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Effect of variety, pressure and specific volume of steam on the head rice yield of milled parboiled rice

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Effects of variety, steam pressure and specific volume of steam on head rice yield of milled parboiled rice were studied. Rice varieties selected were 'Faro 21', 'Faro 27', 'Faro 29' and 'Faro 35'. Four levels each of steam pressure and specific volume of steam were used in parboiling the rice samples with the aid of insulated electric parboiling equipment. The samples were milled after drying and tempering to 13% moisture content. Higher head rice yield of 93.3% was obtained with rice parboiled with the higher process steam pressure (5.5×10^4 N/m^2). The second (1.290 m^3/kg) level of specific volumes of steam gave higher head rice yield. 'Faro 29' gave the highest head rice yield. Regression equations capable of predicting head rice yield at varying steam pressures and specific volumes of steam are also presented.

Keywords: Paddy, Parboiling, Milling, Head rice yield, Rice variety, Steam pressure, Specific steam volume

Rice parboiling is a hydrothermal process that causes gelatinization of starch within the rice grain, which results in irreversible swelling and fusion (Araullo et al 1976). During this process, the starch granule changes from a crystalline form to amorphous one. As a result, the orderly polyhedral structure of the starch granule changes into a coherent mass (Reghavendra and Juliano 1982). Subsequent drying of the parboiled paddy from about 45 to 14% moisture level imparts hardness to the grain that enables it to withstand the milling pressure arising from friction between the rice kernels and the milling chamber and among the kernels. This ability of the dried parboiled rice grain to withstand milling pressure gives increased head rice yield (Juliano 1985). Also other parboiling and drying conditions have been found to affect head rice yield of rice. In related studies, head rice yield and broken grains were observed to be influenced by drying parameters only (Igbeka et al 1991). Gariboldi (1984) and Bhattacharya et al (1989) have also suggested two pass drying with 8-12 h tempering period between them for mechanical drying of parboiled paddy in order to obtain maximum head rice yield. Also, an inter-relationship study between head rice yield and brown rice temperatures from 0°C to 25°C showed a linear inverse relationship (Archer and Sabenmorgen 1995). Since rice parboiling is an hydrothermal process involving the use of heat energy, it is expected that some basic thermodynamic properties play significant role in the gelatinization process of the rice kernel. Thus, the study on the effect of steam pressure, specific volume of steam and variety on head rice yield was undertaken.

Materials and methods

Four rice varieties, 'Faro 21', 'Faro 27', 'Faro 29' and 'Faro 35' representing the conventionally known grain sizes (short, medium and long) grown by Nigerian farmers, were collected from the National Cereals Research Institute, Badeggi. A total of 192 kg of paddy for 64 treatments of 3 replications each were obtained. The paddy samples were shade dried to 13% moisture content (wet basis) before parboiling. Paddy samples were soaked in closed plastic containers with water heated to 70°C under the same condition for 6 h. Samples were heated in closed plastic containers in water to minimize heat loss across the walls of the container. An electric rice parboiler was designed and fabricated to carry out the experiments.

Effect of steam pressure on parboiled rice quality: The soaked paddy samples were put into the steamer of the parboiler. Water was introduced into the boiler to the previously marked level for the corresponding specific volume of steam, water was left to boil and the pressure of the steam was adjusted with the aid of a pressure relief valve to the first level. When a constant gauge pressure was attained, the steam valve was opened for steam to pass to parboil the rice in the steamer for 35 min. This procedure was repeated for the remaining 3 levels of pressure for each variety of paddy and specific volume of steam.

Effect of specific volume of steam on parboiled rice: In this, various levels of steam were used for parboiling rice at constant steam pressures. This was done by evaporating water at different levels in the boiler using the electric heating system before passing the steam to the steamer containing the paddy samples for 35 min.

Effect of rice variety on quality of parboiled rice: Steam was passed at constant level of pressure to parboil a particular rice variety with specific volume of steam at a time. The experiment was repeated for all the rice varieties.

Drying: Steamed paddy samples were thinly spread on a clean concrete floor in the shade to ensure gradual drying of individual kernels to 13% moisture content (Juliano 1985).

Milling: The dried paddy samples were milled separately in a Nr. 45 universal huller. The huller was always adjusted to the same degree of pressure for both dehusking and polishing operations for all samples. The huller was properly cleaned to ensure that no residues were left behind after each milling operation.

*Determination of head rice yield***:** The milled rice was separated into whole and broken grains in 2 passes with sieve 5H 1-40-0807 having 2.8 mm diameter holes (Agrawal et al 1987). The whole and broken grains were weighed with a precision weighing balance, BC 340 and the percent head rice yield (HRY) was computed as follows.

$$HRY\ \% = \frac{\text{Mass of whole grain}}{\text{Total mass of milled rice}} \times 100 \quad ...(1)$$

Results and discussion

Effect of steam pressure on head rice yield: Head rice yields varied from 59.0 to 93.9% (Table 1). The percent head rice yield at steam pressures of 4.0 x 10^4 N/m^2 and 5.5 x 10^4 N/m^2 were higher than those at lower pressures. These observations conform with the findings of Agrawal et al (1987), who reported that head rice yield increased with increase in steaming pressure when both high and low moisture content rice were steamed without soaking. In addition, hardness of parboiled rice kernel has been confirmed to be proportional to the severity of heat treatment during processing (Pillaiyar and Mohandos 1981). This finding agrees with the result of Agrawal et al (1987) in which the rice steamed with lower steam pressure produced some "white belly" rice indicating incomplete parboiling as a result of the inability of the lower pressure to sufficiently transmit the heat energy of the steam into the inner layers of the rice kernel. Subsequently, this condition results in lower head rice yield and corresponding higher levels of broken grains. Resistance to breakage has been correlated to brown rice translucency, which depends on the degree of parboiling (Luh and Mickus 1980).

Effect of specific volume of steam on head rice yield: Head rice yield increased between the initial (1.148 m^3/kg) and second (1.290 m^3/kg) specific volumes of steam but it decreased with further increase in specific volume of steam (Table 1). It was further observed that the head rice yield for any specific volume of steam was higher for 'Faro 27' and 'Faro 29' varieties than 'Faro 21' and 'Faro 35'.

Effect of rice varieties on head rice yield: Rice varieties were also found to affect head rice yield. This can be deduced from Table 1. 'Faro 27' and 'Faro 29' had almost similar higher head rice yield than 'Faro 21' at corresponding steam pressures and specific volume of steam. Head rice yield of 82.1 - 93.9% and 80.3 - 93.3% were obtained for 'Faro 29' at steam pressures of 4.0 x 10^4 and 5.5 x 10^4 N/m^2, respectively while 'Faro 21' had 59 - 71% head rice yield at the lowest steam pressure. This could be as a result of their difference in the physicochemical properties of the grains.

Regression equation: The following regression equations were developed using the data generated in Table 1 in order to predict head rice yield at varying steam pressures and specific volume of steam. During the study, individual parboiling conditions were separately considered.

Head rice yield and steam pressure:

$$H = -3.3833P^3 + 25.05P^2 - 50.867P + 112.4 \quad ...(2)$$

where, H is head rice yield (%) and P is steam pressure (N/m^2)

Head rice yield and specific volume of steam:

$$H = -1.5833v^3 - 16.85v^2 + 50.367v + 46.8 \quad ...(3)$$

where v is specific volume of steam (m^3/kg)

Table 1. Average head rice yield of rice for various combinations of steam pressures, specific volumes of steam in boiler and rice varieties

Steam pressure (x10^4 N/m^2)	Sp steam vol in boiler, m^3/kg	Total head rice yield, %			
		'Faro 21'	'Faro 27'	'Faro 29'	'Faro 35'
1.0	1.148	59.0	64.5	65.7	62.7
	1.290	71.0	83.6	83.3	76.4
	1.433	72.6	76.1	79.4	73.9
	1.576	65.7	72.7	73.0	69.6
2.5	1.148	62.2	69.3	71.6	65.4
	1.290	75.4	81.9	83.7	78.2
	1.433	73.6	78.1	82.7	75.8
	1.576	70.8	74.6	78.8	72.5
4.0	1.148	63.5	68.7	70.2	66.2
	1.290	80.3	89.2	93.9	86.7
	1.433	76.9	83.6	86.6	82.3
	1.576	72.5	80.4	82.1	87.5
5.5	1.148	68.0	74.5	81.8	67.5
	1.290	80.6	90.1	93.3	88.1
	1.433	78.4	84.0	87.9	80.1
	1.576	74.1	77.5	80.3	75.8

Conclusion

Process parameters such as steam pressure and specific volume of steam and rice varieties greatly influence the head rice yield of parboiled milled rice. Higher steam pressures resulted in higher head rice yield while head rice yield increased between 1.148 and 1.290 m^3/kg levels of specific volume of steam but decreased between 1.290 and 1.576 m^3/kg levels. As a result the highest steam pressure (5.5 x 10^4 N/m^2), the second level of specific volume of steam (1.290 m^3/kg), which gave the highest head rice yield are considered as the optimum process parameters while 'Faro 29' is the best suited rice variety for parboiling.

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