*) hybrids.

Hybrids/Checks	L_0 (mm)	B_0 (mm)	L_1 (mm)	B_1 (mm)	L_1/B_1	L_1/L_0	$\frac{L_1/B_1}{L_0/B_0}$	WU (%)	VE (%)
H-1 (P6A/SPS-00-34)	6.77	2.00	10.78	2.62	4.12	1.60	1.22	188	259
H-2 (P6A/PP-01-100)	6.74	1.87	10.43	2.35	4.44	1.55	1.23	201	300
H-3 (P6A/ET-NPT-00-22)	6.80	2.03	10.34	2.98	3.47	1.52	1.04	209	244
H-4 (P6A/SPS-01-51)	7.11	1.88	10.78	2.86	3.77	1.51	1.00	187	304
H-5 (P6A/SPS-00-89)	6.02	2.01	10.23	2.57	3.99	1.70	1.34	117	193
H-6 (P5A/SPS-00-80)	6.77	2.24	12.23	2.41	5.07	1.81	1.67	201	250
H-7 (P5A/SPS-01-51)	6.86	1.70	11.66	2.72	4.28	1.70	1.06	237	346
H-8 (P3A/SPS-00-89)	6.43	1.93	11.67	2.62	4.47	1.81	1.34	192	250
H-9 (P3A/SPS-00-61)	7.30	1.84	12.06	2.85	4.23	1.65	1.06	248	207
H-10 (P3A/ET-NPT-00-26)	7.10	1.84	12.73	2.61	4.88	1.79	1.26	247	250
H-11 (IR25A/SPS-01-176)	6.50	1.87	11.83	2.67	4.43	1.82	1.27	232	367
H-12 (PMS2A/SPS-01-8)	6.61	1.67	10.89	2.59	4.21	1.65	1.07	213	279
H-13 (P6A/SPS-00-100)	5.57	1.75	9.66	3.13	3.08	1.74	0.97	216	300
H-14 (P6A/SPS-00-61)	5.34	1.80	8.84	3.70	2.39	1.65	0.81	205	279
H-15 (P5A/PP-01-100)	5.84	1.67	10.03	3.20	3.14	1.72	0.89	181	338
H-16 (P5A/SPS-00-61)	6.50	1.67	11.07	3.57	3.10	1.70	0.80	203	238
H-17 (P5A/SPS-00-89)	5.70	1.78	9.76	2.63	3.70	1.71	1.16	176	250
Mean	6.46	1.88	10.88	2.83	3.83	1.67	1.13	203	274
Jaya	5.66	2.37	9.33	3.78	2.47	1.65	1.03	192	261
DRRH-1	6.80	1.90	9.80	2.90	3.38	1.44	0.94	197	296
PRH-10	6.72	1.77	11.40	2.84	4.01	1.70	1.06	192	275
SEd ±	0.10	0.05	0.22	0.10	0.12	0.05	0.04	1.16	6.02
CV (%)	1.56	2.45	2.01	3.37	3.15	3.00	3.38	0.58	2.20
CD (5%)	0.21	0.10	0.46	0.21	0.25	0.10	0.08	2.42	3.35

WU = water uptake; VE = volume expansion
CV = coefficient of variation; CD = critical difference; SEd = standard error of difference

long grain types. The present study exclusively on hybrids developed from *indica/japonica* derived lines showed a similar trend of variation and the range of variability was from 117% to 248% (Table 1). The highest water uptake was recorded by H-9 and lowest by H-5. Higher water uptake than the checks Jaya (192%) and DRRH-1 (197%) were observed in 11 of the hybrids. Working with a larger number scented basmati varieties, Sood and Siddiq[20] have reported a wider range (74–439%) of variation for this character. The mean water absorption was 203% of the hybrids under the present study indicating that the majority of the hybrids had moderate to low water absorption capacity. Zaman[2] reported that the good cooking rice varieties have water absorption ranging between 175 and 275%, whereas majority of those showing a pasty appearance have values of 300–570%. He concluded that it would be desirable to select a variety or hybrid with moderate water absorption.

Volume expansion of kernels on cooking is considered another important measure of consumer preference. Large volume expansion is a matter of great satisfaction to an average rice consumer irrespective of whether the increased volume is due to lengthwise or breadthwise expansion. Volume expansion is mostly determined by water uptake, but is also influenced by kernel texture[2]. Varieties showing volume expansion of 500% and above are considered desirable[21]. In the present study, volume expansion ranged from 193% in H-5 to 367% in H-11 (Table 1), and 6 of the hybrids showed a higher value than that of the check DRRH-1 (296%). The majority of the hybrids included in the study were of low to medium volume expansion. Zaman[2] reported that the varieties which tend to show high volume expansion are sticky and give a pasty appearance on cooking, and that all the pasty cooking types have been found to be associated with higher water absorption. However, he concluded that pasty cooking is more closely related to high water absorption than to volume expansion. Therefore, hybrids with low water absorption and high volume expansion are more desirable.

The gelatinization temperature (GT) is considered to be yet another major index of cooking quality of rice. The time required for cooking is determined by the gelatinization temperature. It is the range of temperature within which starch granules begin to swell irreversibly in hot water. The GT of rice varieties ranges from 55 °C to 79 °C and varieties are grouped into low (55–69 °C), intermediate (70–74 °C) and high (74–79 °C) GTs[12,22]. High GT rice becomes excessively soft when overcooked, elongates less and requires more water and time for cooking than those with low or intermediate GT. Rice varieties that have low GT start to swell more at low temperature during cooking than rice varieties with intermediate or high GTs[23]. GT of rice hybrids is intermediate between the parents or similar to the parents, depending on whether or not parents differ in this trait. In the present study, the alkali spreading score ranged between 2.50 and 7.00, with a mean of 4.46 (Table 2). The hybrids with low GT were obtained when both the parental lines had low GT, while those with intermediate GT were derived when intermediate/intermediate and intermediate/high type parents were used. Hybrids H-2, H-7, H-8, H-9, H-13, H-14, H-15, and H-17 exhibited intermediate values for alkali digestion (ASC 3.83–5.24) and hence intermediate GT (Table 2). Hybrids H-1, H-10, H-12, and H-16 showed high alkali digestion (ASC 5.74–7.00) and had low GT. Among the checks, both DRRH-1 and PRH-10 showed intermediate alkali digestion (ASC 5.00 and 4.59, respectively) and hence intermediate GT, but Jaya had a high alkali digestion value (ASC 7.00) as it was of a low GT type. As both the parents used in this study were of different sources (*indica* and *indica/japonica* derivatives), segregation for GT within the same hybrids as well as among the hybrids were observed. Kumar et al[24] proposed that segregation for GT as high and low may not affect acceptability of hybrid rice, since no difference was observed in cooking and eating characters of the bulk grain. Hence segregation in the hybrids may not pose any problem on cooking.

Amylose content is considered to be the most important parameter of cooking quality as it determines the indices such as water absorption, volume expansion, stickiness, gloss, colour, and firmness when cooked[12,24,25]. Rice varieties are grouped on the basis of their amylose content[12,26] into waxy (0–2%), very low (3–9%), low (10–19%), intermediate (20–25%) and high (>25%). Screening of world germplasm collection at IRRI and other Rice Research Centres has revealed the amylose content in rice to range from 0% to 35%. Study of a representative collection of population and highly preferred varieties for amylose content has suggested the range of amylose content to vary between 20.90 and 27.50[27]. Amylose is almost absent from the waxy (glutinous) rices. Such rices do not expand in volume, are glossy and sticky, and remain firm when cooked[12]. These types of rice are the staple food of people in Northern and North-eastern Thailand and Laos. Varieties grown in Philippines, Malaysia, and Indonesia have intermediate amylose content. Intermediate amylose rices are moist and tender upon cooking. High amylose rices are dry, less tender and hard after cooking, and show volume expansion and a high degree of flakiness. Juliano[28], after an extensive study of rice varieties from different parts of the world, concluded that all *japonica* varieties of temperate regions have low amylose and they are preferred in Japan and South Korea for their stickiness, tenderness, gloss, and taste. Rice varieties of Vietnam, Thailand, India, Bangladesh, Philippines, Malaysia, and Indonesia, on the other hand, have high to intermediate amylose[6,29]. In India, although the majority of the varieties have high amylose, the most preferred varieties have intermediate amylose. Preference for intermediate amylose types is the case for the majority of the South and Southeast Asian countries as well.

The present study showed significant differences of amylose content (19–30%, Table 2) among the hybrids due to diverse amylose content parental lines. The amylose percent of hybrids depend on that of the parents used in the crosses. The pollen parents used in this experiment had low, intermediate and high amylose content and ranged from 6.84% in H-6 to 29.32 in H-16. By crossing among the parents, low, intermediate and high amylose content hybrids were developed. Increase of low amylose content hybrids like H-6 and H-11, the female parents of both the hybrids had intermediate amylose content (20.22 and 21.40%, respectively) and pollen parents had very low amylose content (6.84 and 7.84%, respectively). The hybrids low amylose content was a consequence of the very low amylose content of pollen parents. Most of the high amylose content pollen parents produced high amylose content hybrids (H-1, H-2, H-5, H-15, and H-17) except H-8 and H-12 which had intermediate amylose content pollen parents.

Among the hybrids, H-3, H-4, H-7, H-9, H-10, H-13, H-14, and H-16 showed intermediate amylose (20.22 to 24.57%) which is considered the best from the cooking point of view (Table 2). Among the 5 female parents, 4 female parents (P-6A, P-5A, PMS-2a, and IR-25A) showed intermediate amylose content and 1 (P-3A) high amylose content. In the case of pollen parents, 5 pollen parents (PP-3, PP-6, PP-7, PP-8 and PP-9) showed very low amylose content, 3 pollen parents (PP-4, PP-10 and PP-11) showed intermediate amylose content and the remaining 3 pollen parents (PP-1, PP-2 and PP-5) showed high amylose content. Among the checks, DRRH-1 and

Table 2 Chemical properties of inter sub-specific (*indica/japonica*) rice hybrids and amylose content in hybrids and their parent.

Hybrids/Checks	Alkali spreading score	Amylose %		
		Female Parents (FP) (B Lines)	Hybrids	Pollen Parents (PP)
H-1	5.99 ± 0.33	22.33 (FP-1)	29.38	26.22 (PP-1)
H-2	5.24 ± 0.41	22.33 (FP-1)	26.38	25.74 (PP-2)
H-3	2.84 ± 0.17	22.33 (FP-1)	20.57	7.24 (PP-3)
H-4	3.17 ± 0.50	22.33 (FP-1)	22.72	21.54 (PP-4)
H-5	2.50 ± 0.50	22.33 (FP-1)	27.51	25.93 (PP-5)
H-6	2.75 ± 0.08	20.22 (FP-2)	18.80	6.84 (PP-6)
H-7	4.25 ± 0.08	20.22 (FP-2)	22.58	19.23 (PP-4)
H-8	4.25 ± 0.08	27.59 (FP-3)	28.90	25.93 (PP-5)
H-9	4.75 ± 0.58	27.59 (FP-3)	22.80	7.40 (PP-7)
H-10	5.74 ± 0.58	27.59 (FP-3)	21.67	7.94 (PP-8)
H-11	2.84 ± 0.67	21.40 (FP-4)	18.77	7.84 (PP-9)
H-12	7.00 ± 0.00	23.34 (FP-5)	26.08	21.23 (PP-10)
H-13	3.83 ± 0.00	22.33 (FP-1)	22.58	20.32 (PP-11)
H-14	5.24 ± 0.08	22.33 (FP-1)	20.22	7.18 (PP-7)
H-15	4.33 ± 0.00	20.22 (FP-2)	27.45	25.21 (PP-2)
H-16	6.92 ± 0.09	20.22 (FP-2)	24.57	29.32 (PP-7)
H-17	4.17 ± 0.00	20.33 (FP-2)	29.63	25.93 (PP-5)
Mean	4.46	22.65	24.15	18.30
Jaya	7.00 ± 0.00	-	27.56	-
DRRH-1	5.00 ± 0.00	-	20.15	-
PRH-10	4.59 ± 0.09	-	24.55	-
Mean	5.53	-	24.09	-

GT= Gelatinization temperature, FP-1 = P 6A, FP-2 = P 5A, FP-3 = P 3A, FP-4 = IR 25A, FP-5 = PMS 2A.

PRH-10 also showed intermediate amylose content (20.2–24.6%) while Jaya had high amylose content (27.6%). Shobha Rani[10] estimated amylose content of 9 released hybrids in India and reported their range as 20.9–27.8%. In the present study, a few hybrids having diverse parents for amylose content showed segregation of grains for amylose content but after cooking in bulk no distinction could be observed for colour, texture, or shape. Similar observations were also reported by Khush et al[30].

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