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Effect of different levels of polishing on physico - chemical characteristics of barnyard millet (*Echinochloa frumentacea*)

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Abstract
Barnyard millet (*Echinochloa frumentacaea*) is an ancient millet crop grown in warm and temperate regions of the world which thrives well even under adverse agro-climatic conditions. The present investigation was carried out with the objective to study the effect of polishing on physico-chemical characteristics of barnyard millet. The barnyard variety DhBM 93-2, released from UAS Dharwad was used for analysis. The grains were dehusked in Millet rubber Sheller and different levels of polishing were standardised using IDOSAW polisher. The physico – chemical characteristics of the unpolished, semi polished and fully polished Barnyard millet were analysed using standard procedures. Lower seed weight and volume was observed in Semi and fully polished barnyard millet as compared to unpolished barnyard millet. The unpolished grains exhibited significantly higher (p< 0.01) in hydration capacity, water absorption capacity and oil absorption capacity compared to semi polished and fully polished millets, but there was no significant difference observed in hydration index of processed barnyard millets. Thus, from the study it is evident that significant difference existed for physico-chemical characteistics between different levels of polishing in barnyard millet. From the study we can say that, barnyard millet can be polished to diversify their uses, alter their nutritive value and consumer acceptability.

Keywords: Barnyard millet, Dehusk, polish, physico-chemical characteristics

Introduction

Barnyard millet is a multipurpose crop, thrives well even under adverse agro climatic conditions. It is the fastest growing crop as compared to other millets. Barnyard millet (Echinochloa species) is an ancient millet crop grown in warm and temperate regions of the world and widely cultivated in Asia, particularly India, China, Japan, and Korea. It is the fourth most produced minor millet, providing food security to many poor people across the world. Globally, India is the biggest producer of barnyard millet, both in terms of area (0.146 m ha^{-1}) and production (0.147 mt) with average productivity of 1034 kg/ha during the last 3 years (IIMR, 2018) [10]. In India, its cultivation is restricted to hilly and semi-arid regions of Southern peninsula of Tamil Nadu, Andhra Pradesh, Karnataka and Northern states of Jharkhand and Uttar Pradesh (Veena. S *et al.*, 2005) [17]. Barnyard millet is primarily cultivated for human consumption, though it is also used as a livestock feed. Among many cultivated and wild species of barnyard millet, two of the most popular species are *Echinochloa frumentacea* (Indian barnyard millet) and *Echinochloa esculenta* (Japanese barnyard millet) (Sood *et al.*, 2015) [16].

Like rice, the grain of barnyard millet is used as food and can be cooked. To produce most foods, the grains are decorticated using mortars and de-hullers. This treatment removes the bran layer of the grains. The millet bran is therefore a by-product of millet-based food (Hemery. Y *et al.*, 2007) [7]. Daniel. B (2005) [4] has reported that nutrients such as proteins, omega-3, omega-6 fatty acids and antioxidants are present in large amount in the outer layers of Barnyard millet.

Although millet foods are considered among the healthiest food choices that are available, their consumption remains well below in developed countries where diet-related chronic diseases are alarming. It is necessary to increase production and lower cost by introducing revolutionary improvements in production techniques. There is also a lack in the processing techniques, machinery, and standardization of products. Many processed products need to be optimized to give proper benefits to the consumer. Millets have a potential for the preparation of healthy foods.

Because of their health benefits, these grains do need a great promotion to reach heights of the major cereals in terms of their utilization (Himanshu *et al.*, 2018) [8]. Physical properties (weight, volume, bulk density, L/B ratio) are other major parameters influenced by the moisture content of the grains. These factors ultimately influence the processing of grains in the machines (Singh et al., 2010) [15]. Therefore, a study in detail on these properties should be conducted in order to design and develop better milling, polishing, grading, and sorting machineries for barnyard millet.
There is very little information on the studies on effect of polishing on barnyard millet which can alter its physico-chemical characteristics for applications as raw materials in food manufacturing especially in the health and convenience foods. Hence, an investigation was undertaken to evaluate the effect of polishing on physico-chemical of barnyard millet.

Materials and Methods

The investigation was conducted on barnyard millet grains of variety DhBM 93-2 released from UAS Dharwad. Procured grains were dehusked and taken for polishing. The weight of head rice, brokens and unhusked grains were recorded and stored at ambient temperature for further estimations.

A. Dehusking of barnyard millet

Dehusking of Barnyard millet of variety DhBM 93-2 was carried out in Millet rubber Sheller developed at Department of Food Science and Nutrition Lab, College of Community Science, UAS, Dharwad under IDRC project.

B. Stansardisation of Polishing of Barnyard millet

Polishing was carried out in IDOSAW polisher developed under IDRC project of UAS, Dharwad and standardized for level of polishing.

C. Physico – chemical Characteristics of Barnyard millet

The physico – chemical characteristics such as weight, volume, size, colour, bulk density and pH determination for unpolished, semi polished and fully polished barnyard millet were studied using standard procedures.

Weight: Weight of randomly selected thousand grains was recorded in grams using electronic balance with a sensitivity of 0.1 mg (Mishra and Gupta, 1995) [13].

Volume: Thousand randomly selected grains were dropped in measuring cylinder containing known volume of distilled water. The difference in volume was recorded in ml by water displacement method (Mishra and Gupta, 1995) [13].

Bulk density: Grain bulk density was calculated using the formula. The bulk density was expressed as g per ml (Mishra and Gupta, 1995) [13].

$$\text{Bulk density (g/ml)} = \frac{\text{Weight (g)}}{\text{Volume (ml)}}$$

Size: The size of the seed was measured using calipers to the nearest of 0.01mm.

Length (mm), breadth (mm) and L/B ratio whole and milled grains: The average length and breadth of the randomly picked ten grains were measured in mm with a help of Vernier calipers. The length/breadth ratio was obtained by dividing the length of a single grain by the corresponding breadth to determine the size and shape (Graham, 2002) [6].

Colour: Chromatic components 'L' (0=black to 100= white) 'a' (+redness to -greenness) and 'b'(+yellowness to -blueness) values of processed barnyard millet were measured in triplicates, using spectrophotometer CM-260d / 2500d model of Konica Minolta make.

pH: The pH of the flour was measured using Systronics digital pH meter- 335.

D. Functional properties of Barnyard millet

The functional properties like, hydration capacity, hydration index, water absorption capacity, oil absorption capacity and swelling power were evaluated for unpolished, semi polished and fully polished barnyard millet using standard AACC (2000) [1] methods.

Hydration capacity: The 1000 grains were soaked in distilled water for 12 hours. The water was drained. The adhering water to the grains was removed by gently pressing with blotting paper. The increase in weight after soaking was noted. Hydration capacity was calculated using the formula;

$$\text{Hydration capacity} = \frac{\text{weight after soaking - weight before soaking}}{\text{Number of seeds}}$$

Hydration index: Hydration index is calculated by using formula:

$$\text{Hydration index} = \frac{\text{Hydration capacity}}{\text{Weight of seeds}}$$

Water absorption capacity: To determine the water absorption capacity five gram of flour was weighed and added to pre – weighed centrifuge tube (W1). To this, 30 ml of water was added and stirred with a glass rod for 5 min. The contents could stand for 30 min and then centrifuged at 11,000 rpm for 25 min. The free liquid was passed off and the inner sides of the tube were wiped with tissue paper. The centrifuge tube was weighed again (W2). The water absorption capacity was calculated using formula,

$$\text{WAC (\%)} = \frac{\text{W2} - \text{W1 x100}}{5}$$

Oil absorption capacity: To determine the oil absorption capacity one gram of flour was mixed with 10 ml oil (ground nut oil) in weighed centrifuge tube (W1). The tubes were stirred for 1 min for complete dispersion. Sample was centrifuged at 3000 rpm for 25 min. The separated oil was then removed and tubes were inverted on oil absorbent paper to drain the oil prior to reviewing (W2). The oil absorption capacity was calculated using formula,

$$\text{OAC (\%)} = \frac{\text{W2} - \text{W1 x100}}{1}$$

Swelling power: The swelling power and per cent solubility was determined according to the method used by Schoch (1964) [14]. 500 mg (W1) of sample was added to a centrifuge tube, weight of centrifuge tube and test sample was noted

(W2). After addition of 20 ml (VE) distilled water, the centrifuge tube was placed in the water bath at 100 °C for 20-30 min till the contents were cooked. Then it was centrifuged at 5000 rpm for 10 min. The supernatant was transferred to a test tube and the inner side of the centrifuge tube was dried well and weighed (W3). The swelling of flour was calculated as follows.

$$\text{Swelling power (g/g)} = \frac{W3 - W2}{W1} \times 100$$

E. Statistical analysis

SPSS statistical software (version 16, SPSS Inc) was used to perform the statistical analysis of the data. Analysis of variance (ANOVA) followed by Duncan's multiple range test was performed to determine significant differences. For comparison of two treatment means, t-test was used.

Results and Discussions

Dehusking of barnyard millet

The results pertaining to processing parameters of barnyard millet are presented in Figure 1. Results showed that, from 100g of Barnyard millet of DhBM 93-2 variety, 59 per cent of dehusked grains (head rice), 6 per cent of broken grains, 21 per cent of husk and 14 per cent of unhusked grains were obtained. The per cent of unhusked grains was more because of presence of uneven grains.

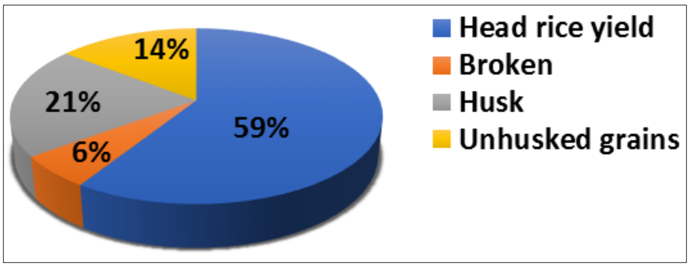

Fig 1: Dehusking parameters of Barnyard millet DhBM 93-2

Standardisation of Polishing of Barnyard millet

Different levels of polishing were tried out for unpolished barnyard millet, taking time as variation. Weight of polished grain, bran and broken grains were recorded (Table 1). The results showed that more milling time influenced the values of milling yield. The removal of bran portion from millet with increased milling time resulted in the reduction of the head rice yield and increase in bran and broken grains portion. The grains polished for 60 seconds were considered as fully polished as it had brighter colour and further polishing for 80 seconds, the percentage of broken grains was more (7.46%). So, the grains which were polished at 30 seconds were considered semi polished (Table 2).

Yield of polished rice after semi and full polish has been presented in Table 2. The polished barnyard millet rice yield was significantly higher (91.70 g) in semi polished millet compared to fully polished millet (88.42 g), whereas bran portion was significantly higher in fully polished millet (5.12 g) compared to semi polished millet (2.48 g). The amount of bran removed increased significantly when the time of polishing was increased in present study. But there was no significant difference observed in broken grains in fully polished millets (6.44 g) and semi polished (5.74 g).The grains polished for 60 seconds were considered as fully polished as further polishing increased the quantity of broken grains. More milling time influenced the values of milling yield, head rice yield and degree of polishing. The removal of bran layers from millet with increasing of milling duration resulted in the reduction of the milling yield and the head rice yield.

Similar study has been reported in Lohani *et al.*, 2012 [12], where the head rice yield and brokens varies according to moisture per cent and milling time.

Table 1: Yield of polished rice as affected by polishing time

Weight (g)	Time (sec)	Head rice	Bran	Broken grains
		(g)		
100	20	93.52	1.68	4.10
100	40	90.94	3.36	5.22
100	60	88.36	5.04	6.34
100	80	85.78	6.72	7.46

Table 2: Yield of polished rice after Semi and Full polish

Sample	Weight of grains (g)	Polished rice	Bran	Broken grains
		(g)		
Semi polished (30 sec)	100	91.70±0.53	2.48±0.03	5.74±0.54
Fully polished (60 sec)	100	88.42±0.10	5.12± 0.12	6.44±0.05
t value	-	5.310**	18.88**	NS

**Significant at 1% level (p< 0.01), NS: Non-significant
No. of replications: 3

Physico – chemical Characteristics of Barnyard millet

In order to understand the changes due to polishing, selected physical parameters of unpolished, semi polished and fully polished barnyard millet were studied. Effect of level of polishing on the physico-chemical properties of barnyard millet are depicted in Table 3(a) and 3(b). The results showed that, the unpolished barnyard millet was significantly higher than semi and fully polished barnyard millet with respect to weight and volume. There was significant difference in weight and volume at p< 0.01. Lower seed volume was observed in Semi and fully polished barnyard millet as compared to unpolished barnyard millet, which is due to removal of outer bran portion. There was no significant difference in bulk density and length to breadth ratio of unpolished, semi polished and fully polished barnyard millets Table 3(a). The bulk density was higher in fully polished barnyard millet, which had higher moisture (9.27%) compared to other variations. Similar result was reported by Balasubramanian and Viswanathan (2010) [2].

Physical characteristics of grains are determined for various reasons. Grain dimensions are very important in cleaning, specifically threshing operations. In these operations, screens are necessary, because it allows the passage of specific size of the grains and various unwanted materials (Brennan *et al.*, 1981) [3].

From L, a and b values it was clear that, fully polished barnyard millet was lighter than unpolished and semi polished barnyard millet Table 3(b). The pH of unpolished barnyard millet was significantly higher (7.47) followed by semi polished and fully polished barnyard millet, having 7.20 each.

The studies on the physico-chemical properties of grains are an important criterion to design any processing instruments like dehullers, polishers, sorters, storage, and other processing machineries (*Singh et al.*, 2010) [15]. In barnyard millet, grain moisture is the prime criteria playing a key role not only in storage but also in the development of processing machineries. The moisture level of barnyard millet grain highly influences the quality as well as the time of milling and polishing. For instance, the 8% moisture content of the grain is better for polishing than at 14% moisture. However, at 14% moisture, the degree of polishing increases grain recovery and decreases the loss of protein, fat, ash, and fiber. Based on this, Lohani *et al.* (2012) [12] suggested 10% as the optimum moisture level for polishing.

Table 3(a): Effect of level of polishing on the physico-chemical properties of Barnyard millet

Processing parameters	Weight (g)	Volume(ml)	Bulk Density (g/ml)	Length (mm)	Breadth (mm)	L/B ratio
Unpolished	2.64^{a}± 0.03	2.00^{a}± 0.00	1.32 ± 0.01	1.71^{a}± 0.03	1.68± 0.05	1.02 ± 0.02
Semi Polished	2.22^{b}± 0.03	1.70^{b}± 0.00	1.30 ± 0.02	1.65^{b}± 0.03	1.64± 0.02	1.01± 0.01
Fully polished	2.13^{c}± 0.03	1.57^{c}± 0.06	1.33 ± 0.02	1.60^{b}± 0.02	1.58± 0.04	1.01 ± 0.01
F value	238.18	133.00	2.54	14.05	5.06	1.91
S.Em±	0.02	0.02	0.02	0.02	0.02	0.02
C.D	0.06**	0.06**	NS	0.06*	NS	NS

*Significant at 5% level (p< 0.05), **Significant at 1% level (p< 0.01), NS: Non-significant
No. of replications: 3

Values in a column followed by different Superscripts are significantly different according to DMRT at the 0.05 level

Table 3(b): Effect of level of polishing on the physico-chemical properties of Barnyard millet

Processing parameters	Colour			pH
	L	a	b	
Unpolished	65.46^{c} ± 0.01	3.95^{a} ± 0.04	17.68^{c} ± 0.04	7.47^{a} ± 0.06
Semi polished	65.68^{b} ± 0.06	3.33^{b} ± 0.05	17.90^{b} ± 0.05	7.20^{b}± 0.00
Fully polished	65.91^{a} ± 0.02	2.84^{c} ±0.05	18.70^{a} ± 0.06	7.20^{b}± 0.00
F value	134.72	434.91	341.39	64.00
S.Em±	0.02	0.02	0.02	0.02
C.D	0.06**	0.06**	0.06**	0.06**

*Significant at 5% level (p< 0.05), **Significant at 1% level (p< 0.01), NS – Non significant
No. of replications: 3
Values in a column followed by different Superscripts are significantly different according to DMRT at the 0.05 level

Functional properties of Barnyard millet

Effect of level of polishing on the functional characteristics of unpolished, semi polished and fully polished barnyard millet are presented in Table 4. The result showed that, unpolished grains exhibited significantly higher (p< 0.01) in hydration capacity, water absorption capacity and oil absorption capacity compared to semi polished and fully polished millets, but there was no significant difference observed in hydration index of processed barnyard millets. Swelling power of fully polished grains was 6.85 which was significantly higher (p< 0.05) than semi-polished (6.64) and unpolished barnyard millet (6.32). The unpolished millets contain more of dietary fiber (10.90%) compared to semi and fully polished which results in more of hydration capacity. Removal of millet husk leads to loss of hydrophilic polysaccharides, which decreases the water absorption capacity (Ghavidel and Prakash, 2006) [5]. Dehulling and debranning decreases the oil absorption capacity and this may be since binding ability of the lipid depends on the surface availability of the hydrophobic amino acids (Kamara et al., 2009) [11].

The swelling power and solubility of starch granules showed a great evidence of interaction on the starch chains between the amorphous and crystalline regions. When starch was subjected to heating in excess water, there is a relaxation of the crystalline structure and the groups of amylose and amylopectin associate with water molecules through hydrogen bonding. This causes an increase in the swelling power and the solubility of the granules (Hoover, 2001) [9].

Table 4: Effect of level of polishing on the functional Characteristics of Barnyard millet

Processing parameters	Hydration Capacity (g/1000 seeds)	Hydration Index (%)	Water absorption capacity (%)	Oil absorption capacity (%)	Swelling power(g/g)
Unpolished	0.51^{a} ± 0.01	19.54±0.69	77.04 ^{a} ± 0.30	64.45 ^{a} ± 0.29	6.32 ^{c} ± 0.11
Semi polished	0.42^{b} ± 0.01	19.26± 0.57	75.02 ^{b} ± 0.30	63.15 ^{b} ± 0.08	6.64 ^{b} ± 0.10
Fully polished	0.40^{c} ± 0.01	18.61 ± 0.39	72.27 ^{c} ± 0.25	62.27 ^{c} ± 0.30	6.85 ^{a} ± 0.10
F value	84.08	2.12	209.31	61.29	19.91
S.Em±	0.02	0.33	0.17	0.14	0.06
C.D	0.06**	NS	0.57**	0.49**	0.21*

*Significant at 5% level (p< 0.05), **Significant at 1% level (p< 0.01), NS – Non significant
No. of replications: 3
Values in a column followed by different Superscripts are significantly different according to DMRT at the 0.05 level

Conclusion

Overall, it can be concluded from the study that the physico-chemical properties like weight and volume of 1000 unpolished grains were significantly higher than semi and fully polished. Functional characteristics at different stages of polishing showed that, per cent water and oil absorption capacity and hydration capacity of unpolished grains were significantly higher than semi and fully polished. Swelling power of fully polished grains was significantly higher than semi and unpolished.

The farming community is still unaware of the true potential of barnyard millet cultivation in terms of advancements in post-harvest technologies, nutritional value and productivity. Farmers generally cultivate this crop under marginal areas, but they still depend on low yielding local landraces. Therefore, support from non-government organizations (NGOs) can help in increasing awareness among the farmers, stakeholders, nutritionists, and consumers to adopt and promote barnyard millet cultivation as well as consumption. There is also an urgent need for advancements in post-harvest technologies for better processing and value-addition in the barnyard and other minor millets. At the same time, a change in consumer preference toward small millets with simultaneous development of suitable food products, along with an increase in market price, would fetch better returns for farmers and healthier choices for consumers.

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