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Effect of physico-chemical properties of rice on hot air puffing

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ABSTRACT

Puffing quality of rice is governed not only by processing conditions but fundamentally by the inherent physico-chemical make-up of the grain itself. This study examined the effect of physico-chemical properties on the hot air puffing performance of three rice varieties - Mahamaya, Barhasal and Rajeshwari - grown and processed in Chhattisgarh. Physical properties (1000-kernel weight, bulk density, true density, geometric mean diameter, sphericity, aspect ratio and surface area) and chemical properties (amylose and amylopectin content) of the three varieties were determined at a fixed moisture content of 12% (wb). Parboiled rice of the three varieties, established to differ significantly from one another in these properties, was then puffed under fixed process conditions (12% moisture, 2% salt concentration w/w, 290 °C air temperature) to isolate the effect of varietal physico-chemical variation from that of process variables. Puffing yield, volume expansion ratio (VER) and crispness of the puffed product were evaluated as response variables. Mahamaya, with the highest true density and amylose content among the three varieties, produced the highest puffing yield (86.72%) and superior expansion characteristics, followed by Barhasal and then Rajeshwari. The results establish that grain density and amylose content are strongly associated with puffing performance, while kernel size and sphericity influence expansion behaviour, providing a physico-chemical basis for varietal selection in the puffed rice industry.

Keywords: Barhasal, Mahamaya, Rajeshwari, Puffing yield, Volume expansion ratio, Crispness

Introduction

Rice or the paddy (*Oryza sativa* L.) is one of the major food crops of the world and staple food for more than half of the world's population. Rice is broadly defined as a semi-aquatic, annual, grass plant. Two species of rice, *Oryza sativa* L. and *Oryza glaberrima* Steud are widely grown in different type of water-soil regimes from dry, hilly slopes to deeply flooded land (Lu *et al.*, 1980) [1]. Properties or the quality of the rice vary with the variation in varietal characteristics, and mostly differ in grain shape, size, hardness and bulk density *etc.* The cooking quality of the rice largely depends on the properties of starch, mainly amylose content (Juliano, 1985) [2].

It is estimated that about 10% of the total paddy production of the country is used for the production of processed or value added rice products like popped, puffed and flaked rice (Narasimha, 1995) [3]. Puffed rice, a staple in the diet is not only as a major source of carbohydrate but to some extent protein and it also contributes beneficial nutrients including dietary fiber, vitamins, minerals and phytochemicals which have been linked to reduce disease risk (FDA, 2006; Maisont *et al.*, 2006) [4, 5].

Puffed rice is usually appreciated and popular due to its crispy texture, lightness and qualities related to its cellular structure. The conversion of compact rice into an expanded structure, the grain has to pass through series of stages or the unit operations during the puffing process (Mahanta *et al.*, 2010) [6]. The puffing not only alters the physical properties of the rice grain but also changes the nutritional profile. The success of puffing is normally adjudged by the volume expansion of grain. The volume expansion or the puffing of rice grains depends on many factors namely, physico-chemical properties, operational parameters of puffing, the method of puffing, the skill of operator or processor and the variety of the rice (Parganiha *et al.*, 2022; Lai *et al.*, 2004) [7, 8].

Proper moisture content in the grain facilitates the production of required pressure inside the kernels before popping or puffing. It has been well established that grain moisture content lesser than the optimum level decreases the popping or puffing performance. Juliano (1979) [9] reported a moisture range of 13-17% for popping in conventional heating at 240 °C for 35 s. Further, in puffing of rice Chinnaswamy and Bhattacharya (1983b) [10] have reported that optimum puffing could be possible with narrow moisture content range of 10.5-11% for successful expansion of the grains. The effect of salt concentration and grain moisture content on puffing of rice has been reported by Maisont and Narkruga (2010) [11].

The application of hot air fluidization method for puffing of different varieties has not been studied extensively which needs to be explored (Parganiha *et al.*, 2026) [12]. The findings of this information would cer

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tainly fill the knowledge gap and be helpful in generating the applicable information for the industries.

Materials and methods

Experimental site

All the experiments were conducted in the laboratories and workshops of the Department of Agricultural Processing and Food Engineering, Swami Vivekananda College of Agricultural Engineering and Technology & Research Station Raipur (CG).

Raw materials selection and their procurement

The test varieties undertaken in this study were Mahamaya, Barhasal and Rajeshwari which were procured from the storage centre of the Department of Plant Breeding & Genetics and National Seed Project, IGKV, Raipur (CG). Among these, Mahamaya is a popular variety of the region commonly used for the production of puffed rice. Barhasal is a local land race with typical characters (pale brownish in colour with typical aroma) and recently developed attraction for the production of puffed rice and flaked rice. Rajeshwari is a recent development to replace the local lesser remunerative varieties being used for the production of puffed rice.

Physico-chemical properties of rice

Physico-chemical properties of rice greatly affect the quality of rice as well as puffing process and quality of the puffed rice. Major physical properties of rice are the thousand-grain/kernal weight (Lakra *et al.*, 2018) [13], surface area (Kumar *et al.*, 2013) [14], geometric mean diameter (Sharma *et al.*, 2014; Reddy *et al.*, 2004) [15, 16], sphericity (Mohsenin, 1980) [17], aspect ratio (Sahu *et al.*, 2018) [18], bulk and true density (Joshi *et al.*, 2014) [19] *etc.* Similarly the major chemical properties which significantly affect are the moisture content (AOAC, 2010) [20], starch content (Sadasivam *et al.*, 2005) [21], content of amylose and amylopectin (Murugesan *et al.*, 1986; Murugesan *et al.*, 1991) [22, 23]. Standard procedures were followed to determine the physico-chemical properties of rice.

Dimensions

Three principal dimensions *viz.*, length, width, and thickness of single rice kernel of all the three varieties were measured using a digital vernier caliper (Mitutoyo, Japan) having 0.01 mm precision.

Puffing of test varieties

The moisture content of rice samples for each of the varieties was kept constant as 12% (wb) and the level of salt treatment was maintained at 2%, w/w. All the experiments were conducted at constant puffing temperature of 290 °C in hot air puffing machine. The responses or indicators used for comparison of puffing due to variation in physico-chemical properties of three test rice varieties were puffing yield, volume expansion ratio (VER) and crispness of the puffed rice (Nath *et al.*, 2012; Nath *et al.*, 2008) [24, 25].

Quality evaluation of puffed rice

Quality of any food product is a measure for its acceptability, uniformity and considered as the most important factor. The quality of any product depends on various factors and may vary with a small change in the process parameters (independent variables). The quality attributes of the puffed product were puffing yield, volume expansion ratio (VER), textural properties *etc.* Following procedures were adopted for determination of the quality parameter.

Puffing yield

Puffing yield is the ratio of the weight of puffed rice obtained to the total weight of the raw sample. Puffed and un-puffed rice were separated manually from the collected sample and weighted. The puffing yield of the sample was calculated using the following relationship (Solanki *et al.*, 2018; Parganiha *et al.*, 2022) [26, 27, 28].

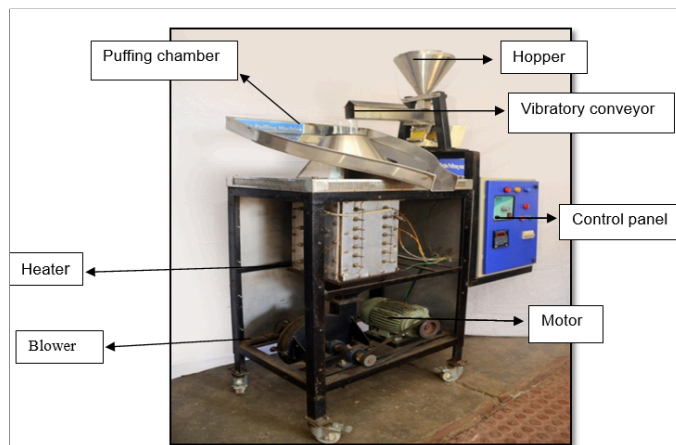


Figure 1. Hot air fluidized grain puffing machine

$$\text{Puffing yield (\%)} = \frac{\text{Weight of puffed rice (g)}}{\text{Total weight of the sample (g)}} \times 100 \quad \dots \text{ (Lu et al., 1980) [1]}$$

Volume expansion ratio

The volume expansion ratio is the ratio of the volume of the puffed sample to the volume of the rice sample before puffing (pre-gelatinized milled rice). The volume expansion ratio was measured by sand replacement method using the following equation (Salam *et al.*, 2015; Pardeshi *et al.*, 2014) [29, 30].

$$\text{Volume expansion ratio} = \frac{\text{Volume of puffed rice (ml)}}{\text{Volume of sample before puffing (ml)}} \quad \dots \text{ (Juliano, 1985) [2]}$$

Crispness

Crispness or the crunchiness is the number of positive peaks obtained from the force versus time curve. It was measured using a Texture Analyzer (TA-HD Plus, Stable Micro System, UK) with a 50 kg load cell. A standard 36-mm diameter cylinder stainless steel probe (P/36 R) supplied with the instrument was used to compress the sample (Fig. 2). A single compression force versus time program was used to compress single puffed rice along with the thickness. The original clearance between the probe and the base of the heavy-duty platform was fixed at 15 mm, so that when the probe moves down it compresses the sample horizontally on the base to a distance of 2 mm. The program was set to move the probe at a speed of 1 mm/s for pre-test and 10 mm/s for post-test phases. To measure the crispness, a macro-region was specified which helped in making the count the number of positive peaks during the compression test through the force-time deformation curve (Nath *et al.*, 2007; Pawar *et al.*, 2014) [31, 32]. The average of 10 determinations was recorded and reported.

Statistical design and analysis of data

All the experiments were conducted for the three varieties of rice selected in the present investigation. Analysis of variance (ANOVA) was carried out for each set of experiment using the software. Based on the ANOVA the efforts have been made to draw the inferences and discussed accordingly.

Result and discussions

Effect of physico-chemical properties of rice on puffing

It is well established that different varieties of paddy differ in their major physico-chemical properties and thereby the variation in milled rice (Adebawale *et al.*, 2011; Zareiforoush *et al.*, 2009) [33, 34]. Therefore, the study on effect of physico-chemical properties of rice on puffing was investigated with three different varieties of parboiled rice.

Physico-chemical properties of three varieties of rice

The three varieties undertaken in the present study were Mahamaya, Barhasal and Rajeshwari. Among these, Mahamaya is a popular variety of the region commonly used for the production of puffed rice.

Barhasal is a local land race with typical characters (pale brownish in colour with typical aroma) and recently developed attraction for the production of puffed rice and flaked rice. Rajeshwari is a recent development to replace the local lesser remunerative varieties being used for the production of puffed rice. In order to establish the differ-

ence in physico-chemical properties of these varieties, number of physical properties *viz.*, 1000-rice kernel weight, bulk density, true density, geometric mean diameter, sphericity, aspect ratio, surface area and, two chemical properties amylose and amylopectin of the test varieties were determined at fixed moisture content of 12% (wb).

Table 1. Physico-chemical properties of test varieties of rice

S. No.	Properties	Varieties			Statistics		
		Mahamaya (V ₁)	Barhasal (V ₂)	Rajeshwari (V ₃)	SEm ±	CD at 5%	CV
Physical properties							
1.	1000-rice kernel weight, g	24.58	24.80	24.11	0.016608	0.049346	0.214409
2.	Bulk density, g/cm ³	0.8125	0.8165	0.7956	0.002295	0.006819	0.897912
3.	True density, g/cm ³	1.4378	1.4285	1.4152	0.003937	0.011698	0.872382
4.	Geometric mean diameter, mm	3.093	3.129	2.713	0.018037	0.053593	1.915098
5.	Sphericity, %	46.804	50.223	44.311	0.013043	0.038753	0.087544
6.	Aspect ratio	41.629	41.659	39.329	0.021064	0.062587	0.162974
7.	Surface area, mm ²	29.808	30.202	22.039	0.024636	0.0732	0.28485
Chemical properties							
8.	Amylose, %	25.309	24.424	20.205	0.029745	0.088381	0.403483
9.	Amylopectin, %	74.691	75.594	79.795	0.025471	0.075681	0.105024

(All the values are the mean of 10 determinations)



Figure 2. Stable Micro System TA-HD plus Texture Analyzer

Upon pursuance of the table 1 it is clear that there exists significance difference (CD at 5%) among the test varieties on different physico-chemical properties. The 1000-rice kernel weight of Barhasal variety (24.80g) was significantly higher than the other two varieties. The comparison of mean values of bulk and true densities indicated that the variety Rajeshwari had the least values of these two attributes (Kanchana *et al.*, 2012) [35]. The bulk density of Barhasal (0.8165 g/cm³) was found to be significantly higher than the other two varieties, whereas the true density of Mahamaya rice kernels (1.4378 g/cm³) exhibited significantly higher value among the three. The density of the rice kernels is important, as the molecules are closely packed in highly dense materials which might affect the puffing quality (Ghadge *et al.*, 2012) [36]. The geometric mean diameter was determined to be the highest for Barhasal rice kernels (3.129 mm) which

was significantly higher than the other two test varieties. The exercise also demonstrated significant variation (at 5% level) in the mean values of sphericity and aspect ratio among the three test varieties. Both the sphericity and aspect ratio for Barhasal variety of rice kernels (50.223% and 41.659) were found to be the highest among the rice kernels of three test varieties (Dahare *et al.*, 2017) [37]. This classification of varieties is important for puffing industries, as smaller and medium kernel varieties would have better yield as compared to larger kernels (Murty *et al.*, 1983) [38]. Similarly, the comparison of chemical properties (contents of amylose and amylopectin) of the test varieties also indicated a significant variation from each other. Significant variation in the contents of amylose and amylopectin were also observed in the test varieties. The values of amylose contents were determined to be 25.309, 24.424 and 20.205% for Mahamaya, Barhasal and Rajeshwari rice varieties, respectively. Similarly the values of amylopectin contents were found to be 74.691, 75.594 and 79.795% for rice varieties of Mahamaya, Barhasal and Rajeshwari, respectively. The amylose content of kernel plays an important role in puffing characteristics. As the high amylose content kernels are harder to shear, there are higher chances of developing higher pressure during roasting treatment (Harbers, 1975) [39]. This would results in sudden expansion of kernel due to which a highly puffed product will be formed compared to the varieties containing low value of amylose content.

Puffing of test varieties

The above mentioned three test varieties differing significantly in physico-chemical properties were subjected to puffing in hot air puffing method. The moisture content of rice samples for each of the varieties was kept constant as 12% (wb) and the level of salt treatment was maintained at 2%, w/w. All the experiments were conducted at constant puffing temperature of 290 °C in hot air puffing method. The responses or indicators used for comparison of puffing due to variation in physico-chemical properties of three test rice varieties were puffing yield, volume expansion ratio (VER) and crispness of the puffed rice.

Puffing yield

The variation in puffing yield with the variation in varieties of rice and method of puffing are recorded. The minimum and maximum values of puffing yield for Mahamaya, Barhasal and Rajeshwari vari-

eties of rice were recorded to be 86.41-87.05, 82.37-83.41 and 76.25-77.08%, respectively in hot air puffing method.

Table 2. ANOVA for puffing yield

Variety (B)	Mahamaya (V_1)	Barhasal (V_2)	Rajeshwari (V_3)
Mean	84.71*	82.68	75.10
CV	0.29		
CD at 5%	0.17		

On comparison from table 2 of the three varieties it could be seen that the performance of Mahamaya variety rice had been the best among the three test varieties. The mean values of puffing yield for test varieties were calculated to be 84.71, 82.68 and 75.10% for Mahamaya, Barhasal and Rajeshwari, respectively. The result further indicated that the puffing capacity of Rajeshwari variety rice was significantly lowest from the other two varieties. Thus, it can be very well established that the puffing yield is dependent on variety of rice. They have (Dahiwal et al., 2018) [40] reported variation in puffed yield with the variation in varieties of rice.

Volume expansion ratio (VER)

The variation in volume expansion ratio with the variation in physico-chemical properties of rice samples (*i.e.* varieties). The minimum and maximum values of volume expansion ratio for Mahamaya, Barhasal and Rajeshwari varieties of rice samples were recorded to be 6.98-7.05, 6.18-6.32 and 6.00-6.20, respectively in hot air puffing method. On comparison of the three varieties it could be seen that the performance of Mahamaya variety rice had been the best among the three test varieties. The effect of varieties on expansion of puffed rice has been indicated by Kumar et al. (2017) [41].

Table 3. ANOVA for volume expansion ratio

Variety (B)	Mahamaya (V_1)	Barhasal (V_2)	Rajeshwari (V_3)
Mean	6.76*	6.18	6.08
CV	0.79		
CD at 5%	0.04		

The mean values of volume expansion ratio for three varieties of rice were calculated to be 6.76, 6.18 and 6.08 for Mahamaya, Barhasal and Rajeshwari, respectively. The result further indicated that the volume expansion ratio of Rajeshwari variety rice was significantly lowest from the other two varieties. The results are in agreement with the findings of Marihonappanavara et al. (2017) [42] and Mishra et al. (2014) [43] indicating that higher the amylose content in the rice increases the expansion ratio. On the contrary the results reported by Chanlat and Songsermpong (2015) [44] indicate that there was a negative correlation between amylose content and volume expansion ratio of puffed rice. The performance of Mahamaya variety of rice in

hot air puffing was found to be best as the ANOVA indicates the volume expansion ratio of 7.01. It is well documented by Hoke et al. (2005) [45] and Joshi et al. (2014b) [46] that the kernel properties of cereals affect the expansion. However, the investigation in greater detail for more number of varieties would be helpful to arrive to conclusion.

Crispness

The variation in the crispness of the puffed rice obtained from three varieties of rice is recorded. The minimum and maximum values of crispness of puffed rice for Mahamaya, Barhasal and Rajeshwari varieties of rice were recorded to be 39-46, 55-65 and 44-54, respectively for the samples prepared by hot air puffing.

Table 4. ANOVA for crispness

Variety (B)	Mahamaya (V_1)	Barhasal (V_2)	Rajeshwari (V_3)
Mean	44.00	51.56*	46.00
CV	7.23		
CD at 5%	2.47		

The statistical analysis of the experimental data on crispness of puffed rice is shown through analysis of variance (ANOVA) in Table 4. The results of crispness of puffed rice obtained from the two methods of puffing are significantly different at 5% level. The crispness of puffed rice prepared from Barhasal variety of rice was recorded to be the best due to highest mean value of crispness (51.56). The mean values of crispness of puffed rice for test varieties were calculated to be 44.00, 51.56 and 46.00 for Mahamaya, Barhasal and Rajeshwari, respectively.

There is no literature available directly indicating the effect of physico-chemical properties of rice on crispness of the puffed rice. However, They (Gaul et al., 2008) [47] reported that kernels with high amylopectin content produced a low density product with homogeneous expanded texture, but kernels with high amylose content resulted in a hard product with expansion. Since the textural properties like hardness and crispness with the variation in rice varieties or the

physico-chemical properties of the rice have not been investigated and reported by the earlier researchers in detail, it is difficult to compare the findings.

Conclusion

The puffing yield and VER both were recorded to be declined with the increase in the moisture content of the rice and a sharp decrease was observed when the moisture content of the rice exceeded beyond 12% (wb). This was true for all the three varieties and temperatures tested in case of hot air puffing. Variation in puffed yield and volume expansion ratio with the variation in varieties of rice due to their different physico-chemical properties were also found. Since the textural properties like hardness and crispness with the variation in rice varieties or the physico-chemical properties of the rice have not been investigated and reported by the earlier researchers in detail, it is difficult to compare the findings.

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The authors do not have any conflict of interest.

Data availability statement

Available upon reasonable request. The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics statement

This research did not involve human participants, animal subjects, or any material that requires ethical approval.

Informed consent statement

This study did not involve human participants, and therefore, informed consent was not required.

Clinical trial registration

This research does not involve any clinical trials.

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Not Applicable.

Author contributions

- **Deepak Parganiha:** Conceptualization, Methodology, Writing – Original Draft.
- **Sadanand Patel:** Visualization, Supervision, Project Administration, Writing.
- **Chandan Solanki:** Review, Resources, Formatting and Editing.
- **Purnima Verma:** Data Collection, Analysis.

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