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Puffing characteristics of three test varieties of parboiled milled rice

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Abstract
Puffing is a combined process of gelatinization of starch and expansion which is accomplished by exposing the grains to a high temperature for short time. Hence the process may be called as high temperature short time process. During the puffing process, the moisture inside the grain vaporizes as superheated vapour within a short period suddenly and cooks the grain, and escapes due to which the grain expands. Puffed rice is an age old traditional breakfast food regularly consumed in many rice growing countries. The puffing of pre-gelatinized rice is a very easy way of adding value to the rice and convert into ready to eat food. Different methods are used to convert pre-gelatinized milled rice into puffed rice, some of the popular and common methods are hot air puffing, sand roasting, hot oil puffing, gun puffing and microwave puffing. Puffing characteristics were studied for three test varieties of rice at different levels (10, 12, 14 and 16% wb) of moisture content and hot air temperature (280, 2900 and 300 ^{o}C). The salt concentration was kept constant as 2% w/w. 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) for all three verities of rice. It was further observed that with the increase in air temperature, the values of puffing yield and VER increased for all the varieties irrespective of the moisture content. It was found that the puffing of rice was better at higher air temperature (300 ^{o}C). The puffing yield and VER for Mahamaya variety of rice were found to be superior compared to other two varieties (Barhasal and Rajeshwari).

Keywords: Puffing characteristics, parboiled milled rice**,** moisture content, puffing yield and volume expansion ratio

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 *Oriza Glaberrima steud* are widely grown in different type of water-soil regimes from dry, hilly slopes to deeply flooded land (Lu and Chang, 1980) [6]. India is the second largest producer of rice in the word after China. Paddy being the major cereal crop of India grown in almost all the parts of the country. Rice is the staple food for the majority of Indian population, it is consumed in different forms but consumption as whole rice is the tradition for the major population and forms minimum one diet of the day. 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) [10]. Among the breakfast cereals made out of rice, puffed rice is one which is very popular and remains on demand for centuries in India due to its typical crispness and lightness properties. It is commonly used as ready-to-eat breakfast cereal, snacks, cereal drinks and infant food. 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 [3]. Maisont and Narkrugsa, 2009) [7]. Puffing is a combined process of gelatinization of starch and expansion which is accomplished by exposing the grains to a high temperature for short time. Hence, the process may be called as high temperature short time process. This causes sudden heating and expansion of the moisture present in the inter-granular spaces of the starch granules in the form of vapour which results in puffing or expansion of the grains. With the advancement of time, puffing of rice on hot sand bed has been replaced to some extent by hot air fluidized bed method. However, the infrastructure and operational cost of hot air puffing method is quite high compared to hot sand puffing technique.

The hot air puffing or popping is also known as HTST fluidized bed puffing. In this method the grain or the material to be puffed is placed under appropriate conditions so as to material (grains) behave as a fluid. It is established that upon fluidization the effectiveness of heat and mass transfer is increased as the product (grains) surface is uniformly exposed to the heating medium *ie.* hot air. Therefore, the fluidized bed puffing is more efficient than conduction or the sand roasting process. In recent years, puffing has gained popularity over other processing technologies and has proved to be a superior method for the preparation of low cost ready-to- eat value added products from cereals and other starchy grains. The puffing or popping is not only convenient for consumption but at the same its storage and handling also do not require sophisticated techniques. 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. 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. Considering the above facts, a study was undertaken to characterize the puffing characteristics of three varieties of parboiled milled rice in a domestic microwave oven.

Material and Methods

To study the puffing characteristics of three test varieties of rice namely; Barhasal, Mahamaya, and Rajeshwari (IGKV R1) varieties of paddy were procured from the storage center of the Department of Plant Breeding & Genetics and National Seed Project, IGKV, Raipur (CG). From all the paddy varieties specks of dirt and foreign materials were properly removed. Parboiling was performed as a pretreatment for production of puffed rice, for which paddy samples were soaked in Luke warm water (50 °C) for overnight (12-14 hours) followed by steaming for 25-30 min (Hoke *et al*. 2005) [4].

(a) (b) (c)

Fig 1: Varieties of paddy (a) Barhasal (b) Mahamaya (c) Rajeshwari (IGKV R1)

The hot air fluidized puffing of rice was accomplished by the continuous experimental hot air fluidized puffing machine designed and developed by IIFPT, Tanjavur (Sheriff *et al.*, 2002) [12]. To study the puffing characteristics in hot air method, the air temperature (puffing temperature) was varied in the range of 280 to 300°C and the moisture content of the parboiled rice was varied in the range of 10 to 16% (w/w). It is worth mentioning here that below 10% (wb) moisture content of rice, the puffing performance was very poor in terms of puffing yield and volume expansion ratio both. The pre-treatment using common salt given to the rice prior to puffing was kept constant as 2% (w/w) for all the experiments based on the experience gained through preliminary experiments. In order to evaluate the puffing characteristics of selected varieties of rice, two indicators namely; puffing yield and volume expansion ratio (VER) have been used to understand the effect of process variables.

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 (Chinnaswamy and Bhattacharya, 1983 [2]. Joshi *et al.*, 2014) [5] using the following equation.

$$\text{Volume expansion ratio} = \frac{\text{Volume of puffed rice (ml)}}{\text{Volume of sample before puffing (ml)}}$$

Puffing yield

Puffing yield is the ratio of the weight of puffed rice obtained to the total weight of the raw sample (Maisont and Narkrugsa, 2009) [7]. 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.

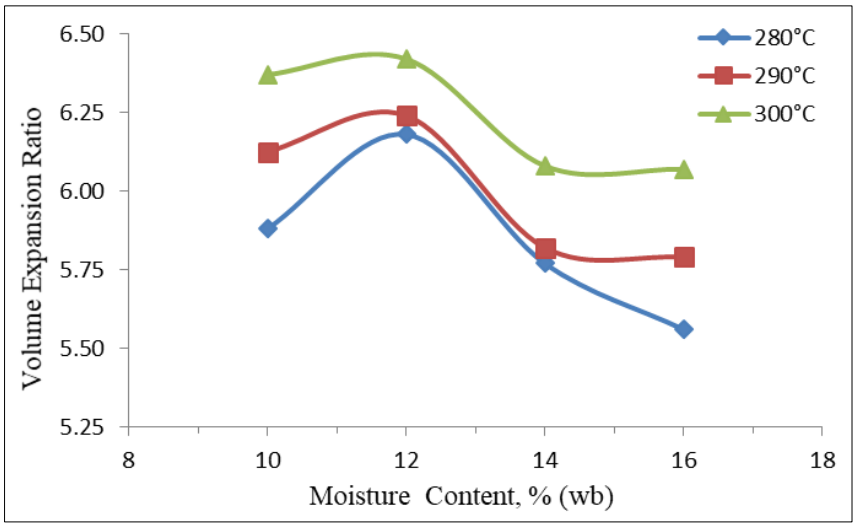
$$\text{Puffing yield (\%)} = \frac{\text{Weight of puffed rice (g)}}{\text{Total weight of the sample (g)}} \times 100$$

Statistical Analysis

Statistical analysis of variance (ANOVA) was carried out using Microsoft excel. In order to execute the experiments systematically full factorial design was adopted to find out the effect of the process parameters (independent) on responses or the dependent variables.

Results and Discussion

The effect of puffing temperatures with the variation in moisture content of the grain on puffing yield and VER is shown in Fig. 2 to 4. It can be seen that the temperature has distinct effect on both the attributes of puffing. It is clearly depicted that the puffing yield and VER have been recorded to be the highest at the highest temperature of puffing (300°C) for all the three varieties of rice. Probably this may be due to the fact that with the increase in heating temperature, it accelerates both the melting of kernels and evaporation of water in rice. Melting causes the rice kernel elastic and makes expandable whereas, the evaporation exerts the pressure required for expansion. Hence, the expansion of kernel increases with the increase in heating temperature (Salam *et al.*, 2015) [11]. This is true for the entire range of moisture content (10 to 16%, wb).



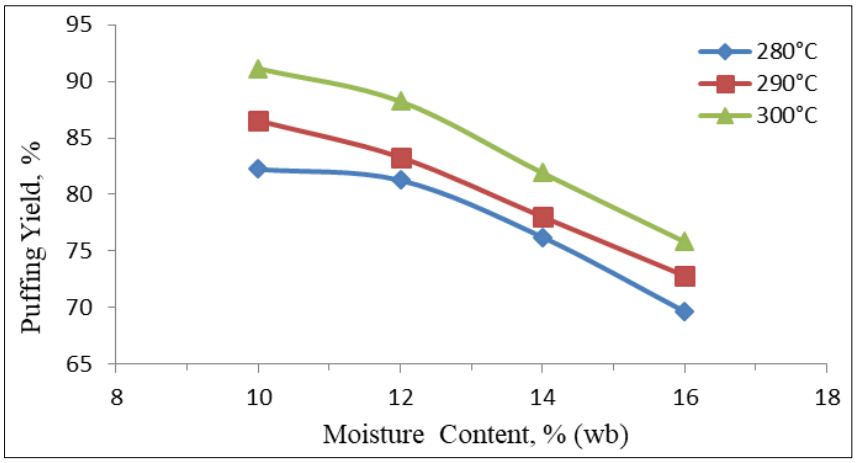
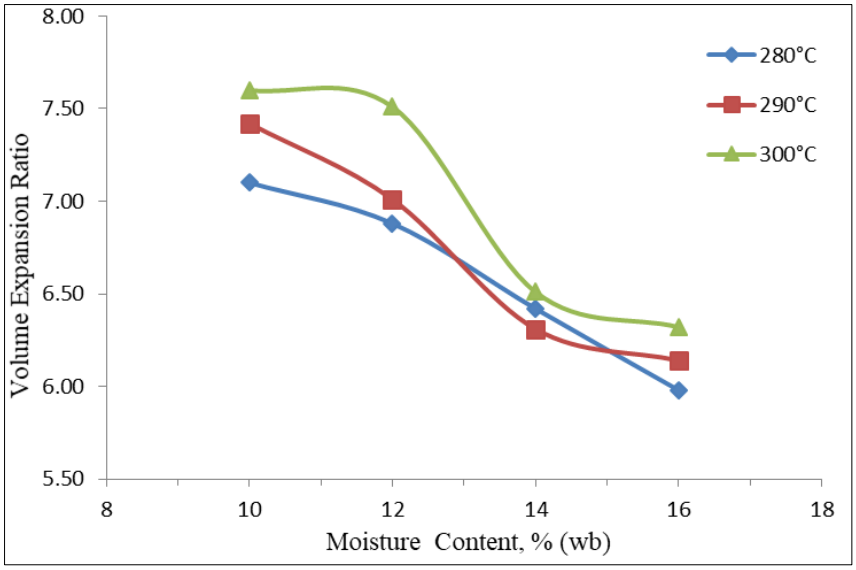


Fig 2: Variation in volume expansion ratio and puffing yield at different air temperature and moisture content of rice for Barhasal variety

The maximum and minimum puffing yield for Barhasal, Mahamaya and Rajeshwari were recorded to be 91.7 and 70.58%, 91.13 and 69.65% and, 82.9 and 61.08%, respectively. Similarly, the maximum and minimum VER for these varieties were found to be 7.6 and 5.98, 6.42 and 5.56, and, 6.27 and 5.17, respectively. The significant effect of moisture content on puffing of different varieties of rice has also been reported by Chanlet and Songserpong (2015) [1]. In case of Barhasal, the highest VER was obtained at 12% grain moisture, whereas in other two varieties the highest value of VER was recorded at 10% moisture content. This may be due to the varietal characteristics. This was not true in case of puffing yield; the puffing yield was noted to be the highest at 10% moisture content for all the three varieties and puffing temperatures.



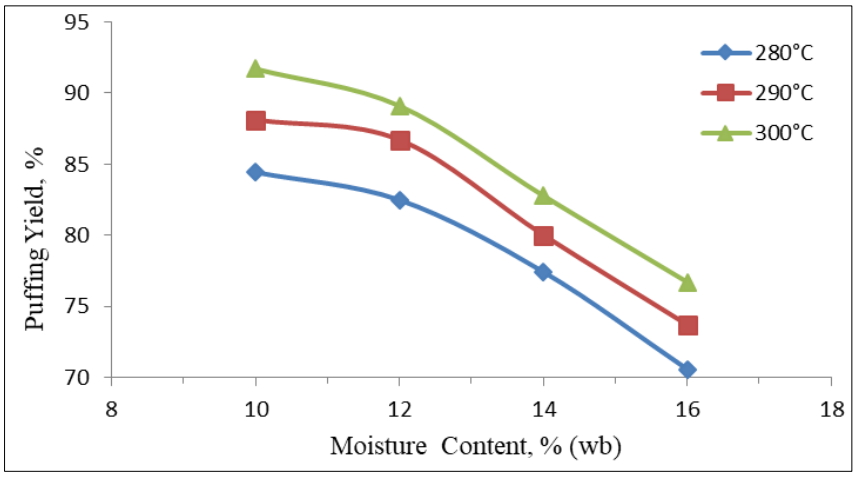
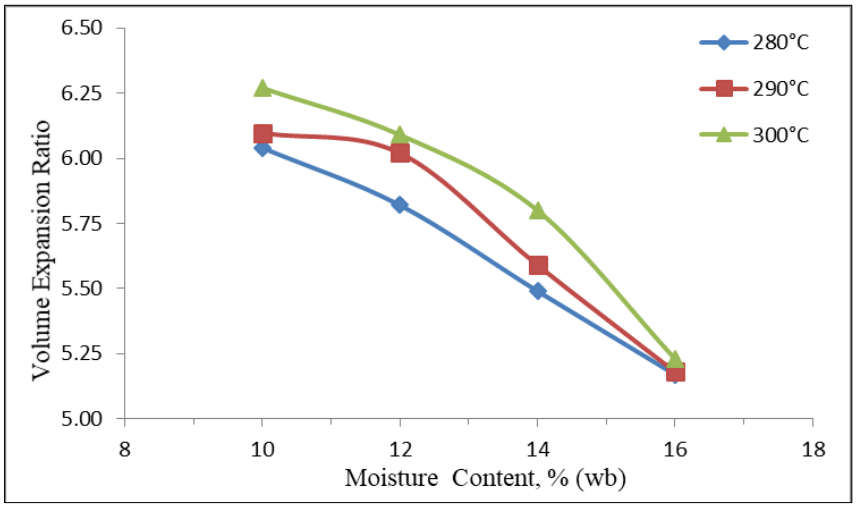


Fig 3: Variation in volume expansion ratio and puffing yield at different air temperature and moisture content of rice for Mahamaya variety

The lowest value of VER was recorded at 16% grain moisture (highest moisture content) for all the three varieties and temperatures. Similar findings have also been recorded by Maisont and Narkrugsa (2010) [8]. This indicates that critical moisture content is necessary in obtaining maximum VER and puffing yield.



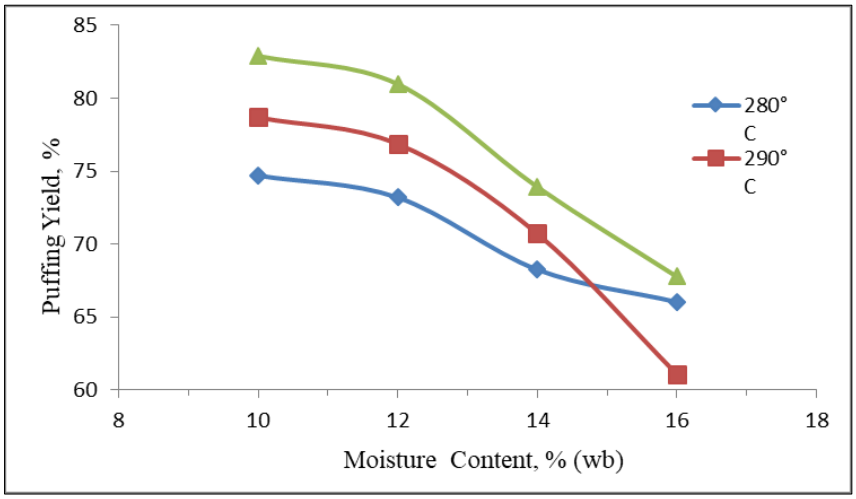


Fig 4: Variation in volume expansion ratio and puffing yield at different air temperature and moisture content of rice for Rajeshwari variety.

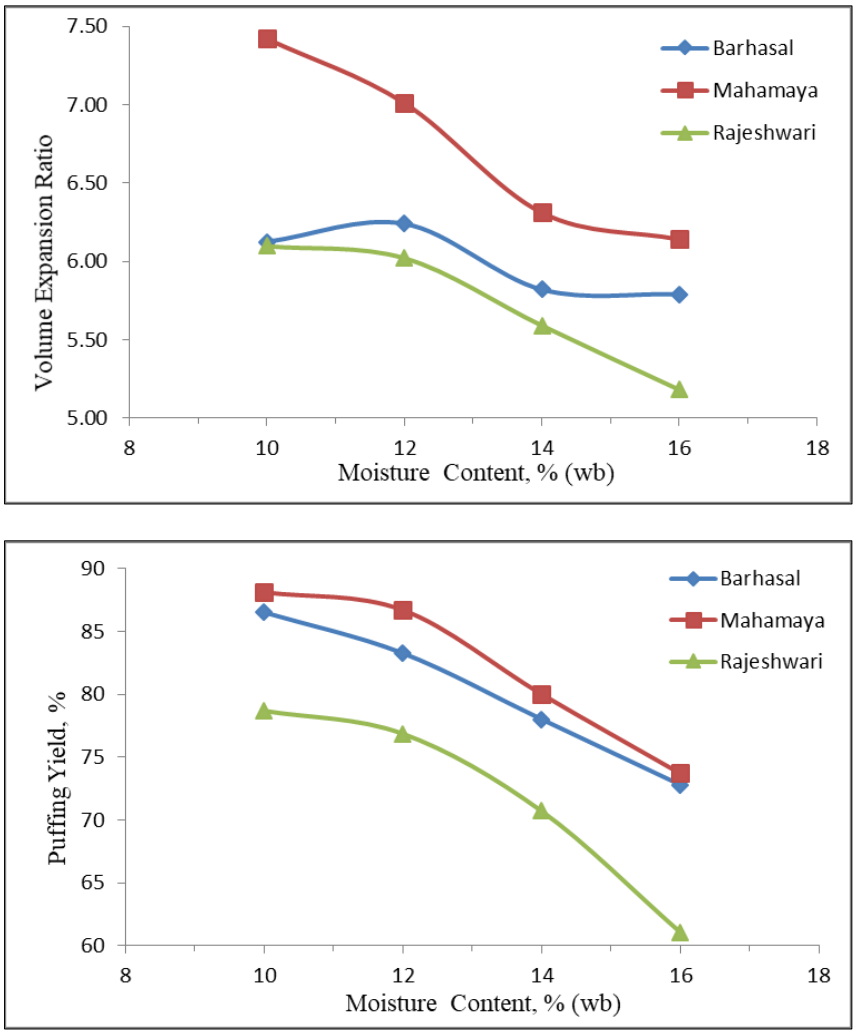


Fig 5: Comparison of volume expansion ratio and puffing yield for three test varieties of rice at 290 °C puffing temperature.

It can be further seen that the puffing yield and VER have been found to be decreased with the increase in moisture content and a sharp decline was observed after 12% moisture content irrespective of varieties and puffing temperature. Similar findings have been reported by Solanki *et al.* (2018) [13] in case of maize popping. The probable reason could be that with the increase in moisture content, complete expansion of rice grain do not take place because the complete moisture do not get evaporated. Due to sudden thermal gradient, the moisture inside the grain vaporizes and tries to escape out through the micro pores. At higher moisture content it is difficult for the grain to attain an adequate level of temperature within a very short period of time which would sufficient enough to escape out the vapor from the grain completely and thereby the available moisture. A comparative performance of the three test varieties on VER and puffing yield is shown in Fig. 5 at 290 °C Over the range of experimental moisture contents. It can be seen that the puffing characteristics of all the three test varieties are nearly identical. However, the puffing characteristics of all the three varieties were found to vary with the variation in kernel moisture content in hot air temperature. The figures also suggest that an appreciable variation in puffing potential of different variety paddy exists. This further indicates that the selection of proper variety of rice is critical for mass production of puffed rice.

Conclusions

The snack food market is one of the most important areas of the food industry. Snack foods have always been a significant part of modern life style and they represent a distinct, constantly widening and changing group of food items. Production of snack foods today can be a complex process to meet changing consumer's expectations and their taste. Puffed rice is one such product made from the parboiled rice normally produced by roasting of rice traditionally on hot sand bed at a high temperature at domestic level. The puffing characteristics of all the three test varieties (Mahamaya, Barhasal and Rajeshwari) were found to vary with the variation in moisture content and hot air temperature. The puffing yield and VER for Mahamaya variety of rice were found to be superior compared to other two varieties (Barhasal and Rajeshwari). From the experimentation, it can be concluded that the puffing characteristics of all the three test varieties of rice (Mahamaya, Barhasal and Rajeshwari) was found to be affected by the moisture content of the rice and hot air temperature in addition to the variety of rice.

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