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Relationship between the degree of milling, ash distribution pattern and conductivity in brown rice

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Abstract

Four Indian rice cultivars differing in their shape (length–breadth ratio) were evaluated for ash distribution pattern using a McGill No.2 rice miller. Brown rice obtained from all rice cultivars was milled for 10, 20, 30, 40 and 50 s and analysed for ash content, conductivity and percentage of bran removed. All the cultivars differed significantly with respect to percentage loss of ash content at various milling stages. Cultivars with lower length–breadth ratio showed a higher loss of ash than those having a higher length–breadth ratio under similar stages of milling. Ash content showed a linear relationship with conductivity of solubles extracted from brown rice milled for different intervals. R^2 values, for (the relationship between ash content determined by standard AACC method and the conductivity, was in the range of 0.90–0.99. The effect of extraction time and temperature on the relationship between ash content and conductivity of solubles was also studied. Statistical analysis showed a significant effect of extraction duration and extraction temperature on the intercept and slope values obtained from linear regression between ash and conductivity values for different cultivars. © 2000 Published by Elsevier Science Ltd. All rights reserved.

Keywords: Brown rice; Milled rice; Degree of milling; Ash content; Conductivity

1. Introduction

In rice milling, rough rice is dehusked to obtain brown rice which is subjected to abrasive or friction pressure to remove bran layers from the endosperm. The extent of removal of the bran layers is termed degree of milling, which determines the whiteness of rice. The degree of milling has been reported to affect head rice recovery, starch gelatinization, resistance to insect infestation and sensory quality (Champagne, Marshall & Goynes, 1990; Marshall, 1992; McGaughey, 1970; Piggot, Morrison & Clyne, 1991; Roberts, 1979; Sun & Siebenmorgen, 1993). In a number of studies, various chemical constituents, such as fat, ash, thiamine, phosphate and pigments which are concentrated in the outer branny layers, have been related to the degree of milling. Tsugita, Kurata and Kato (1980) observed a significant difference in both the odour of cooked rice and quantity of volatile components in rice with different degrees of milling. Villareal, Maranville and Juliano (1991) reported that with 10% bran-polish removal, milled rice retains 13% thiamine. Bajaj, Arora, Chhibbar and Sidhu (1989) investigated the loss of minerals during extended milling of rice in a laboratory miller (Model, Type-2, Kett Electric Co. Japan). They observed a loss of 53–71% for P, 57–96% for Ca and 62–98% for Mg with milling of rice. Bhattacharya and Sowbhagya (1972) reported that the concentration of the extractable pigment in successive layers of bran decreased linearly from the outermost to the innermost layer of brown rice. The estimation of degree of milling by measuring the amount of surface fat remaining on kernels through petroleum ether extraction has been described earlier (Hogan & Deobald, 1961; Watson, Dikeman & Stermer, 1975). This method is accurate and elaborate but time-consuming. Siebenmorgen and Sun (1994) established a linear relationship between degree of milling measured using a Satake MMI-B milling meter and surface fat concentration. Bhashyam and Srinivas (1984) described the determination of degree of milling by measuring whiteness using a photovoltaic reflectance meter. Determining the intensity of the visible or near

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infra-red light, reflected from or transmitted through milled rice, has also been reported as a method for determining the degree of milling (Delwiche, McKenzie & Webb, 1996). In our earlier study (Singh, Singh & Bakshi, 1998), we have reported that determination of ash content in wheat, based on conductivity, is a quick and alternate method to the routinely used method based on measurement of oxidized residue remaining after incineration at high (600°C) temperature for 5–6 h.

The objectives of the present research were to: (1) investigate the effect of milling duration on percent bran removed from brown rice, (2) determine the effect of milling duration on ash content in brown rice obtained from different rice cultivars, (3) establish the relationship between the ash concentration and conductivity of solubles extracted from brown rice, and (4) determine the effect of temperature and extraction duration on the conductivity of solubles–ash content relationship.

2. Materials and methods

2.1. Paddy samples

Jaya, PR-110, PR-106 and Basmati-370 were collected from Punjab Agriculture University Rice Research Station from the 1997 harvest and had moisture contents in the range of 14–15%.

2.2. Dehusking and milling

The samples were dehusked at 14% moisture content (wb) on a McGill rice sheller (Rapsco. Brookshire TX, USA). The full brown rice kernels (150 g) were separated from the brokens and milled in triplicate for 10, 20, 30, 40 and 50 s in the McGill Miller No.2 rice miller (Rapsco Brookshire, TX, USA) equipped with an automatic timer. The pressure on the rice during milling was controlled by placing a weight (660 g) on the mill lever arm. The weight was placed at a distance of 21.5 cm from the centre of the saddle to the centre of weight. The miller was thoroughly cleaned after each milling interval by brushing the bran and broken rice kernels from the screen and rotor. The mean length of ten rice kernels was divided by mean breadth of ten kernels to obtain length/breadth ratio.

2.3. Analysis

The brown rice samples, milled for different time intervals, were ground to pass through a 52 mesh sieve and analysed for ash content and conductivity. The ash contents of all samples were determined using the method (American Association of Cereal Chemists, AACC, 1995). The accuracy of the ash content determinations was +0.04–0.06%. Each sample [l g, 14% moisture basis (mb)] was dispersed with 25 ml of deionized water for 1, 2 and 3 h at 30, 40 and 50°C with stirring after every 15 min. The material was then centrifuged at 4000 *g* for 5 min and the supernatant was collected and analysed for conductivity. The conductivity was measured with a digital conductivity meter at a fixed frequency of 1000 Hz (Elico Pvt Ltd., Hyderabad). A dip type cell with cell constant 1.12 was used in all the measurements. The accuracy of the conductance measurements was ±0.5%.

2.4. Statistical analysis

The data in Fig. 1 and regression coefficients obtained for the relationship between conductivity and ash content were subjected to analysis of variance using Minitab statistical software (State College, PA). The data reported for ash content and conductivity are an average of three observations. The data reported for length–breadth ratio are an average of 10 observations.

3. Results and discussion

3.1. Relation between ash content and milling duration

Fig. 1 illustrates the effect of milling duration on ash content in different cultivars. Analysis of variance of data reported in Fig. 1 is shown in Table 1. Significant differences in ash content were observed among the

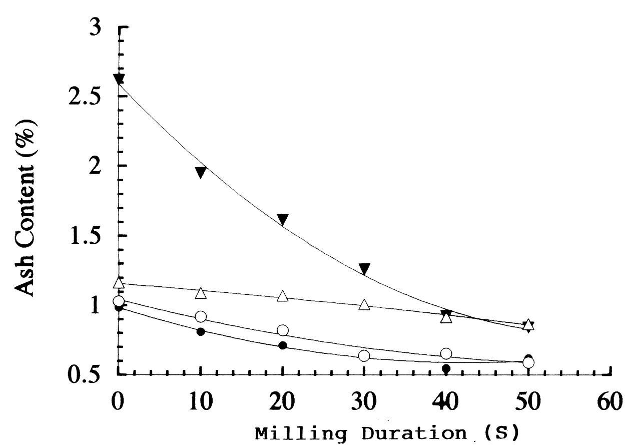

Fig. 1. Effect of milling duration on ash content in different cultivars. Jaya, ▼; Pr-110, ●; PR-106, ○ and Basmati-370, Δ.

Table 1
Analysis of variance of data in Fig. 1

Source	Degree of freedom	Sum of squares	*F*-value	P
Cultivars	3	5.096	538.2	0.001
Error	8	0.0253		
Total	11	5.121		

cultivars ($P \leqslant 0.001$). Jaya showed the highest ash content while PR-110 showed the lowest. The ash content progressively decreased with the increase in milling duration in all the cultivars. A similar effect of the degree of milling on ash content has been reported earlier (Miller, Lee & Rousser, 1979).

Table 2 shows the quadratic and exponential equations for the relationship between ash content and milling duration. R^2 values for the quadratic and exponential equations were in the range of 0.977–0.994 and 0.956–0.987, respectively. Jaya changed more in ash content after each successive milling interval than did PR-106, PR-110 and Basmati-370. These differences among the cultivars may be attributed to the variation in the removal of bran layers rich in ash content after each milling interval. Fig. 2 illustrates the effect of milling duration on percentage ash loss in different rice cultivars. The percentage loss of ash increased with the increase in milling duration in all the cultivars. Jaya cultivar had the highest loss of ash whereas Basmati-370 had the lowest loss of ash content at different milling stages. The percentage loss of ash increased with increase in removal of bran in different cultivars. A higher concentration of ash in outer bran layers of brown rice than in endosperm is well reported (Juliano & Bechtel, 1985). The ash distribution in brown rice has been reported as 51% in bran, 11% in polish, 10% in germ, and 28% in milled rice (Leonzio, 1967).

Table 2
Regression equation for the relationship between milling duration and ash content

Cultivar	Regression equation[a]	R^2
PR-110	$y = 0.0001x^2 - 0.0152x + 0.9689$	0.9827
PR-110	$y = 0.9298e^{-0.011x}$	0.9603
PR-106	$y = 0.0001x^2 - 0.015x + 1.0434$	0.9779
PR-106	$y = 1.018e^{-0.0118x}$	0.9569
Jaya	$y = 0.0005x^2 - 0.0612x + 2.5873$	0.9941
Jaya	$y = 2.5368e^{-0.0233x}$	0.9874
Basmati-370	$y = -0.00003x^2 - 0.0044x + 1.1647$	0.9922
Basmati-370	$y = 1.1843e^{-0.0061x}$	0.9773

[a] y = Ash(%), x = milling duration (s).

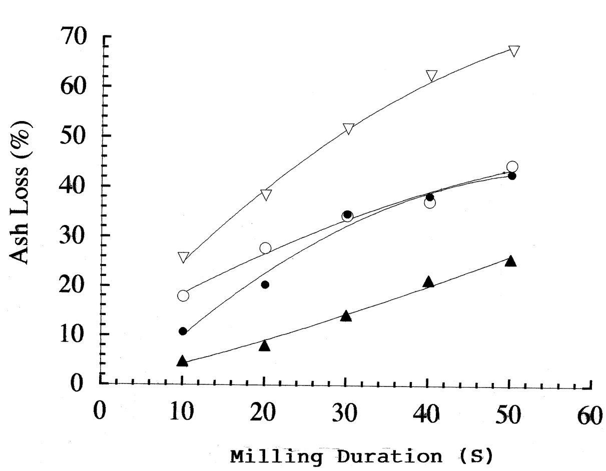

Fig. 2. Effect of milling duration on percent ash loss in different cultivars. Jaya, ∇; PR-110, ○; PR-106, ● and Basmati-370, ▲.

3.2. Relationship between milling duration and percentage bran removed

Fig. 3 shows the effect of milling duration and percentage bran removed in different cultivars. Each successive milling stage caused higher removal of bran from Jaya and lower from Basmati-370. A regression analysis was performed to determine the relationship between milling duration and percentage of bran removed in different cultivars. Table 3 lists the quadratic equations along with coefficient of determination for the relationship between milling duration and percent bran removed. The percentage of bran removed at successive milling intervals differs significantly in different cultivars. Jaya had the highest value for regression coefficient (slope), indicating highest rate of loss of bran and Basmati-370 had the lowest value, indicating its lowest rate. These differences in loss of bran at successive milling intervals in different cultivars are due to differences in shape and hardness of grains. The length: breadth ratio for Jaya, PR-106, PR-110 and Basmati-370 was 2.7, 3.1, 3.3 and 4.4, respectively, and percentages

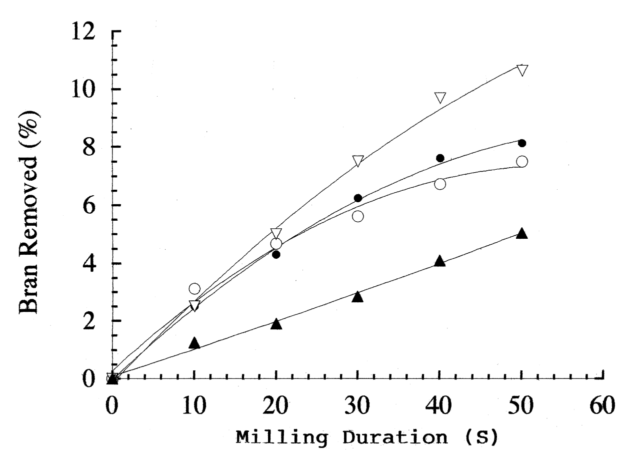

Fig. 3. Effect of milling duration on percent bran removed in different cultivars. Jaya, ∇; PR-110, ○: PR-106, ● and Basmati-370, ▲.

Table 3
Regression equation for the relationship between milling duration and bran removed

Cultivar	Regression equation[a]	R^2
PR-110	$y = -0.0021x^2 + 0.2733x - 0.0557$	0.9958
PR-106	$y = -0.0023x^2 + 0.2478x + 0.3682$	0.9662
Jaya	$y = -0.0016x^2 + 0.3015x - 0.1671$	0.9963
Basmati-370	$y = 0.0002x^2 + 0.0916x + 0.0954$	0.9946

[a] y = Bran removed (%); x = milling duration (s).

of bran removed after 50 s of milling from these cultivars was 10.6, 7.5, 8.0 and 5.1%, respectively.

3.3. Relationship between ash content and conductivity

To explore the relationship between ash content and conductivity, the conductivity of solubles extracted at different temperatures for varied extraction periods for different cultivars were fitted to a two parameter straight line. Tables 4–7 list the regression coefficients and coefficients of determination. The R^2 values for different models represents the proportion of variability in the data accounted for by the model. The R^2 values for different cultivars for the relationship between conductivity and ash content of solubles under different extraction conditions were in the range of 0.90–0.99. The R^2 values revealed that most of the variability in conductivity had been accounted for by the ash content in all the cultivars. The conductivity of solubles extracted from different cultivars showed a linear relationship with ash content. Fig 4 shows the relationship between conductivity of solubles extracted at 30°C for different intervals and ash content of PR-106. The regression coefficients obtained from regression analysis were subjected to analysis of variance to see the effect of extraction time and temperature. Both the extraction time and temperature showed significant effects on regression coefficient in all cultivars. The coefficient (slope) increased with the increase in extraction temperature and period of extraction in all the cultivars. This suggests that, with the increase in extraction time and temperature, greater amounts of inorganic salts have been extracted, resulting in an increase in conductivity. A similar conclusion can be drawn from the variation in coefficient (intercept).

All rice cultivars differ significantly with respect to ash distribution pattern and weight of bran removed during different milling intervals. Ash content in brown rice milled for different milling intervals showed a linear relationship with conductivity. The determination of ash content and degree of milling of milled rice by conductivity measurement is a simple and quick method. However, during ash determination in rice by conductivity, factors such as extraction time and extraction temperature should be taken into account. There is a need to carry out research work on the effect of parboiling

Table 4
Regression equation for the relationship between ash content versus conductivity

Cultivar	Extraction temperature (°C)	Extraction time (h)	Regression equation[a]	R^2
PR-110	30	1	$Y = 39.13 + 69.63X$	0.98
	40	1	$Y = 70.45 + 66.11X$	0.93
	50	1	$Y = 90.46 + 102.9X$	0.94
	30	2	$Y = 58.30 + 88.76X$	0.98
	40	2	$Y = 82.98 + 135.80X$	0.97
	50	2	$Y = 92.00 + 152.60X$	0.99
	30	3	$Y = 74.10 + 97.00X$	0.99
	40	3	$Y = 87.40 + 155.87X$	0.99
	50	3	$Y = 97.82 + 186.14X$	0.99

[a] X = ash content, Y = conductivity.

Table 5
Regression equation for the relationship between ash content and conductivity

Cultivar	Extraction temperature (°C)	Extraction time (h)	Regression equation[a]	R^2
PR-106	30	1	$Y = 70.90 + 60.60X$	0.90
	40	1	$Y = 76.63 + 66.20X$	0.96
	50	1	$Y = 55.85 + 82.11X$	0.90
	30	2	$Y = 104.8 + 69.25X$	0.90
	40	2	$Y = 92.90 + 101.1X$	0.95
	50	2	$Y = 80.00 + 141.0X$	0.90
	30	3	$Y = 116.10 + 82.8X$	0.90
	40	3	$Y = 110.30 + 113.9X$	0.97
	50	3	$Y = 94.55 + 156.50X$	0.90

[a] X = ash content, Y = conductivity.

Table 6
Regression equation for the relationship between ash content and conductivity

Cultivar	Extraction temperature (°c)	Extraction time (h)	Regression equation[a]	R^2
Jaya	30	1	$Y = 51.00 + 35.00X$	0.94
	40	1	$Y = 69.80 + 52.70X$	0.98
	50	1	$Y = 85.50 + 48.10X$	0.99
	30	2	$Y = 79.00 + 57.60X$	0.98
	40	2	$Y = 92.70 + 57.12X$	0.99
	50	2	$Y = 95.58 + 59.90X$	0.99
	30	3	$Y = 72.80 + 69.50X$	0.97
	40	3	$Y = 91.65 + 67.10X$	0.98
	50	3	$Y = 103.1 + 65.75X$	0.99

[a] X = ash content; Y = conductivity.

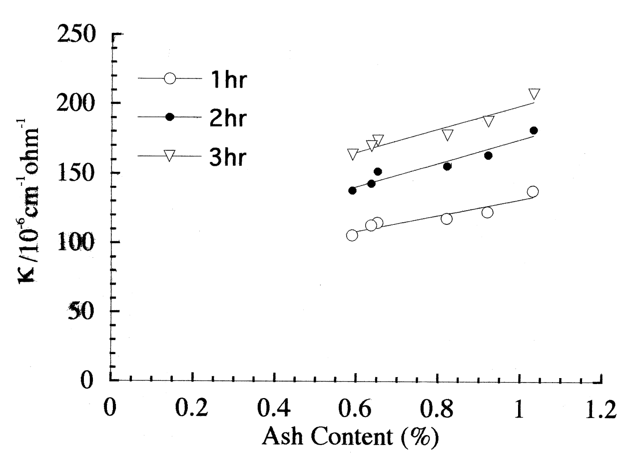

Fig. 4. Relationship between conductivity of solubles extracted at 30°C for different intervals and ash content for PR-106 cultivar.

conditions on the ash distribution pattern of different rice cultivars.

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