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Research Article

Evaluation of rice varieties for physicochemical characters related to puffing quality

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Abstract
Puffed rice is one of the convenient rice based popular products in India. Variability among varieties for important physicochemical characters of the grain like amylose, protein, gelatinization temperature, grain length breadth ratio, bulk density, expansion volume and expansion ratio affecting the puffing qualities were reported. The varieties with more length breadth ratio and high amylose will enhance the expansion ratio (ER) of puffed rice, whereas protein content shows a negative relationship with ER. Eight popular rice varieties *viz*., ADT 42, ASD 20, Bhavani, CO 43, INTAN, IR 64, MDU 6 and Paiyur 1 were analyzed for the physicochemical characters related to puffing quality. Based on the kernel length/breadth ratio, ADT 42, ASD 20, Bhavani, INTAN, IR 64, MDU 6 and Paiyur 1 were classified as long slender and CO 43 was identified as medium slender. The varieties Bhavani, INTAN, IR 64 and Paiyur 1 were classified as high amylose types (more than 25%) and ADT 42, ASD 20, CO 43 and MDU 6 as intermediate amylose types (20-20%) with regard to amylose. Bhavani, CO 43, Paiyur 1, INTAN and IR 64 had low protein content, while ADT 42 had highest protein content. The puffing yield ranged from 62.36% to 78.54% and higher values were recorded in Bhavani, INTAN, IR 64 and Paiyur 1. The association studies of physicochemical characters related to puffing quality revealed that puffing yield registered significantly positive correlation with starch content, amylose content, expansion volume and expansion ratio and negative correlation with protein and ash content. Amylose had negative association with protein and ash content. Out of eight varieties evaluated, Bhavani, IR 64, INTAN and Paiyur 1 had more length breadth ratio, high starch, high amylose and low protein which in turn resulted in high puffing yield. Hence, these varieties are highly suitable for making puffed rice.

Keywords
Puffed rice, Amylose, Protein, Grain length breadth ratio, puffing yield.

INTRODUCTION

Among the food crops grown throughout the world, rice (*Oryza sativa* L.) is the most extensively cultivated crop feeding half of the world's population. Even though it is practically grown in most of the continents under various climates, about 90% of world's rice production and consumption is in South and South East Asia. It provides about one third of the protein in addition to 60-70% of the total calories required by a human for a day. Out of the total grain composition, carbohydrate constitutes 72-75% in the form of starch, and protein contributes 7%. Rice is not only consumed as dietary staple food but also processed into various kinds of snacks and consumed (Kamaraddi and Prakash, 2015). Due to the changing lifestyles and food habits, processed foods are highly preferred (Basavaraj *et al*. 2015).

Raw rice is processed into products like puffed rice, popped rice, flaked rice, rice noodles, cereal bars, rice crackers etc., Puffed rice is one of the popular snacks in South East Asia. It is a whole grain puffed product, during the processing became light, airy and crispy (Villareal and Juliano, 1987). It is considered not only as a conventional and nutritious one but also as a prebiotic food that is cheap and easily available to people. In addition, puffed rice also contains some beneficial nutrients like dietary fibre, vitamins, minerals and phytochemicals that reduces the risk of degenerative diseases (Joshi *et al*. 2014). It is reported that many physicochemical characters affect the puffing quality significantly, which includes amylose, protein, gelatinization temperature, length-breadth ratio, bulk density etc., which differs from variety to variety. Expansion is highly related to amylose content, maximum expansion is achieved at 27% amylose or 13 % insoluble amylose. Protein content is negatively related to expansion, since protein and starch content are inversely proportional to each other. (Chinnaswamy and Bhattacharya, 1983). The kernel length/breadth ratio is positively correlated to the expansion ratio. Kernel length, breadth, thousand grain weight and bulk density are highly related to processing quality in rice. Keeping this in view, the present study was undertaken to analyze the physicochemical characters of grain in eight rice varieties that is related to puffing quality.

MATERIALS AND METHODS

Based on the previous studies and literatures for puffing quality eight rice varieties *viz*., ASD 20, ADT 42, Bhavani, CO 43, INTAN, IR 64, MDU 6 and Paiyur 1 were selected for the study. The salient features of these varieties are given in **Table1**.The quality seeds were obtained from Tamil Nadu Rice Research Institute, Aduthurai and Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai. The seeds of these varieties were hulled, milled and used for physical analysis *viz.,* kernel length, kernel breath, length/breadth ratio, hulling percentage, milling percentage and head rice recovery as per the standard protocol followed in rice.

A simplified colorimetric method was followed (Sowbhagya and Bhattacharya, 1971) for the estimation of amylose. Powdered rice sample (100 g) was taken to which 1 ml distilled ethanol and 10 ml of 1 N NaOH were added and left overnight. Next day, volume was made up to 100 ml. From this, 2.5 ml of the extract was taken and 20ml of distilled water was added to this followed by two to three drops of phenolphthalein and 0.1 N HCl was added until the pink colour disappears. 1 ml of iodine reagent was added and the volume was made up to 50ml and the colour was read at 590 nm in a spectrophotometer.

Starch content was estimated using Anthrone reagent method (Sadasivam and Manickam, 2005). 100 mg sample was homogenised in hot 80% ethanol to remove the sugar. Centrifuge process was repeated using 80% ethanol until the supernatant did not give colour to anthrone reagent. Then the dried residue was centrifuged with water and perchloric acid, and the supernatant was made up to 100 ml then anthrone agent was added and colour was read at 630nm.

Protein estimation was done using Lowry's method. 500 mg of sample was grinded with phosphate buffer and supernatant was used for estimation. 0.1 ml and 0.2 ml sample solution were taken and made up to 1 ml with water to which 5 ml of reagent C (solution of sodium carbonate and copper sulphate) was added. Then 0.5 ml of folin-ciocalteau reagent was added and the developed colour was read at 660 nm (Lowry *et al*., 1951). Ash content was estimated according to the procedure (Sadasivam and Manickam, 2005). The crucible with sample was placed in a muffle furnace at 600° C for four hours and then taken out, cooled and weighed, the ash content was calculated by using the formula,

Ash content % = $(W_2 – W_1) / W \times 100$

W_2 - Weight of the crucible with sample after taken out from the muffle furnace

W_1 - Weight of the empty crucible

W - Weight of the sample taken

Parameters related to puffing

Puffing yield

Puffing yield (%) = Weight of puffed rice (g)/ Weight of paddy grains (g) x 100

Expansion volume

Expansion volume (ml/g) = Volume of puffed rice (ml)/ Weight of paddy grains (g)

Expansion ratio

Expansion ratio = Volume of the puffed rice (ml) / Volume of the paddy grains (ml)

Table 1. List of rice varieties used for the study

S. No	Variety	Duration	Parentage	Salient features
1	ADT 42	115-120	AD 9246/ ADT 29	Long slender grain with 1000 grain weight of 24.50 g
2	ASD20	110-115	IR-18348-38-3 x IR-25863-61-3-2 x IR-58	Long slender grain with 1000 grain weight of 22.08 g
3	BHAVANI	130-135	Peta x BPI 76	Long slender grain with 1000 grain weight of 21.50 g
4	CO 43	135-140	Dasal x IR 20	Medium slender grain with 1000 grain weight of 20 g
5	INTAN	160-165	Introduction from Indonesia	Long slender grain with 1000 grain weight of 26 g
6	IR 64	115-120	IR 5657-33-2-1/ IR 2061-465-1-5-3	Long slender grain with 1000 grain weight of 23.10 g
7	MDU 6	110-115	MDU 5 / ACM 96136	Long slender rice with 1000 grain weight of 16 g
8	PAIYUR 1	130-135	IR-1721-14 x IR-1330-3-3-2	Long slender grain, low input response variety

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Physicochemical parameters and puffing characters of eight varieties were used for correlation analysis (Pearson's correlation coefficient) to understand the inter relationship among the quality parameters.

RESULTS AND DISCUSSION

All the characters under study were significantly different indicating the diverse nature of selected genotypes. The physical parameters which are related to puffing for the selected eight varieties are presented in **Table 2.** The kernel length and breadth of the grains varied between 7.10 to 9.72 mm and 2.05 to 2.80 mm respectively. The grains of INTAN variety were the longest whereas MDU 6 variety had the highest breadth. Paiyur 1 variety had the lowest length and ASD 20 had the lowest breadth value. The length/breadth ratio varied from 2.89 to 4.44, which categorized these varieties into long and medium slender types. Based on length/breadth ratio, ADT 42, ASD 20, Bhavani, INTAN, IR 64, MDU 6 and Paiyur 1 were categorized as long slender grain types and CO 43 was identified as medium slender grain types. This has a great significance in puffing industry as longer and medium variety would have better puffing yield, when compared to shorter and slender ones. However due to the organoleptic reasons and availability even short and bold grains are also used for puffing purpose (Joshi *et al.,* 2014). Hulling percentage varied from 65.25 % (IR 64) to 79.00 % (ADT 42) among the eight varieties and milling percentage value showed the range of 55.75% (ASD 20) to 68.60 % (Paiyur 1). The range of head rice recovery (HRR) varied from 50.35 % (CO 43) to 57.00 % (ADT 42).

Table 2. Physical properties of grain in selected rice varieties

Characters	Rice varieties								CD Value (5%)
	ADT 42	ASD 20	BHAVANI	CO 43	INTAN	IR 64	MDU 6	PAIYUR 1	
Kernel length (mm)	9.20	9.10	8.90	7.20	9.72	7.85	8.45	7.10	0.62
Kernel breadth (mm)	2.65	2.05	2.45	2.50	2.30	2.10	2.80	2.20	0.11
Length/ breadth ratio	3.48	4.44	3.64	2.89	4.24	3.75	3.02	3.24	0.47
Hulling %	79.00	73.20	75.50	76.65	70.00	65.25	78.15	73.85	2.05
Milling %	62.75	55.75	61.50	60.45	60.82	60.35	62.20	68.60	0.65
Head rice recovery	57.00	52.20	55.00	50.35	56.25	55.40	55.80	54.60	0.85

The chemical characters related to puffing includes starch content, amylose content, ash content and protein content of eight varieties are presented in **Table 3.** The degree of puffing expansion is affected by the conditions of thermal treatment, amylose content of the rice and the parboiling conditions (Chinnaswamy and Bhattacharya, 1983). Among the varieties, starch was highest in Paiyur 1 (75.69%) followed by IR 64 (75.10%) and INTAN (74.95). The highest value of amylose was observed in IR 64 (26.70) and the lowest value was observed in CO 43 (22.10). Based on amylose content, ADT 42, ASD 20, CO 43 and MDU 6 were classified as intermediate amylose type (20-25%) and Bhavani, INTAN, IR 64 and Paiyur 1 as high amylose type (> 25%) as per the method given by Juliano (1971). The amylose content is highly related to puffing character, as the grains of high amylose content rice are composed of linear chains, they will align themselves in shear field and thus are difficult to pull apart during the extrusion process (Moraru and Kokini, 2003). Since the high amylose rice is hard to shear, pressure may build up during thermal treatment. Due to this there may be a sudden expansion of endosperm resulting in highly puffed product, when compared to low amylose rice variety (Joshi *et al*., 2014). In this study, Bhavani, INTAN, IR 64 and Paiyur 1 had high amylose which resulted in high puffing yield. IR 64 had the highest amylose content of 26.70%, which is used in the local industries for making puffed rice.

Table 3. Chemical properties of grain in selected rice varieties

Characters	Rice Varieties								CD Value (5%)
	ADT 42	ASD 20	BHAVANI	CO 43	INTAN	IR 64	MDU 6	PAIYUR 1	
Starch content (%)	73.09	72.87	74.87	71.85	74.95	75.10	74.88	75.69	0.15
Amylose content (%)	24.56	24.28	26.28	22.10	26.66	26.70	22.44	26.68	1.60
Protein content (%)	6.11	7.09	5.11	5.23	5.50	5.64	6.37	5.24	0.50
Ash Content (%)	3.50	4.15	3.15	4.13	3.15	3.60	3.15	3.60	0.62

The ash content value was found to vary between 3.15% (Bhavani) and 4.15% (ASD 20). The protein content among the genotypes varied from 5.11% (Bhavani) to 7.09% (ASD 20). In this study, Bhavani had low protein content followed by CO 43, Paiyur 1, INTAN and IR 64. It is reported that the high protein content decreases the puffing yield of cereals (Chandrasekar and Chattopadhay, 1983).

Table 4. Parameters related to puffing

Characters	Rice Varieties								CD Value (5%)
	ADT 42	**ASD 20**	**BHAVANI**	**CO 43**	**INTAN**	**IR 64**	**MDU 6**	**PAIYUR 1**	
Expansion volume (ml/g)	23.35	22.02	38.12	21.56	36.03	34.32	26.32	31.77	1.31
Expansion ratio	13.25	12.17	21.85	11.68	21.56	18.54	16.35	17.36	0.87
Puffing yield (%)	69.22	63.50	78.54	63.36	75.05	74.25	68.58	69.45	2.63

The puffing related characters like expansion volume, expansion ratio and puffing yield are presented in Table 4. The expansion volume ranged between 21.56 ml/g (CO 43) and 38.12 ml/g (Bhavani) and expansion ratio ranged from 11.68 (CO 43) to 21.85 (Paiyur 1). High expansion ratio was also registered by Bhavani (21.85), INTAN (21.56), IR 64 (18.54) and Paiyur 1 (17.36). The puffing yield was highest in Bhavani (78.54%) followed by INTAN (75.05 %), IR 64 (74.25%) and Paiyur 1 (69.45%) and lowest in CO 43 (63.36%). In the present study, varieties *viz.,*Bhavani, INTAN, IR 64 and Paiyur 1 with high expansion volume and expansion ratio also registered high puffing yield.

Pearson's correlation coefficient which describes the linear relationship among the various characters is presented in Table 5. Kernel length was positively correlated to length/breadth ratio which was in accordance with the findings of Joshi *et al*. (2014) and Kamarraddi and Prakash (2015). Puffing yield had significant positive correlation with starch and amylose content, expansion volume and expansion ratio and high positive correlation with kernel length, length/breadth ratio and head rice recovery. However, it revealed negative association with kernel breadth, hulling percentage, milling percentage and protein and ash content. Kernel breadth had a significant positive correlation with hulling percentage. Starch content was positively correlated with expansion volume, expansion ratio and puffing yield. Amylose content registered significant positive association with expansion ratio and puffing yield and significant negative correlation with protein content. Similar results were reported by Kamaraddi and Prakash (2015), Joshi *et al*. (2014), Hoke *et al*. (2005) and Villareal and Juliano (1987). The protein content had negative correlation with puffing yield, expansion volume and expansion ratio. Expansion volume was positively correlated to starch and amylose content and expansion ratio and negatively correlated to ash content. Expansion ratio exhibited significant positive correlation with starch content and significant negative correlation with ash content. Based on the association studies varieties with high amylose, more expansion volume, high expansion ratio, low protein and low ash content are highly preferred for making puffed rice.

Table 5. Correlation among the characters of grain in selected rice varieties

Traits	Kernel length	Kernel breadth	Length/ Breadth ratio	Hulling %	Milling %	Head rice recovery	Starch	Amylose	Protein	Ash	Expansion volume	Expansion ratio	Puffing yield
Kernel length	1.000	0.107	0.743*	0.044	-0.482	0.509	0.116	0.262	0.126	-0.204	0.349	0.206	0.338
Kernel breadth		1.000	-0.674	0.792*	0.229	0.271	0.052	-0.002	-0.098	0.097	0.153	0.299	-0.340
Length/ Breadth ratio			1.000	-0.565	-0.589	0.160	0.052	0.243	0.136	-0.023	0.142	-0.088	0.498
Hulling%				1.000	0.203	-0.070	-0.337	-0.457	0.180	0.149	-0.279	-0.089	-0.564
Milling %					1.000	0.367	0.394	-0.415	0.269	-0.729*	0.107	0.266	-0.117
Head rice recovery						1.000	0.695	0.095	0.308	-0.871**	0.572	0.574	0.356
Starch							1.000	0.551	-0.317	-0.821*	0.855**	0.916**	0.721*
Amylose								1.000	-0.867**	-0.125	0.785*	0.685	0.745*
Protein									1.000	-0.002	-0.588	-0.542	-0.512
Ash										1.000	-0.771*	-0.779*	-0.655
Expansion volume											1.000	0.950**	0.866**
Expansion ratio												1.000	0.741*
Puffing yield													1.000

* - Significant at 5% ** - Significant at 1%

In the selected eight rice varieties, physicochemical characters of grain related to puffing along with puffing characters were studied which revealed that puffing yield was positively correlated with starch and amylose content, expansion volume and expansion ratio. Kernel length had a significant positive correlation with length/breadth ratio. Starch content was positively correlated with expansion volume, expansion ratio and puffing yield. The amylose content was negatively correlated with protein content. Ash content was negatively correlated to starch content. The varieties with high starch and amylose, more length breadth ratio and low protein were highly suitable for puffing. Out of eight varieties evaluated IR 64, INTAN, Bhavani and Paiyur 1 had more length breadth ratio, high starch, high amylose and low protein which resulted in high puffing yield. Hence these rice varieties are highly suitable for puffing.

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