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Mechanizing the conditioning process of rice before puffing

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ABSTRACT

The conditioning process involving slow and uniform heating of salt soaked high moisture parboiled rice coupled with turning or agitation before puffing is the most critical factor for obtaining good quality of puffed rice. A mechanized set-up has been developed to produce pre-conditioned rice for puffing with 0.0, 2.5, 3.5 and 5.0% salt (w/w). Pre-conditioning process irrespective of the salt contents continued for about a time period of 90 minutes (except for no salt condition taking about 80 minutes) till the final hardness of the grain was achieved between 44-47N. The final moisture content of the pre-conditioned grain was achieved as 10-10.30 % (wb). Percentage puffing and expansion ratio of machine pre-conditioned rice were observed as 97.8±1.26 %, 6.3±0.28 and 92.2±0.69 %, 6.4±0.22 respectively for microwave puffing and traditional puffing. Therefore, the developed machine is able to produce well conditioned rice for producing quality puffed rice.

Keywords: *puffed rice, pre-conditioning, mechanization*

INTRODUCTION

Puffed rice is a popular low cost breakfast cereal and snack used worldwide because of its ready to eat (RTE), lighter and crispness characteristics. India produces annually 89 million tonnes of rice (second largest producer of rice in the world), but, only 10 percent of it is converted to different value added products such as puffed rice, popped rice or flaked rice (Chattopadhyay, 2004). Puffed rice has got a highest demand both in national and international market. Quality factors such as uniform puffing, contamination free, good colour, crispness etc are the major concern for export of puffed rice. However, the production of puffed rice in India is only limited to village levels.

The puffing method traditionally followed in India is sand-roasting. In this process, parboiled rice (double boiling) is mixed with salt and water (45 g salt per1 kg rice with 150 ml water): soaked for 8-9 hours and then the moistened rice (about 30% moisture content wb) exposed to slow and uniform heating by constantly turning/ agitating the grain in a large bowl to a final moisture content of 10.0 to 10.5 % (wb). The conditioned rice prepared was then roasted over hot sand bed (temperature between 250-260ºC) (Chinnaswamy and Bhattacharya, 1983b, Chandrasekhar and Chattopadhyay, 1991) for 20-25 s. The whole process of puffing is very tedious, time consuming and involves a large amount of skilled labour working in hot conditions. There is a need to mechanize the puffing process of rice for commercial production.

Puffing of rice is done in different methods such as conduction puffing on hot sand bed (Chinnaswamy and Bhattacharya, 1983b, Srinivas and Desikachar, 1973); hot oil (Villareal and Juliano, 1987); convection heating in hot air (Chandrasekhar and Chattopadhyay, 1991); explosion puffing, employing pressure differential in a closed chamber (Villareal and Juliano, 1987, Mariotti *et al.*, 2006, Hoke *et al.*, 2007) or more recently by microwave puffing (Singh and Singh, 1999, Maisont and Narkrugsa, 2010). The pre-puffing conditioning (pre-conditioning) of rice is the most critical factor for achieving the good quality expanded product (Chinnaswamy and Bhattacharya, 1983a, 1983b, Chandrasekhar and Chattopadhyay, 1989). It is basically uniform and slow heating of high moisture (water soaked) parboiled grains coupled with turning or agitation. This facilitates proper structural changes of grains like, surface modifications and hardness,

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removal of moisture and thus produces highly expanded and smooth surfaced puffed rice. Non-uniform heating of grains severely impairs the puffing quality and rough and blistered puffed rice. This laborious and tedious process of conditioning necessitates replacement with a developed mechanical system to produce uniformly conditioned rice for improving puffing quality. This study was undertaken to develop a machine for pre-conditioning of parboiled rice before puffing and then evaluation of its puffing quality (by hot sand bed and microwave puffing method).

MATERIALS AND METHODS

A batch type motorized pre-conditioner of 2 kg capacity was developed and evaluated.

Heera, a fine quality rice variety with the dimension of length 6.50 mm, breadth 2.46 mm and length to breadth ratio is 2.64 was used for pre-conditioning. Double and pressure parboiled rice was collected from nearby village '*Bondeuli' (22.167ºN, 87.250ºE)*, in the district of West Medinipore, West Bengal, India. Common salt (0.0, 2.5, 3.5 and 5.0 % w/w) was added to the water soaked parboiled rice for salting. Water was added at the rate of 150 ml per kg of parboiled rice. Soaking was done for 8 to 9 hours (in accordance with the normal traditional process), so that equilibration of moisture was achieved. After soaking, the moisture content of grains was found to be around 30% (wb).

A lot of 2 kg soaked rice was put into the pre-conditioning machine and spread uniformly. The process of agitation and heating were started simultaneously. The grains inside the pre-conditioner were turned at 12±2 rpm while the temperature gradually raised to 90°C. The material temperatures at three zones were recorded with the help of thermocouples placed inside the pre-conditioner. At 15-minute interval, rice samples were scooped out from different zones of the vessel for determination of moisture content as well as measurement of its hardness. The process was completed when the moisture reached around 10.5 % (wb). However, the completion of the process (end moisture content) was determined indirectly by measuring the hardness (breaking force) of the grain. The hardness and moisture content of the grain has been previously correlated from the experimental data of conditioned rice and it was around 45 - 50 N at 10-11% (wb) moisture content.

Moisture content of pre-conditioned grains was determined by the hot-air oven at 105ºC for 24 h (ASAE, 1996). Grain hardness was measured by a grain hardness tester (Kiya, Japan; maximum load 20 kg with Least Count of 0.2 kg). The grain was placed on the platform and the handle was rotated to press the rice grain until a crack occurs. Twenty representative samples were taken to find out the hardness of the grain. The conditioned rice prepared in the above mentioned process is puffed under hot sand bath and the microwave oven. Puffing is done in a large cast iron pan in which 200-250 gm sand is heated and 20 g pre-conditioned rice put for puffing in the hot sand bath (200-250 ºC). In microwave puffing, a constant volume of pre-conditioned rice (appx. 9ml) was packed in a microwavable packet and then puffed, setting microwave power as 850W for 35 s, which was found as optimum power level required for good puffing quality (Mohapatra, 2010). The puffing percent and expansion ratio were then calculated.

The percentage of puffing was determined by the ratio of number of rice puffed to the number of actual pre-conditioned rice taken for puffing multiplied by 100.

$$\text{Percent of Puffing} = \frac{(N_{pc} - N_{up})}{N_{pc}} \times 100 \quad ....(1)$$

Where, N_{PC} and N_{up} correspond to numbers of initial grains and number of un-puffed grains (remained un-puffed during puffing) respectively.

The expansion ratio (ER) of puffed rice is the ratio of the true volume of the puffed rice (V_p) to the volume of pre-conditioned rice before puffing (V_{PC}).

$$ER = V_P/V_{PC}$$

Two measuring cylinders of 25 and 100 ml were used for measuring the volume of pre-conditioned rice and puffed rice respectively. True volume of puffed rice (V_P) was obtained by measuring the volume of puffed rice with void space filled with fine sand (V_T) and subtracting the volume of the separated sand (V_S). True volume of puffed rice (V_P) = V_T - V_S

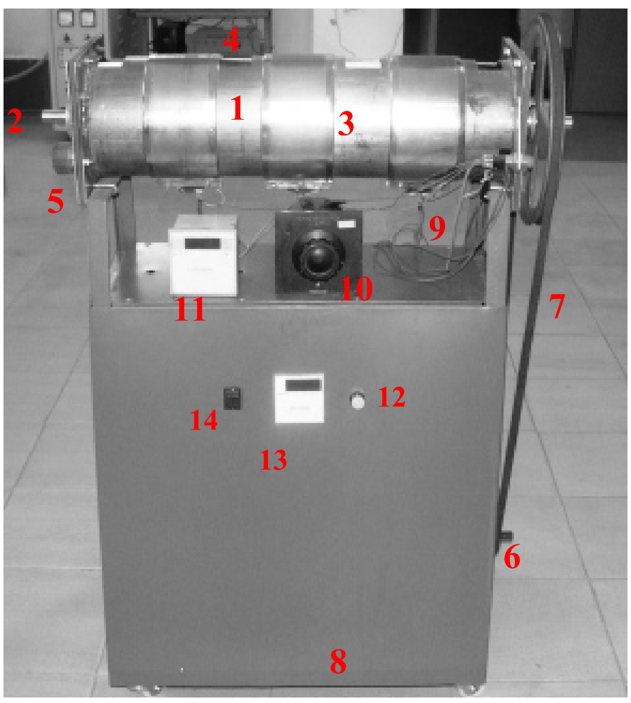
Volume of pre-conditioned rice (V_{PC}) that generated expanded rice would be -

$$V_{PC} = V_{PCT} - V_{UP}$$

Where, V_{PCT} is the total volume of pre-conditioned grain and V_{UP} is the volume of the un-puffed grains.

RESULTS AND DISCUSSION

The experimental set-up (Fig.1) consisted of a cylindrical vessel (610 mm length, 152 mm diameter and 0.4 mm thickness) with a central rotating shaft attached with



1. Cylindrical vessel
2. Mechanical Agitator
3. Band heater
4. Inlet slots
5. Discharge port
6. Motor
7. Driving pulley and belt
8. Base
9. Thermocouples
10. Selector switch
11. Temperature indicator
12. Speed regulator
13. RPM indicator
14. Motor on/off switch

Fig. 1 Machine developed for pre-conditioning of rice

agitators made from Teflon sheets (Fig. 2) for mixing of the materials inside the cylinder. The shaft is attached with a 0.5 hp motor driven by means of belt and pulley and a speed controller unit is provided to give variable speed. Four slits (50 x 80 mm^2 each) are present on the upper surface of the cylinder, through which materials were put inside the machine for mixing. An outlet port of 65 mm diameter has been provided to discharge the material after conditioning is over. Three band heaters (500W, 10 cm length) have been attached

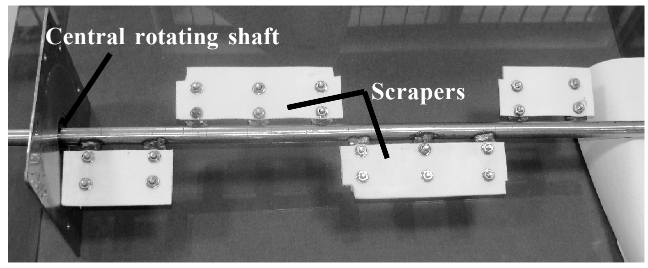


Fig. 2. Agitator shaft with scrapers

on the cylinder surface to provide heat during the process. Thermocouples (J-type iron constantan), temperature indicator and selector switch attachments are provided for online record and assurance of uniform heating of the material throughout the cylinder surface. The mixing of rice is accomplished by the rotation of the shaft with the agitators at a constant speed of 10-12 rpm, exposing the material for uniform heating of each grain.

The pre-conditioned rice was prepared with this machine at four different salt levels (i.e., 0.0, 2.5, 3.5, and 5.0% w/w). The changes in moisture content of the kernel and its hardness with time are shown in Fig. 3 and 4. The time required for removal of moisture from about 30% wb to 10.30 % (wb) of the grains was 90 minute irrespective of different salt contents. The change of moisture content of rice with increment of time of pre-conditioning up to 90 minutes varied significantly (F_{ratio} =130.87, p<0.001) (Table 1) and it follows an exponential relationship in all the samples (Fig.3). It may be further noted that, this decrease in moisture content was rapid for kernel containing no

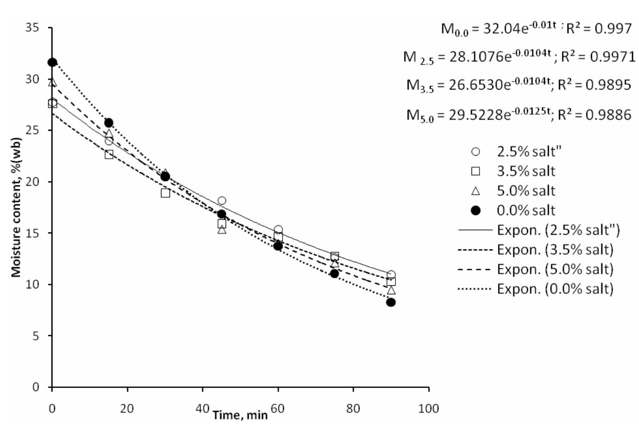


Fig. 3. Variation in moisture content of rice kernels over time during pre-conditioning

salt than that of others, and took about 80 minutes to reach puffing moisture content around 10-10.5% (wb). Possibly, due to hygroscopic nature of the salt, kernel containing salt has a tendency to retain more moisture. However, there is non-significant difference among the samples containing salt (F_{ratio}=0.435, p>0.5^{ns}) (Table 1). Thus, the results revealed that, salt content in the kernel during heat curing has no effect on the rate of moisture removal if other operating parameters in the pre-conditioning process were kept fixed. In other words, the machine needs to operate same period of time for curring rice kernels irrespective of salt contained in it.

Table 1. ANOVA showing effect of salt and time of pre-conditioning on moisture content of grains

Source	df	Mean squares	F-ratio	p-Value
Time	6	190.522	130.870	0.000**
Salt	3	0.634	0.435	0.517^{ns}
Error	20	1.456		

**significant at 5 % level of significance, ns- non significant

During the process of heat curing, the hardness of the grain increased from 8 to 50 N with time, following similar exponential but opposite trend to that of moisture content (Fig. 4). It implies that, hardness of grain could be linearly related to its moisture content (Fig. 5). This phenomenon of change in hardness in texture (glass transition) is common in foods that changes from rubbery state to glassy state as moisture is removed (Roos and Karel, 1991). It is quite apparent form these results that this phase transition was rapid for kernels containing no salt, causing fast change in

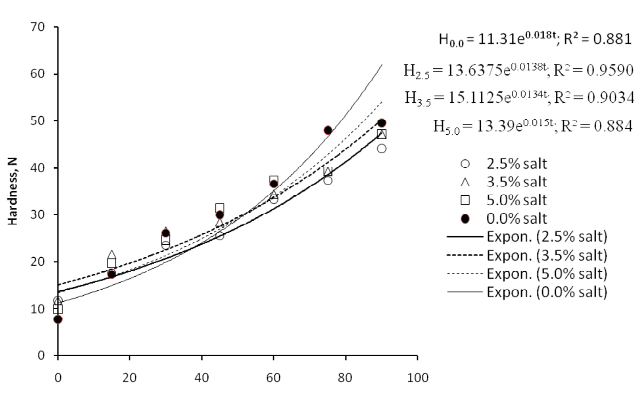


Fig. 4 Variation in hardness of rice kernels with time during pre-conditioning

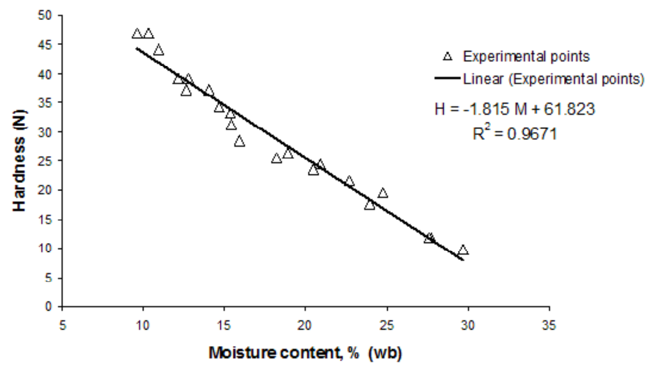


Fig. 5 Hardness (H) of pre-conditioned rice at different moisture levels (M)

texture of the kernel from soft and malleable state (rubbery) to glassy (brittle) state. It may be pertinent to mention that, the final moisture content in the kernel is very important for good puffing quality. Thus, this end-point moisture content could be determined indirectly with reasonable accuracy and rapidity by measuring the hardness of the kernel during pre-conditioning.

Pre-conditioned rice prepared with this developed machine was evaluated in terms of percentage of puffing and expansion ratio, typically for a sample containing 3.5% w/w salt. These quality characteristics were compared between the puffed samples obtained by traditional method of hot sand bed puffing and by microwave puffing. The average values of both percentage of puffing and ER are given in Table 2. It revealed that puffing quality obtained with two methods was comparable to each other (non-significant difference); rather percentage of puffing was slightly more in microwave puffing (97.84 ± 1.60). The Expansion of puffed rice volume were achieved more than 6.30 in both the puffing methods. Thus, it could be concluded that, the machine could be utilized for bulk production of the conditioned rice. This prepared rice

Table 2 Comparison of puffing performance of conditioned rice prepared in the machine

Puffing Method	% Puffing	Expansion Ratio
Microwave oven at 29.75kJ@	97.84 ±1.6	6.3±0.28
Traditional	92.2 ±0.69	6.4±0.22
t-test	2.044^{ns}	0.8875^{ns}

@ 850 W for 35 seconds, ns- non-significant could be puffed well by either of the two puffing methods without deterioration of its puffing quality significantly.

The developed machine can efficiently produce pre-conditioned rice suitable for making puffed rice. The pre-conditioning process takes about 90 minutes for pre-conditioning the grain with proper hardness of about 44-47 N and moisture content of 10-10.3 % (wb). The pre-conditioned rice produced by the newly developed machine has puffed well both in hot sand bed and microwave puffing.

REFERENCES

ASAE 1996. American Society of Agricultural Engineers Standards: Standards, Engineering Practices and Data. The Association, St. Joseph, MI.

Chandrasekhar PR and Chattopadhyay PK, 1989. Heat transfer during fluidized bed puffing of rice grains. J Food Process Engg. 11:147-157.

Chandrasekhar PR and Chattopadhyay PK, 1991. Rice puffing in relation to its varietal characteristics and processing conditions. J Food Process Engg. 14: 261-277.

Chattopadhyay P K, 2004. Post harvest technology for rice in India: A changing scenario, In : Rice is life: Scientific Perspectives for the 21st Century, Toriyama K, Heong K.L, Hardy B., (Eds.). Proceedings of the World Rice Research Conference held in Tokyo and Tsukuba, Japan, 4-7, November 2004. Los Baños, Philippines, pp., 294-296

Chinnaswamy R and Bhattacharya KR, 1983a. Studies on expanded rice, physico-chemical basis of varietal differences. J Food Sci. 48: 1600-1603

Chinnaswamy R and Bhattacharya KR, 1983b. Studies on expanded rice, optimum processing conditions. J Food Sci. 48: 1604-1608

Hoke K, Housˇka M, Pruchova J, Gabrovska D, Vaculova K and Paul I, 2007. Optimisation of puffing naked barley. J Food Engg. 80: 1016–1022

Maisont S and Narkrugsa W, 2010. Effects of salt, moisture content and microwave power on puffing qualities of puffed rice. Kasetsart J Natural Sci. 44(2): 251-261

Mariotti M, Alamprese C, Pagani MA and Lucisano M, 2006. Effect of puffing on ultrastructure and physical characteristics of cereal grains and flours. J Cereal Sci. 43: 47-56

Mohapatra M, 2010. Mechanized pre-conditioning of rice and its microwave puffing. Unpublished Ph.D. Thesis. IIT, Kharagpur, India, pp 94-98

Roos YH and Karel M, 1991. Phase transitions of amorphous sucrose and sucrose solution. J Food Sci. 56: 266-267

Singh J and Singh N, 1999. Effects of different ingredients and microwave power on popping characteristics of popcorn. J Food Engg. 42: 161-165

Srinivas T and Desikachar HSR, 1973. Factors affecting the puffing quality of paddy. J Sci. Food Agric. 24: 883 – 891

Villareal CP and Juliano BO, 1987. Varietal differences in quality characteristics of puffed rices. Cereal Chem. 64 : 337-342