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Effect of Milling on Quality Attributes and Nutritional Security of Indigenous Rice Varieties of Assam

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Abstract

The present study aims to evaluate the effect of polishing on the quality attributes of the indigenous rice varieties of Assam namely *Aghuni bora* and *Kajoli chakua*. In the study procured paddy varieties were processed using standard protocols into unpolished, 5% polished and 10% polished forms. Standard analytical procedures were followed to evaluate the physical, chemical and sensory quality of the rice samples. Cooking characteristics of the rice varieties were also evaluated in terms of their water uptake ratio, grain elongation ratio and cooking time. Data obtained were analysed statistically to determine significant differences (p<0.05). The findings revealed a progressive reduction in kernel dimensions and mass. The Thousand kernel weight decreased from 19.62 to 15.64 g in *Aghuni bora* and from 20.68 to 15.22 g in *Kajoli chakua*. The Bulk density of the samples increased from 0.63 to 1.29 g ml^{-1} in *Aghuni bora* and from 0.71 to 1.36 g ml^{-1} in *Kajoli chakua* across polishing. The lightness value showed an increasing trend from 65.99 to 72.78 in *Aghuni bora* and from 65.40 to 69.81 in *Kajoli chakua*, while a* and b* values decreased, indicating a loss of natural pigmentation. An improvement in cooking quality in terms of water uptake ratio and a decrease in cooking time was evident from 16.00 to 10.12 min in *Aghuni bora* and from 17.33 to 9.80 min in *Kajoli chakua*. A significant reduction in protein, fat, crude fibre, ash and mineral contents with increased polishing were also observed. The study concludes that with milling up to 5.00%, an optimal balance could be achieved between nutritional retention, cooking efficiency, sensory acceptability and reduced processing losses.

Keywords: Cooking quality, Degree of milling, Indigenous rice varieties, Physico-chemical properties, Sensory quality

Introduction

Rice is a staple food crop that contributes significantly to the nation's food and nutrition security. It forms the backbone for food security and socio-economic development for the people of Assam. The state being a region of diverse agro-climatic conditions is a home to numerous indigenous rice varieties. These varieties have high genetic variability and adaptation to local conditions. However, with the emergence of the Green Revolution the high yielding rice varieties gained immense popularity (Mackill and Khush, 2018). This transition led to the dominance of limited rice cultivars globally. These varieties despite being high yielding in nature, exhibited reduced adaptability to local conditions (Ficiciyan *et al.*, 2018). Further, the replacement of indigenous varieties with high yielding ones resulted in the erosion of rice genetic diversity and the loss of important quality attributes of rice grains. In contrast, the traditional varieties are genetically diverse, resilient to environmental conditions, possess unique ethno-medicinal properties and have enhanced nutritional potential (Harlan, 1975). These unique traits make them crucial for sustainable agriculture, climate resilience and long-term nutritional security.

Article History

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Alongside, with the arrival of modern technologies, the traditional milling process involving preparation of hand-pounded rice has shifted toward mechanically milled rice. Milling nowadays involves use of advanced machinery for husk removal followed by polishing to produce white rice. Consumer preferences have also shifted towards highly polished rice due to its better sensory and cooking qualities (Li *et al.*, 2021). Higher polishing, however, results in substantial loss of nutrients concentrated in the bran and germ layers (Sandhu *et al.*, 2018). The nutritional quality of indigenous rice landraces is extensively affected by their nutrient retention and loss during milling. This is similar to a broader pattern seen in staple food crops, where decline in nutrient levels is seen despite an increase in crop yields (Tiwari *et al.*, 2020). Consequently, malnutrition due to micronutrient deficiency linked to reliance on polished cereals remains a serious public health concern (Sow and Ranjan, 2021). Despite growing recognition of the nutritional and genetic value of indigenous rice landraces, research focuses mainly on the effect of milling on commercial rice varieties. There exists little systematic evaluation of how polishing affects the quality attributes of traditional Assamese rice varieties.

Aghuni bora and *Kajoli chakua* were selected purposefully for the present study owing to their wider utility, distinct grain and cooking characteristics that are valued in traditional Assamese preparations. The availability of limited scientific documentation on the processing behavior of these rice varieties was also taken into consideration while selecting them for the present investigation. While, earlier reports have characterized the proximate composition of Assam's indigenous rice varieties in their raw and unpolished form (Chatterjee and Das, 2019; Kalita and Hazarika, 2022; Mudoi and Das, 2019). These studies have not studied the effect of the milling process on altering the physical, chemical, cooking and sensory quality of these landraces. The present investigation addresses this gap by generating variety-specific data on nutrient retention across defined degrees of milling. This could serve as a practical guide to an optimal milling threshold that balances nutritional retention with consumer acceptability. Therefore, the present investigation was designed to analyze the nutrient contents of two indigenous rice landraces from Assam. The study also aims to assess their nutritional variability and evaluate the changes in their nutritional composition during milling to promote environmentally sustainable rice processing and improved nutritional security.

Materials and Methods

Experimental Design

This study was conducted to determine the impact of degree of polishing (DOP) on the physico-chemical, culinary, nutritional and sensory attributes of two indigenous rice varieties of Assam, *i.e.*, *Aghuni Bora* and *Kajoli Chakua* For each variety, a single-factor design was adopted. DOP was taken as the sole factor at three levels, unpolished (0%), 5% polished and 10% polished. The two varieties were thus evaluated independently under an identical single-factor (DOP) design, rather than as a combined factorial design.

For each variety, a single batch of paddy was procured, cleaned, dried, husked and polished to each of the three DOP levels. Physical, cooking, chemical and sensory analysis for all treatments was done in triplicates on a single batch of paddy for each variety. Replicates were thus conducted in analytical terms on a single batch and not on independent biological replicates of separate batches.

Procurement and Processing of Paddy Varieties

The research was conducted in the Department of Food and Nutrition, Assam Agricultural University, Assam. The study was conducted during the period of January to July, 2021. For the research purpose, two indigenous rice varieties, *Aghuni bora* and *Kajoli chakua*, were procured from the Assam Rice Research Station, Titabor, Assam (26°36´ N, 94°12´ E). Rice kernels were obtained following Reddy *et al.* (2017) with minor modifications. Paddy samples were manually cleaned and tray-dried at 50 °C for 4 h to approximately 12% moisture. Drieds samples were subjected to husking operation by passing through a Satake paddy dehusker (model: ASR 1103, manufactured by Ambala Associates) to yield brown rice. The brown rice obtained on hulling were polished up to 5.00 percent degree of polishing (DOP) using Satake rice polisher (model: ASR 1104, manufactured by Ambala Associates). The degree of polishing (%) was calculated as per the following equation (Ravindra Babu *et al.*, 2009):

$$\text{Degree of polishing (\%)} = \frac{\text{Weight of dehusked rice - Weight of polished rice}}{\text{Weight of dehusked rice}} \times 100$$

The polished rice samples were then stored in a stainless-steel container until further application in a cool and dry place.

Milling Quality

Milling quality of the paddy varieties was assessed in terms of hulling percentage, milling recovery, head rice yield (HRY) and broken rice yield. Hulling percentage was analysed using the formula of Bhattacharya (2011). HRY was evaluated following the standard laboratory milling procedure described by Bualuang *et al.* (2011). Broken rice yield (BRY) was calculated by separating kernels ≤¾ of the original kernel length from the head rice fraction, as per Reddy *et al.* (2017).

Physical Characteristics of Rice Samples

Grain length and width of rice samples were measured following Nádvorníková *et al.* (2018). The length-to-breadth (L/B) ratio was calculated as the ratio of the cumulative length to cumulative breadth of ten kernels (Gujral *et al.*, 2002). Grain shape was expressed as the length-width ratio of a milled rice kernel using the equation of Bhattacharya (2011). Thousand kernel weights were determined as the cumulative weight of one thousand grains using a digital weighing balance (Singh *et al.*, 2003). Thousand grain volumes were estimated following Ponnappan *et al.* (2017) and bulk density (g cm^{-3}) was calculated using the formula of Fraser *et al.* (1978).

Thousand kernel weight (TKW),

TKW (g) = $V_{1000} = V_2 - V_1$

Where,

V_{1000} = Volume of 1,000 grains (cm^3)

V_1 = Initial volume of liquid (cm^3)

V_2 = Volume after immersing 1,000 grains (cm^3)

Bulk density (g cm^{-3}),

$$P_b = \frac{M_{1000}}{V_{1000}}$$

Where,

M_{1000} = Mass of 1,000 grains filling the container (g)

V_{1000} = Volume of 1,000 grains (cm^3)

Cooking Characteristics of Rice Samples

Water uptake ratio (WUR) of rice samples were determined by cooking 2 g of rice samples in 20 mL distilled water to optimum time, weighing the cooked rice and calculating WUR as described by Thomas *et al.* (2013). Cooking time and grain elongation ratio (GER) were determined following Zaupa *et al.* (2015) and Subedi *et al.* (2018), respectively. Chromatic properties of milled rice samples were measured using a HunterLab MiniScan XE Plus colorimeter.

Chemical Characteristics

The proximate compositions of rice samples were determined in terms of their moisture, crude protein, crude fat and ash contents using standard AOAC methods (AOAC, 2005). Total carbohydrate contents were calculated by difference method (Nitisewojo, 1995) and the energy value was calculated using Atwater conversion factors (James, 1995). Iron, calcium, phosphorus and zinc were determined using an atomic absorption spectrophotometer. Amylose content was determined following the colorimetric iodine-binding method (Juliano, 1971). All chemical analyses were performed on a dry-weight basis.

Sensory Acceptability

Sensory evaluation of rice samples was conducted at the Department of Food and Nutrition, College of Community Science, Assam Agricultural University. The sensory panel consisted of 15 semi-trained panelists of age group ranging from 22-65 years. The panelists were introduced to the scoring card which consisted of codes and information about the 9-point hedonic scale. The samples were prepared in standardized manner and then coded and presented to the panelists in a random order to avoid positional bias. The coded samples were presented to the panelists at room temperature on white plates under natural daylight and the panelists were given water to clean their mouth before evaluating each sample. The panelists were asked to evaluate the samples in terms of appearance, smell, taste, texture and overall acceptability using a 9-point hedonic scale.

Statistical Analysis

For each variety, data were statistically analysed and expressed as mean ± standard deviation of three analytical replications. Statistical analysis was done using the software Statistical Package for Social Sciences (SPSS). One-way analysis of variance was carried out within each variety to determine significant differences among the three DOP levels, followed by Duncan's multiple range test.

Results and Discussion

Milling Characteristics

Paddy varieties were evaluated for their milling characteristics in terms of hulling percentage, milling recovery, HRY and BRY (Table 1). Results revealed no significant difference between the two selected paddy varieties in terms of their hulling percent, milling recovery and HRY. The hulling, milling recovery and HRY of *Aghuni bora variety* was recorded 79.83±3.01%, 75.84±2.86% and 71.67±2.08%, respectively. While corresponding values for *Kajoli chakua* variety were 78.17±1.04%, 74.36±0.99% and 73.18±1.00%, respectively. A significant difference was observed in the BRY between two paddy varieties. The *Aghuni bora* variety exhibited a higher BRY (4.17±1.78%) compared to *Kajoli chakua* (1.18±0.22%) variety. This difference may be attributed to their grain length; longer grains are more susceptible to cracking and breakage during milling (Wiset *et al.*, 2001; Yang *et al.*, 2023; Du *et al.*, 2025).

Table 1: Milling characteristics of selected paddy varieties

Parameters (%)	Aghuni bora	Kajoli chakua
Hulling percent	79.83±3.01^a	78.17±1.04^a
Milling recovery	75.84±2.86^a	74.36±0.99^a
HRY	71.67±2.08^a	73.18±1.00^a
BRY	4.17±1.78^a	1.18±0.22^b

Values with different superscript are significantly different in a row (p<0.05)

Physical Characteristics

The physical characteristics of polished and unpolished rice kernels of *Aghuni bora* and *Kajoli chakua* is depicted in table 2. The table indicates a marginal decrease in the kernel length, breadth and length- breadth (L/B) ratio across polishing. However, these changes were not statistically significant (p<0.05). The kernel length decreased from 7.42±0.49 mm (0% polishing) to 7.00±0.41 mm (5% polishing) and 6.70±0.25 mm (10% polishing) in *Aghuni bora.* Similarly, in *Kajoli chakua* the kernel length decreased slightly from 6.37±0.29 mm (0% polishing) to 6.16±0.32 mm (5% polishing) and 5.92±0.41 mm at 10% polishing. A marginal decline in kernel breadth and length-breadth ratio was also observed on polishing. Consequently, the length-breadth ratio remained relatively stable for unpolished and polished rice kernels. A significant reduction (p<0.05) on polishing for both *Aghuni bora* and *Kajoli chakua* was also evident in case of thousand kernel weight and thousand kernel volume; whereas, a significant increment was observed in the bulk density in both varieties. The observed reduction in kernel length, breadth, length-breadth ratio and thousand kernel weight in the present study could be due to the dimensional shrinkage that resulted from the removal of the bran layer

Table 2: Physical characteristics of polished and unpolished rice kernel

Parameters	*Aghuni bora*			*Kajoli chakua*		
	Unpolished	Polished (5%)	Polished (10%)	Unpolished	Polished (5%)	Polished (10%)
Kernel length (mm)	7.42±0.49^{a}	7.00±0.41^{a}	6.70±0.25^{a}	6.37±0.29^{b}	6.16±0.32^{b}	5.92±0.41^{a}
Kernel breadth (mm)	2.05±0.18^{a}	1.93±0.19^{a}	1.85±0.16^{a}	3.02±0.13^{b}	2.92±0.17^{b}	2.80±0.09^{a}
Length-breadth ratio	3.64±0.31^{a}	3.62±0.47^{a}	3.63±0.15^{a}	2.11±0.13^{b}	2.10±0.37^{b}	2.11±0.06
Kernel shape	Slender	Slender	Slender	Medium	Medium	Medium
Thousand kernel weight (g)	19.62±0.32^{a}	17.33±0.45^{b}	15.64±0.33^{c}	20.68±0.28^{d}	18.44±0.09^{e}	15.22±0.12^{c}
Thousand kernel volume (ml)	16.46±0.44^{a}	13.44±0.28^{b}	12.08±0.12^{c}	16.40±0.26^{a}	12.67±0.21^{c}	11.12±0.21^{d}
Bulk density (g ml^{-1})	0.63±0.02^{a}	0.75±0.02^{b}	1.29±0.01^{c}	0.71±0.02^{b}	0.80±0.03^{d}	1.36±0.01^{c}

Values with different superscript are significantly different in a row (p<0.05)

during polishing. The concomitant increase in bulk density may result from the reduced volume during polishing. Furthermore, the polishing process involves removal of low-density components in the form of bran such as lipid and dietary fiber, leaving behind the comparatively dense starchy endosperm (Razavi and Farahmandfar, 2008; Olayanju *et al.*, 2021; Qadir and Wani, 2023). This was attributed to the porous nature of the bran and aleurone layers, which have less density when compared to the endosperm's compact and crystalline granules. In this case, removal of the outer layers with high content of bran means that the kernel left will have higher density of endosperm, thus reducing the void spaces through better packing of the kernels in the storage container. Thereby allowing more efficient packing with less interstitial space resulting increased bulk density on polishing to 10.00 percent level (Rahmawati *et al.*, 2023; Elancheran *et al.*, 2026).

The colour characteristics of polished and unpolished rice kernels, *Aghuni bora* and *Kajoli chakua* is shown in table 3. A significant increase (p<0.05) in the lightness (L*) and a corresponding decrease in the redness value (a*) was evident on polishing. On polishing the L* value increased from 65.99±1.07 to 69.05±0.96 and 72.78±0.84 in *Aghuni bora* variety. Similar trend was observed in *Kajoli chakua* variety. A significant reduction in a* values was also evident with polishing. No significant effect of polishing was seen in the yellowness value (b* value) of *Aghuni bora* and a significant reduction of b* value in case of *Kajoli chakua* was evident. This varietal difference in colour response may be attributed to the genetic makeup of the rice grain and other inherent or external influences. This increase in L* value and a concomitant reduction in a* and b* value with polishing may be primarily related to the exclusion of bran which is rich in pigment and subsequent exposure to the white-coloured starchy endosperm (Mohapatra and Bal, 2014; Lamberts *et al.*, 2007; Bani *et al.*, 2024).

Table 3: Hunter colour lab values of polished and unpolished rice kernel

Parameters	*Aghuni bora*			*Kajoli chakua*		
	Unpolished	Polished (5%)	Polished (10%)	Unpolished	Polished (5%)	Polished (10%)
L*	65.99±1.07^{a}	69.05±0.96^{b}	72.78±0.84^{c}	65.40±1.37^{a}	67.38±1.84^{d}	69.81±0.82^{b}
a*	2.98±0.12^{a}	1.62±0.07^{b}	1.18±0.06	2.63±0.62^{a}	1.16±0.23^{c}	0.98±0.21
b*	10.01±0.86^{a}	9.83±0.27^{a}	9.12±0.08^{a}	12.80±1.02^{b}	11.94±0.82^{c}	10.24±0.28^{c}
Chroma	10.44±0.78^{a}	9.96±0.65^{b}	9.20±0.08	13.08±0.82^{c}	11.99±1.10^{d}	10.29±0.28
Hue	73.42±1.27^{a}	80.64±1.49^{b}	82.60±0.38^{b}	78.39±2.06^{c}	86.07±1.75^{d}	84.50±1.18^{b}

Values with different superscript are significantly different in a row (p<0.05)

Cooking Characteristics

Table 4 shows the cooking qualities of polished and unpolished *Aghuni bora* and *Kajoli chakua* kernels. Polishing significantly increased the water uptake ratio (WUR) from 2.04±0.09 to 2.31±0.09 and 2.64±0.08 for *Aghuni bora* and from 1.53±0.08 to 1.88±0.15 and 2.02±0.07 for *Kajoli chakua*, with *Aghuni bora* showing higher WUR (p<0.05). Cooking time decreased after polishing for *Aghuni bora* (16.00±0.00 to 12.66±1.15 and 10.12±0.30 min) and *Kajoli chakua* (17.33±1.15 to 12.00±0.00 and 9.80±1.12 min).

Table 4: Cooking quality of polished and unpolished rice kernel

Parameters	*Aghuni bora*			*Kajoli chakua*		
	Unpolished	Polished (5%)	Polished (10%)	Unpolished	Polished (5%)	Polished (10%)
WUR	2.04±0.09[a]	2.31±0.09[b]	2.64±0.08	1.53±0.08[c]	1.88±0.15[a]	2.02±0.07[a]
CT (min)	16.00±0.00[a]	12.66±1.15[b]	10.12±0.30	17.33±1.15[c]	12.00±0.00[b]	9.80±1.12
GER	1.11±0.002[a]	1.24±0.005[b]	1.38±0.01	1.07±0.006[a]	1.18±0.006[b]	1.22±0.01[b]

Values with different superscript are significantly different in a row (p<0.05)

Grain elongation ratio (GER) increased with polishing in *Aghuni bora* (1.11±0.002 to 1.24±0.005 and 1.38±0.01) as well as *Kajoli chakua* (1.07±0.006 to 1.18±0.006 and 1.22±0.01) without significant varietal differences. Bran restricts starch expansion, reducing GER. Unpolished rice has longer cooking times due to thicker aleurone and pericarp layers that impede water penetration (Deepa *et al.*, 2008). Improved cooking of polished rice is attributed to facilitated water diffusion after removal of fiber-rich bran, reducing cooking time and enhancing WUR and GER (Juliano and Bechtel, 1985; Monks *et al.*, 2013; Ojediran *et al.*, 2020). Water absorption during the coking process is attributed to two mechanisms namely, diffusion of water into the kernel walls or gelatinization of starch within the endosperm upon attaining a threshold degree of hydration and temperature (Wang *et al.*, 2019; Donmez *et al.*, 2021; Yildirim, 2021). Unmilled rice kernels have intact outer surfaces that prevent water entry, delaying gelatinization of the endosperm; whereas milled kernels allow water to access the starchy interior of the rice. Also, lower-milled rice is higher in fiber and proteins, which compete with the starch for water during the process of gelatinization (Zhang *et al.*, 2023; Zhu *et al.*, 2016).

Chemical Compositions

Unpolished rice is recognized as a valuable source of nutrients due to the presence of rice bran, which constitutes 10.00% of the total rice grain and serves as a major contributor of nutrients (Leardkamolkarn *et al.*, 2011; Chen *et al.*, 2023). The table 5 indicates a significant change in the chemical compositions of the rice kernels from *Aghuni bora* and *Kajoli chakua* after polishing. Additionally, the differences in chemical compositions between the two varieties were pronounced, likely due to the inherent varietal differences. Table illustrates a marked reduction in protein levels following polishing in both rice varieties. Additionally, a statistically significant decline (p<0.05) in fat content was observed upon milling. The unpolished rice exhibited fat levels of 1.23±0.21 g/ 100g for *Aghuni bora* and 1.36±0.32 g/ 100g for *Kajoli chakua*, which decreased to 0.55±0.03 g/ 100g and 0.61±0.18 g/ 100g, respectively, in 5.00% polished kernels. A substantial decrease in total ash content was recorded after polishing. The levels of carbohydrates, energy and amylose were found to be higher in polished grains compared to their unpolished counterparts. The amylose content increased from 2.67±0.12 to 3.42±0.28 and 3.88±0.14 g/ 100g in *Aghuni bora*, while in *Kajoli chakua*, it increased from 16.02±0.14 to 17.43±0.33 and 16.82±0.24 g/ 100g following polishing. A statistically significant difference (p<0.05) was also observed in the levels of calcium, phosphorus, iron and zinc between polished and unpolished rice kernels in both varieties.

Table 5: Chemical compositions of polished and unpolished rice on dry matter basis

Parameters	*Aghuni bora*			*Kajoli chakua*		
	Unpolished	Polished (5%)	Polished (10%)	Unpolished	Polished (5%)	Polished (10%)
Protein (g/ 100g)	15.04±0.05[a]	13.73±0.12[b]	10.87±1.12	13.12±0.17[c]	11.82±0.21[d]	10.02±0.54
Fat (g/ 100g)	1.23±0.21[a]	0.55±0.03[b]	0.38±0.02	1.36±0.32[a]	0.61±0.18[b]	0.32±0.21
Carbohydrates (g/ 100g)	79.65±0.71[a]	83.79±0.46[b]	90.63±0.76	83.08±0.86[b]	86.25±0.67[c]	91.04±0.11
Energy (Kcal/ 100 g)	389.83±0.75[a]	395.03±1.09[a]	409.42±0.77	393.04±0.12[a]	397.37±0.22[a]	407.12±2.85
Total ash (g/ 100g)	1.18±0.11[a]	0.58±0.21[b]	0.36±0.12	1.26±0.32[a]	0.64±0.23[b]	0.41±0.18
Crude fibre (g/ 100g)	2.60±0.34[a]	1.35±0.10[b]	0.76±0.05	1.18±0.05[b]	0.68±0.05[c]	0.33±0.01
Amylose (g/ 100g)	2.67±0.12[a]	3.42±0.28[b]	3.88±0.14	16.02±0.14[c]	17.43±0.33[d]	16.82±0.24
Calcium (mg/ 100g)	22.80±1.56[a]	15.78±1.14[b]	10.12±1.12	26.10±2.45[a]	17.93±1.70[b]	11.78±0.82
Phosphorus (mg/ 100g)	289.31±6.20[a]	121.10±5.25[b]	98.22±6.84	182.77±4.13[b]	84.59±2.50[c]	72.49±5.26
Iron (mg/ 100g)	2.19±0.06[a]	1.75±0.06[b]	1.18±0.02	2.90±0.05[c]	2.41±0.01[d]	1.84±0.01
Zinc (mg/ 100g)	1.78±0.02[a]	1.49±0.06[b]	1.08±0.03	2.75±0.04[c]	2.53±0.06[a]	1.74±0.01

Values with different superscript are significantly different in a row (p<0.05)

The reduction in protein, fat, ash, fiber and mineral contents during polishing is due to the removal of the bran, aleurone and germ layers, which are rich in non-starchy polysaccharides, fats, fiber, proteins, vitamins and minerals (Juliano and Bechtel, 1985; Li *et al.*, 2025). The increase in carbohydrate content after polishing reflects the higher starch proportion, as the outer brown layer of unpolished rice contains substantial non-starch components and accounts for approximately 20.00-30.00% of starch (Thongbam *et al.*, 2012; Akhter *et al.*, 2023). Polishing also increased amylose content, likely due to the removal of bran components, resulting in a higher relative starch fraction predominantly composed of amylose (Monks *et al.*, 2013). The rice grain is organised into seed coat or pericarp, aleurone, embryo and endosperm, which constitutes the main edible fraction (Achary and Reddy, 2021; Li *et al.*, 2021). The aleurone layer surrounding the starchy endosperm is unusually abundant in protein, fat, vitamins and mineral nutrients relative to its weight. Histologically, a subaleurone gradient exists, where the protein bodies in the outer endosperm exceed those in the inner starchy endosperm (Yu *et al.*, 2014; Li *et al.*, 2021). With increasing milling degrees, the left-over grain will become relatively starchier since milling takes away the outer tissues which contain more nutrients at a faster rate compared to the starchy endosperm core. This is the reason why carbohydrate content increases during milling despite no increase in carbohydrates (Li *et al.*, 2025; Akter *et al.*, 2025).

The increase in amylose resulting from polishing was attributed mainly to the concentration effect of the rice kernel. Polishing increases measured amylose while reducing protein, fat and ash, which supports a concentration mechanism as nutrient-dense outer tissues are removed and the remaining kernel becomes more endosperm-dominated. Thus, the removal of bran led to an increase in the amylose content in the kernel due to bran removal, thereby exposing tissue with higher amylose deeper in the caryopsis, while the shells have low amylose contents (Tumanian *et al.*, 2021; Handoko *et al.*, 2021).

Mineral content depletion noticed through milling process was caused by high mineral content present in the aleurone layer, mainly in the form of phytate complexes with divalent cations. Phosphorus, calcium, iron and zinc minerals are primarily stored in the aleurone layer as phytin globoids. Polishing of grains has results in removal of the aleurone layer and also removal of pericarp and germ layers. The starchy endosperm is less rich in minerals compared to aleurone layer (Iwai *et al.*, 2012; Antonini *et al.*, 2018).

Sensory Evaluation

Sensory evaluation using a nine-point hedonic scale showed significantly lower scores for products prepared from unpolished *Aghuni bora* and *Kajoli chakua* rice kernels (Table 6). Products made from polished *Aghuni bora* rice exhibited marked improvements in overall acceptability, appearance, taste, texture, flavour and colour. Similarly, products prepared from polished *Kajoli chakua* rice kernels recorded significantly higher sensory scores (p<0.05) for all attributes compared to unpolished samples. The lower acceptability of unpolished rice products may be attributed to undesirable eating qualities such as increased hardness, longer cooking time and darker appearance (Yu *et al.*, 2014; Gondal *et al.*, 2021).

Table 6: Sensory scores for products prepared from polished and unpolished rice varieties

Sensory Attributes	*Aghuni bora*			*Kajoli chakua*		
	Unpolished	Polished (5%)	Polished (10%)	Unpolished	Polished (5%)	Polished (10%)
Appearance	6.30±0.12[a]	8.20±0.42[b]	8.30±0.25[b]	6.80±0.60[a]	8.00±0.30[b]	8.20±0.42[b]
Taste	6.40±0.18[a]	7.90±0.12[b]	8.80±0.30[b]	6.20±0.20[a]	7.80±0.12	8.30±0.20[b]
Texture	6.00±0.60[a]	8.50±0.18[b]	8.00±0.20[b]	5.80±0.40[a]	7.80±0.12	8.80±0.30[b]
Flavour	6.20±0.80[a]	8.50±0.14[b]	8.80±0.12[b]	5.40±0.40[c]	8.00±0.20	8.00±0.12[b]
Colour	6.80±0.70[a]	8.10±0.40[b]	8.30±0.14[b]	6.80±0.80[a]	8.20±0.20	8.20±0.25[b]
Overall acceptability	6.40±0.30[a]	8.20±0.60[b]	8.50±0.20[b]	6.80±0.20[a]	8.00±0.18	8.00±0.42[b]

Values with different superscript are significantly different in a row (p<0.05)

Conclusion

The study revealed that rice processing techniques greatly influences the overall quality of the final product. Polishing led to considerable decrease in nutritional components owing to removal of bran and germ layer. It was clear that milling up to 5.00 percent provides a good balance between nutritional retention, cooking quality, sensory acceptability and processing losses. Thus, indicating that a lower degree of milling represents an environmentally sustainable processing strategy. This could be beneficial in enhancing the utilization of indigenous rice varieties for nutrition security within sustainable agricultural systems. Retaining more protein, fat and minerals at this level without compromising cooking quality suggests that 5% milling could be applied more widely thus offering a practical way to improve dietary quality. Lowe DOP preserves processing time, energy usage and also results in lower breakage of kernels. Demonstrating that indigenous varieties maintain desirable quality after the low milling becomes an additional reason for their breeding and marketing as a special product.

Limitations

The values reported in the study are based mainly on analytical replicates from a single processed batch per variety. Therefore, the variability that could have resulted from field conditions, storage or separate milling runs could not be captured. Further, the work was limited to two indigenous varieties of rice at three discrete DOP levels (0%, 5% and 10%) within a single growing season and location. Thus the results obtained may not be a representative of all other varieties, agro-climatic conditions or milling equipment.

Recommendations

The future research should take into consideration the effect of multiple growing seasons and locations. A broader range of indigenous rice varieties with finer gradients of milling level should be considered to precisely study the optimal degree of polishing for different varieties. More research involving starch granule analysis, storage stability of minimally milled rice and consumer-level acceptability studies will provide a solid basis for encouraging the use of minimal milling as an appropriate and nutritious processing technology for indigenous rice.

Ethical Statement

The authors declare that no generative artificial intelligence tools were used in drafting or preparing this manuscript. The manuscript was written, interpreted and revised solely by the authors, who take full responsibility for its content.

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