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Effect of Milling Quality and Hardness of Parboiled Paddy under Microwave Drying

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

The objective of this study was to investigate the effect of bed thickness (1.5, 3, 4.5 and 6 cm) and microwave power level (180, 360, 540 and 720 W) on milling quality and of parboiled paddy under microwave drying. Major factor to reduce the head yield was observed increasing drying rate with increasing microwave power. Head yield varied from 47.9 to 70.3% within a variance of 1% significance. The Hardness of parboiled rice varied from 17692.3-13790.2 g/mm^2, depending upon the microwave power treatment and bed thickness at 1% level of significance. Highest hardness was observed at low microwave power and lower bed thickness.

Keywords: Microwave drying; parboiled paddy; quality parameters of paddy.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the most important staple food in world. According to the FAO reports, nearly 162 million hectares were under cultivation of rice with the total yield of 741 million tons in the world in year of 2014. At the time of harvesting the moisture content of paddy was 20-

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24% (wet basis). The moisture content of paddy from 12-13% w.b is considered safe for storage and milling [1]. Parboiling is a premilling treatment of paddy. Parboiling process consist of, first soaking of paddy in cold or hot water to increase the moisture content of paddy, second passing of steam into a paddy and third drying of high moisture paddy in sun or mechanical dryers. Gelatinization of starch takes place during the steaming process and it changes physiochemical properties of rice [2,3]. Parboiling reduces breakage, fat, protein, amylose content and increases thiamine content according to [4].

Several methods used for drying of parboiled rice, include sun or shade drying, hot air drying, vacuum drying, rotary dryers, etc. Most of rice millers use conventional method of hot air drying which consumes more energy, time and has low drying efficiency. To overcome this problem, fluidized-bed paddy dryer is used which is more competitive than conventional hot air dryers especially at high moisture level, i.e low energy consumption [5,6] proposed that a high heating rate and rapid moisture removal for drying of freshly harvested rice can be achieved with a relatively short heating time with an application of microwave for drying [7,8]. [8] proposed that microwave energy gives maximum drying efficiency. The use of microwave power combined with hot air drying of corn and oil seeds led to higher drying rates in comparison with the conventional hot air drying [9,10].

Keeping in view, the above consideration no reported research has focused on microwave drying of parboiled paddy. The objective of the present work is to evaluate the effect of microwave power and grain bed depth on percent head yield, hardness and specific energy consumption using microwave drying.

2. MATERIALS AND METHODS

2.1 Experimental Procedure

IR 36 variety of paddy, a long-grain type was used in this experiment which was stored at Rice mill of Department of Agricultural and Food Engineering IIT Kharagpur. Paddy was cleaned by an aspirator (Mc Gill Co., USA) (Fig. 1) to remove the immature paddy, chaff, twigs and dirt etc. The initial moisture content of the paddy used during experimentation was found in the range of 9.9-10.62% (wb). Moisture content was determined by gravimetric method in an air-oven at 105℃ for 24 hours [11]. Cleaned paddy soaked in hot water at temperature of 70-75°C in water bath with a time of 2-2.5 hours [12]. Water bath is laboratory equipment made from a container filled with heated water. It is used to incubate samples in water at a constant temperature over a long period of time. Pressurized steam was passed through a perforated pipe at 1.5 kg/cm^2 until husk began to crack in steaming unit [13]. The laboratory steaming unit consists of steam generator and pressure vessel connected with a high pressure pipe. The steaming unit can generate up to 5 kg/cm^2 pressure. The pressure chamber consists of a strainer and a perforated pipe for uniform distribution of steam throughout the soaked paddy. After steaming the moisture content of paddy was 42.86% (db) or 30% (wb) which was measured by digital balance (Shimadzu TX-423L) with an accuracy of ±1 gm. Paddysamples at 42.86% (db) moisture content were dried in microwave at a different bed depths of 1.5, 3, 4.5 and 6 cm and microwave power level of 180, 360, 540 and 720 W.Samples were dried up to moisture content of 14±1% (db).

2.2 Milling Quality Evaluation

On completion of drying operation, the sample moisture content of 14±1 (db) were de-husked in a laboratory model rubber roll Sheller (Satake, Japan) as shown in Fig. 2. The brown rice was then separated into the head rice grains and broken grains by vibratory grader (Burrows Equipment Company, Illinois, USA) as shown in Fig. 4. For milling process, brown rice was put into the abrasive roller polisher (Satake, Japan) and polished to white rice as show in Fig. 3. The product from the polisher was cleaned and separated from the head rice and broken by vibratory grader (Burrows Equipment Company, Illinois, USA) as shown in Fig. 4. Separated fractions of head rice and broken grains were weighed separately. The percent head yield was then calculated with respect to the initial weight of paddy. The various milling quality parameters are calculated as follows:

Head Yield (%) =

$$\frac{weight\ of\ milled\ head\ rice}{weight\ of\ paddy} \times 100 \tag{1}$$

Broken content (%) =

$$\frac{weight\ of\ broken\ milled\ rice}{weight\ of\ total\ milled\ rice} \times 100 \tag{2}$$

Fig. 1. Aspirator

Fig. 2. De-husker

Fig. 3. Abrasive type polisher

Fig. 4. Grader

2.3 Hardness

Hardness of each kernel was determined by texture analyzer machine (Texture Technologies Corp., Stable Microsystems Ltd, TA-XT2i, UK). The cylindrical probe of 6 mm diameter attached to a 25-kg load cell was used to compress the kernel. The values were reported by the mean of three replications.

3. RESULTS AND DISCUSSION

3.1 Effect on Milling Quality of Microwave Dried Paddy

The 3D surface graph for the effect of microwave power and thickness on head yield of parboiled paddy showed that, by decreasing the microwave power, head yield highly significantly increased ($p<0.0001$) Similarly, increasing the thickness, head yield also significantly increased ($p=0.0006$).

The Head yield of parboiled paddy varied from 47.9 to 70.3%. A second order polynomial equation (Eq. (1)) was fitted on the experimental data and tested for significance through ANOVA. Eq. (1) showed the predicted values of head yield (HY) as a function of coded values of bed thickness (A) and microwave power (B). A High correlation coefficient (r^2=0.966) obtained for the response variable, indicated that the developed model for the head yield explained the 96.6% of the total variation.

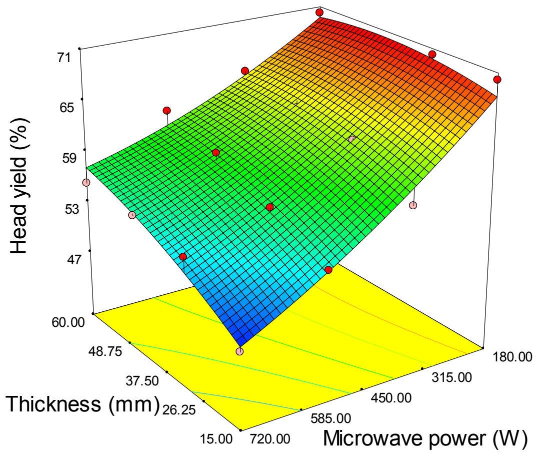

Fig. 5. Effect of microwave power and bed thickness on head yield

Head yield =60.76+2.52* A-8.10* B+1.87* A * B-1.13 * A^2+1.33* B^2 (3)

The result showed that, for the selected range of variables, microwave power (B) had significant effect on head yield at 1% level of significance, while bed thickness (A) had significant effect on head yield at 1% level of significance (Table 1). The combined effect of microwave power and bed thickness affect non-significantly the head yield for a selected range of variables (p>0.05). From the observation of combined effect, it can be said that higher microwavepower when applied tolower bed thickness, the head yield decreases due to higher rate of microwave power absorption. Rapid removal of moisture could be stated as contributing to a higher stress in the rice kernel at the time of drying resulting in a high percent of breakage. Same result found was also observed earlier by [14].

3.2 Effect on Hardness of Microwave Dried Paddy

The Hardness of parboiled rice varied from 17692.3-13790.2 g/mm^2, depending upon the microwave power treatment and bed thickness. A second order polynomial model was adequately fitted to the observed data with a correlation coefficient of (r^2=0.9547). The result showed that, for the selected range of variables, microwave power (B) had significant effect on hardness at 1% level of significance, while bed thickness (A) had significant effect on hardness at 1% level of significance (Table 1). [15] suggested the relationship between hardness and milling yield of parboiled rice was increase in head rice yield with increase in hardness.

Hardness = 15303.62-1196.85* A-1016.44* B+195.19* A * B+95.23* A^2+158.61* B^2 (4)

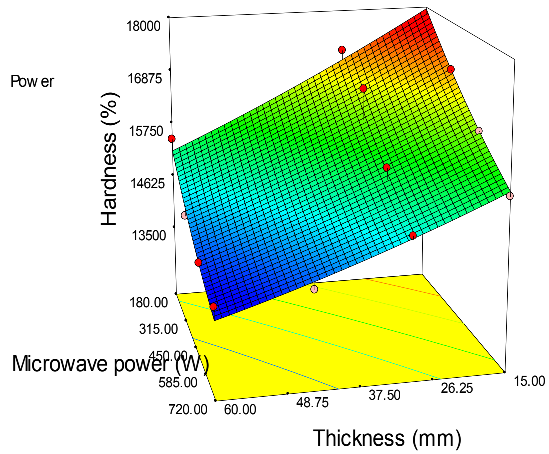

Fig. 6. Effect of microwave power and bed thickness on hardness

The combined effect of microwave power and bed thickness affects the for a selected range of variables (p>0.05). From the observation of combined effect, it can be said that higher microwave power when applied for higher bed thickness, hardness can decrease due to higher rate of microwave power absorption. The quadratic term of pressure had non-significant effect (p>0.05). The model F value of 42.28 implies the model is significant. There is less than 0.01% chance that an F-value this large could occur due to noise.

3.3 Optimization of Parameters

Optimization of quality parameters was carried out. To perform this operation "Design Expert 7.0.0" software was utilized and used for simultaneous optimization of multiple responses. The desired goals for each factors and response were chosen and different weights were assigned to each goal to adjust the shape of its particular desirability function.

The optimum condition was selected at maximum desirability by software itself which gave the common optimum condition for all quality indices.

Based on the desirability, the optimized solution was chosen as the best solution, given in Table 2.

Table 1. ANOVA for different quality attributes of microwave dried paddy and specific energy consumption

Source of variation	Sum of square	DF	Mean sum of square	F -value
(a) Head yield				
A-Thickness	56.6	1	56.6	24.83^{**}
B-Microwave power	583.15	1	583.15	255.78^{**}
AB	17.19	1	17.19	7.54^{*}
A^2	4.03	1	4.03	1.77^{ns}
B^2	5.56	1	5.56	2.44^{ns}
Residual	22.8	10	2.28	
(b) Hardness				
A-Thickness	1.27E+07	1	1.27E+07	120.94^{**}
B-Microwave power	9.18E+06	1	9.18E+06	87.23^{**}
AB	1.88E+05	1	1.88E+05	1.79^{ns}
A^2	28664.18	1	28664.18	0.27^{ns}
B^2	79509.9	1	79509.9	0.76^{ns}
Residual	1.05E+06	10	1.05E+05	

ns =Non significant.
*** Significant at 1% level.*
** Significant at 5% level*

Table 2. Optimized solution for quality parameters

Thickness (mm)	Microwave power (W)	Head yield (%)	Hardness (g/mm^2)	Desirability	
15.00	291.21	63.43	17363.14	0.78	Selected
15.00	293.37	63.34	17351.92	0.78	
15.00	283.52	63.76	17403.07	0.78	

4. CONCLUSION

The Effect of microwave power level (180, 360, 540 and 720 W) and grain bed thickness (1.5, 3, 4.5, and 6 cm) on quality attributes of microwave dried parboiled paddy was studied. At a particular power level an increase in bed thickness resulted in a decrease in head yield while at lower thickness the grains absorbed more energy causing an increase in brittleness of milled rice thereby reducing the head yield. At a particular bed thickness, an increase in power level lowered the head yield. These results were due to the higher energy absorption of the paddy grains which led to a sharp increase in grain temperature. Though a rapid increase of temperature results in the higher rate of water removal, it causes an increase in brittleness of grain. The head yield was influenced by microwave power level at 1% level and bed thickness at 5% level of significance. As the power level increased, the hardness decreased and as the thickness was decreased the hardness got increased because of higher energy absorption.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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