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The influence of variety and various process parameters on the total milling yield of parboiled rice

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ABSTRACT: The effect of steam pressures, specific volume of steam and variety on total milling yield was investigated. Four rice varieties, 'Faro 21', 'Faro 27', 'Faro 29' and 'Faro 35' popularly adopted in Nigeria were used. An insulated electric rice parboiler was used to steam the rice samples previously soaked in hot water for 6 hours under recommended conditions. The samples were dried, milled and analysed. Results showed that a higher total milling yield of 71% was observed at the higher process steam pressure of 5.5 x 10^4 N/m^2. The 1.29 m^3/kg specific volume of steam also had higher milling yields while the 1.15 m^3/kg and 1.58 m^3/kg levels of specific volume of steam had lower values. Rice variety, Faro 29 recorded the highest total milling yield of 71%.

Key Words: Process parameters; Rice varieties; Parboiled rice; Milling yield.

Introduction

The paddy contains about 68-72% edible portion, 20% husk, 5% bran and 2.5-3% germ (Badyopadhay and Roy 1992). The starch, iron and amylose contents have been assessed to be 66.4%, 12% and 26.5% respectively (Resurrection *et al* 1979). The rice kernel energy content is 3.75%, whilst the protein content of 7.5% is the same as that of maize.

This protein content value ranks it third after wheat and sorghum (IRRI 1993). Although paddy could be milled raw, it has been reported that raw milling of rice always results in reduced total milling yield in addition to other numerous disadvantages (Juliano 1985, Araullo *et al* 1976). Thus paddy parboiling, which originated in India (Ramiah 1937) was found to have many advantages including increased total milling yield. In order to obtain parboiled milled rice, other processes which includes drying after parboiling and tempering before milling are essential.

Various parameters of all these processes have been reported to influence the quality of the product. Among these qualities, total milling yield has been found to be greatly affected by various parboiling parameters (Juliano 1985). Total milling yield is the percent total edible rice recovered after processing the harvested paddy. Various research works have shown that some parameters affect the milling out-turn of rice.

Araullo *et al* (1976) asserts that removal of excess water after parboiling of paddy is very important but emphasised that rapid drying creates cracks and checks in the kernels which result in rice breakage during milling and subsequently low milling recovery. However, an increase in milling yield was observed with rapid drying to 12% moisture content (wb) with 80^{o}C air followed by tempering at 90^{o}C for an hour (Stipe *et al* 1975).

Also dried parboiled rice was observed to record a 5.3% increase in milling yield after 48 hours of tempering period after drying compared with milling similar material immediately after drying (Luz *et al* 1993).

However it was not advisable to exceed 168 hours tempering period. An exhaustive literature review on the paddy parboiling process shows that the effect of the interaction of variety and some important process parameters such as steam pressure and specific volume of steam on total milling yield of Nigerian rice varieties has not been investigated. The basic thermodynamic properties of the steam used in parboiling the paddy may influence the result of the total milling yield of parboiled milled rice. Thus, this study investigates the effect of steam pressure, specific volume of steam and variety on total milling yield of parboiled rice.

Materials and Methods

Four popular Nigerian rice varieties, 'Faro 21', 'Faro 27', 'Faro 29' and 'Faro 35' were collected from the National Cereals Research Institute, Badeggi, they represent the conventionally known grain sizes (short, medium and long) grown by farmers in Nigeria. The rice samples were shade dried to 13% moisture content (w. b.) before parboiling. A total of 192 kg of rice for 64 treatments of three replications each were obtained. The materials were prepared for the experiments by completely soaking the paddy samples in water heated to 70^{o}C with the boiler under the same condition for 6 hours in closed plastic containers which were used to minimise heat loss across the container walls. An electric rice parboiler was designed and fabricated to carry out the following three experiments.

Effect of pressure of steam on total milling yield of parboiled rice:

Each of the soaked rice samples was placed in the steamer of the parboiler. The electric heating system of the boiler was switched on after introducing water into the boiler to the level previously marked for the corresponding specific volume of steam and was left to boil. The pressure of the steam was then adjusted with the aid of a pressure relief valve to the first level. When a constant gauge pressure indicated by the bourdon pressure gauge attached to the steamer was attained, the steam passage valve of the steam conveying pipe that connects the boiler and the steamer was opened for steam to pass to parboil the rice in the steamer for 35 minutes as previously tested. This procedure was repeated for the remaining three levels of pressure for each variety of rice and specific volume of steam.

Effect of specific volume of steam on total milling yield of parboiled rice:

Various specific volumes of steam were used in parboiling the rice samples at constant steam pressures. This was done by evaporating water at different levels in the boiler with the aid of the electric heating system before passing the steam to the steamer containing the rice samples for 35 minutes.

Effect of rice variety on total milling yield of parboiled rice:

This experiment was performed by passing steam to parboil a particular rice variety using constant level of steam pressure and specific volume of steam at a time. The experiment was repeated for all the rice varieties studied.

Drying:

The 192 (4 pressures x 4 specific volumes x 4 varieties x 3 replications) steamed samples of paddy from the three experiments were thinly spread on a clean concrete floor in the shade in order to ensure gradual drying of individual kernels to 13% m.c. (w.b.). Thin layer shade drying was preferred to open sun drying because stress gradients in the dried kernels which result in high breakage during milling are usually associated with rapid open sun drying (Juliano 1985). Also, shade drying ensures even tempering of the rice kernel resulting in less broken grains when milled.

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 no residues left behind after each milling operation.

Determination of total milling yield:

Each of the samples was weighed with a precision balance (BCW 340) and the total milling yield was expressed (Bandyorpadhay and Roy 1992) as a percentage of the mass of the rice sample before milling.

Results and Discussion

The results obtained from the total milling yield analysis on the rice samples that were subjected to varying levels of steam pressure and specific volume of steam in the parboiling process are presented in (Table 1).

Effect of steam pressure on total milling yield:

The total milling yield generally increased with increase in steam pressure. The highest total milling yield means of 61.5% and 60.9% were observed for the highest steam pressures of 5.5 x 10^4 N/m^2 and 4.0 x 10^4 N/m^2 respectively while the lowest milling yield range of 54% is recorded for the lowest steam pressure of 1.0 x 10^4 N/m^2. This could be as a result of higher starch gelatinisation and hardness imparted on the rice kernels due to higher severity of heat treatment with the higher levels of steam pressures compared to those of the lower levels. This observation seems to conform to the results of an earlier study (Juliano 1982) where the ability of the parboiled rice grain to withstand milling pressures was found to increase with increasing severity of heat treatment using steam.

Effect of specific volume of steam on total milling yield:

Specific volume of steam in the boiler affected total milling yield at all the steam pressures as indicated in (Table 1). Total milling yields increased sharply with increase in specific volume of steam between 1.15 m^3/kg and 1.29 m^3/kg levels and decreased with further increase in specific volume of steam between the 1.29 m^3/kg – 1.58 m^3/kg levels. The higher total milling yield at the 1.29 m^3/kg level of specific volume of steam is attributable to relatively high steam density of 0.7752 kg/m^3 and high specific enthalpy of vapour of 2688.23 kJ $kg^{-1}k^{-1}$ compared with the steam of higher specific volumes of steam of 1.43 m^3/kg and 1.58 m^3/kg that have corresponding lower steam densities of 0.6978 kg/m^3 and 0.6345 kg/m^3, respectively, as seen in (table 2). Though the density of the 1.15 m^3/kg level of specific volume of steam is even higher (0.8711 kg/m^3) than the others, milling yield was not as high as that of the 1.29 m^3/kg level. This might be as a result of comparatively lower specific entropy of 7.20 kJ kg^{-1} k^{-1}. Unlike the 1.43 m^3/kg and 1.58 m^3/kg levels of specific volume of steam, the relatively moist nature of the steam of the second level of specific volume of steam with the corresponding higher enthalpy seems to ensure efficient migration of steam into the inner layers of the rice kernels to properly gelatinise the starch. This assertion seems to conform to the findings of Araullo *et al* (1976) and Gariboldi (1989) that moist heat and saturated steam having higher density are more suitable to gelatinise soaked rice. In addition to the lower milling yield of the 1.58 m^3/kg, 1.43 m^3/kg and 1.58 m^3/kg levels of specific volume of steam, higher breakages, and dryness of rice sample immediately after parboiling and presence of some white bellied rice were observed.

Table 1: Average total milling yield of rice for various combinations of pressures, Specific volumes of steam in boiler and rice varieties.

Gauge pressure of steam (x 10^4 N/m^2)	*Specific volume of steam in boiler,(m^3/kg)*	*Total milling yields, % Rice Varieties*			
		'Faro 21'	'Faro 27'	'Faro 29'	'Faro 35'
	1.15	44.7	48.2	49.0	46.9
10	1.29	57.5	61.4	63.0	60.1
	1.43	55.4	58.0	59.6	57.4
	1.58	51.4	53.8	55.6	52.5
25	1.15	46.2	46.2	50.6	48.1
	1.29	60.0	60.0	63.6	60.5
	1.43	55.3	55.3	62.3	58.1
	1.58	54.8	54.8	59.6	56.3
40	1.15	49.3	49.3	52.3	50.2
	1.29	65.4	65.4	70.6	67.9
	1.43	60.8	60.8	65.3	62.5
	1.58	58.6	58.6	64.3	63.3
55	1.15	50.6	50.6	54.3	52.6
	1.29	64.0	64.0	71.0	76.0
	1.43	56.6	56.6	66.0	65.0
	1.58	55.6	55.6	64.6	64.3

Table 2: Steam Properties

Temp. of steam (^{0}C)	Specific volume of steam (m^3/kg)	Specific Internal Energy U(KJ/kg)	Specific Enthalpy h(KJ/kg)	Specific entropy, S(KJ/kg^{0}K)	Density (kg/m^3)
111.7	1.15	2519.316	2693	7.0	0.8711
108	1.29	215.818	2688.227	7.288	0.7752
104.5	1.43	2510.568	2682.64	7.302	0.6978
101.8	1.58	2509.259	2679.074	7.333	0.6345

Effect of rice variety on total milling yield:

Rice varieties also influenced total milling yield values significantly when parboiled at constant pressures and specific volume of steam. Total milling yields were higher for 'Faro 29' and lower for 'Faro 21' at corresponding levels of steam pressure and specific volume of steam. Generally, the highest total milling yields for all rice varieties were recorded at the higher steam pressures, 4.0 x 10^4 N/m^2 and 5.5 x 10^4 N/m^2 and 1.29 m^3/kg specific volume of steam while the lowest total milling yield was obtained at the lowest steam pressure, 1.0 x 10^4 N/m^2 and highest (1.58 m^3/kg) and lowest (1.15 m^3/kg) specific volumes of steam. These results are indicative of the influence of varietal difference on total milling yield. The relatively higher amylose content of 19.6% and 20.5% for 'Faro 27' and 'Faro 29', respectively, compared to 'Faro 21' which has a very low amylose content of 13.7% as given in (Table 3) seems to be responsible for their higher total milling yields. Plank and Hogan (1988) had earlier defined amylose content as the starch constituent which is responsible for the development of blue colour when treated with iodine and that rice varieties having high amylose contents usually have tendencies to yield a firm, dry and non sticky product. This observed firmness and nonstickiness property of the high amylose content of the long and medium grain rice after parboiling may have been responsible for the rice to resist breakage during milling. Thus, higher milling recoveries were obtained for Faro 29 and 'Faro 27' which are medium grain varieties. Generally, all the main variables: steam pressure, specific volume of steam and rice variety and their interactions showed very high statistical significant at 5% on total milling yield.

Table 3: Protein and Amylose Contents

Rice	Replications	Average Amylose Content %	Average Protein Content %	Grain type
'Faro 21'	1 2 3	13.7	9.37	Short
'Faro 27'	1 2 3	19.6	7.77	Medium
'Faro 29'	1 2 3	20.5	6.77	Medium
'Faro 35'	1 2 3	23.0	9.0	Long

Conclusion

Total milling yield of parboiled rice were greatly affected by variations in steam pressure, specific volume of steam and rice variety. In general, the highest steam pressure levels (5.5 x 10^4 N/m^2 and 4.0 x 10^4 N/m^2) and 1.29m^3/kg specific volume of steam had the highest total milling yields. For the rice varieties, 'Faro 21', 'Faro 27', 'Faro 29' and 'Faro 35', 'Faro 29' produced the highest total milling yield. The optimum process parameters in this study are 4.0 x 10^4 N/m^2 - 5.5 x 10^4 N/m^2 steam pressures and 1.29m^3/kg specific volume of steam while the best rice variety is 'Faro 29'.

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