RESEARCH ARTICLE Asian Journal of Dairy and Food Research, Volume 45 Issue 1: 101-105 (February 2026)

Optimizing Dehulling Quality in Barnyard Millet Through Pre-processing Techniques

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10.18805/ajdfr.DR-2420

ABSTRACT

Background: Minor millets, with their small size and hard husk, pose challenges in dehulling that affect overall yield and utility. Pretreatment methods were employed to facilitate more efficient dehulling.

Methods: The current study was undertaken to assess the dehulling efficiency and evaluate the impact of various pre-treatments on the spatial and functional properties of barnyard millet (*Echinochloa crusgalli* L.). The grains were subjected to abrasive dehulling [A] for 2[A2], 4[A4], or 6[A6] minutes followed by centrifugal dehulling and the efficiency indices were calculated.

Result: A2 and A4 samples exhibited superior milling efficiency and whole kernel recovery reflecting better grain integrity after processing. The A6 treatment resulted in highest head rice yield with intact grains whereas the control has lower retention and reduced dehulling performance. Spatial analysis of the grain revealed that A4 has the largest grain dimensions compared to other samples. Functional property evaluation indicated that A6 had the highest water holding capacity and swelling power making it ideal in developing rehydrated formulations, A4 was more appropriate for processed foods applications, A2 has good hydration properties, while the control sample was best suited for snack preparation. Among the pre-treated samples A2 sample was reported significantly dominant among the other pre-treated samples.

Key words: Barnyard millets, Dehulling efficiency, Functional properties, Performance indices, Spatial.

INTRODUCTION

Millets, historically recognized as nutri-rich grains and now termed nutri-cereals, have their origins deeply embedded in ancient scriptures and diverse cultures globally. In India, their cultivation dates back to the Indus valley civilisation, marking them among the earliest domesticated grains, Historically played a significant role in ancient diets and agricultural with their resilience to adverse climatic conditions and nutritional benefits made them a staple in Indian food culture, a legacy that continues today (Jinu *et al.,* 2024). The rich nutritional profile of millets has established them as a valuable dietary source, offering a reliable option for managing various metabolic disorders. Their high fibre content, complex carbohydrates and abundance of essential micronutrients make them a beneficial alternative for maintaining overall health and fitness. Additionally, their glycemic index and presence of bioactive compounds contribute to improved digestion, sustained energy levels and better metabolic regulation (Pardeep *et al.,* 2024). Millet, being rich in polyphenols and other bioactive compounds, is thought to reduce fat absorption and promote a slower release of sugars (low glycemic index), thereby contributing to a lower risk of cardiovascular disease, diabetes and hypertension (Chaudhary *et al.*, 2025).

The wide spread consumption of millets is often hindered by the efficient primary processing technologies. Owing to their tough outer hulls many millet varieties require specialized dehulling techniques, however processing methods can lead to lower grain recovery, loss of nutrients and reduced consumer appeal. The challenges include high kernel breakage rates, however uneven polishing and inadequate sorting mechanisms, all of which impact the overall quality of millet-based products. Advancements in processing technologies, such as improved dehulling, milling and sorting techniques, could significantly enhance millet utilization, making them more accessible and appealing for modern consumers. Encouraging the development of better processing infrastructure and techniques can help unlock their full potential as sustainable, nutrient-rich food sources (Sujana, 2023).

Primary processing technologies are vital in enhancing millet usability and value. They help minimize post-harvest losses, boost grain quality and increase millet consumption. Beyond these benefits, such technologies support farmer

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How to cite this article: Roberts, T.P.P. and Sharada, S. (2026). Optimizing Dehulling Quality in Barnyard Millet Through Pre-processing Techniques. *Asian Journal of Dairy and Food Research.* **45(1):** 101-105. doi: 10.18805/ajdfr.DR-2420.

Submitted: 19-11-2025 **Accepted:** 22-12-2025 **Online:** 06-01-2026

income generation and strengthen nutritional security, thereby contributing to rural economic development. The availability of cost-effective access through custom hiring models, enabling farmers to utilize machinery without large investments. This accessibility encourages the adoption of secondary processing techniques, thereby expanding market opportunities for millet based products (Rajendra *et al.*, 2025).

Dehulling plays a vital role in millet processing, but it comes with several challenges, particularly for minor millets. Traditional dehulling methods are often labor-intensive and inefficient, leading to high grain breakage and nutrient loss. Additionally, the small grain and hard husk of minor millets further complicates the process, reducing both yield and usability. Pre-treatment methods, such as soaking, parboiling, steaming, drying, lime treatment, rubber roll shelling and hydrothermal treatments were used to enhance dehulling efficiency of little millet, finger, pearl millet and kodo millet (Swapna *et al.*, 2020; Ravindra *et al.*, 2008). Building on this, the current study was designed to assess the dehulling efficiency and evaluate the impact of various pre-treatments on barnyard millet (*Echinochloa crusgalli* L.) spatial and functional properties.

MATERIALS AND METHODS

Barnyard, millet was sourced from local markets in Madurai, Tamil Nadu. To remove physical impurities like stones, sand and pebbles, the grains underwent cleaning using a three-stage grader cum aspirator (Make: DHAN Foundation, Tamil Nadu) followed by dehulling using a centrifugal dehuller (Make: DHAN Foundation, Tamil Nadu), which efficiently separated the output into three distinct outlets: dehulled rice, undehulled components and husk. The entire study done in Millet Processing and Incubation Centre, Professor Jayashankar Telangana Agricultural University, Rajendranagar, Hyderabad in the year of 2023. Grain that underwent cleaning and was directly subjected to dehulling served as the Control sample, as direct dehulling is considered the standard process. Meanwhile, pre-treatments were applied prior to dehulling as part of the experimental modifications.

Pre-treatments opted

Processing minor millets is challenging due to their tough, multi-layered and indigestible husk that encloses a soft endosperm. To separate the husk from the endosperm, a certain amount of pressure is required, which can be applied through a centrifugal dehuller. However, this force alone is insufficient to break the husk. Therefore, an abrasive dehuller was chosen to rub the grains, softening the husk through continuous friction. Cleaned grains were initially subjected to abrasive dehulling for 2, 4 and 6 minutes. This rubbing action helped loosen the husk, making it more receptive to further processing. Subsequently, the grains underwent centrifugal dehulling to achieve effective husk removal. The grains treated with abrasive dehulling [A] for 2[A2], 4[A4], or 6[A6] minutes were selected as mechanical and non-thermal pre-treatments followed by centrifugal dehulling [C].

The outcome of dehulling was evaluated based on produces obtained during the dehulling process, measurements included the initial weight of grain sample (i) and components such as whole kernel comprising both dehulled and brokens (k), dehulled grain (d), undehulled grain (ud), husk (h), broken grits (b) as coarse grits (cg) and fine grits (fg). These parameters were recorded to calculate the efficiency metrics of dehulling (Swapna *et al.*, 2020).

Calculation of dehulling quality

$$\text{Grain retention (\%)} = \frac{\text{Weight of grain retained (g)}}{\text{Weight of sample (g)}} \times 100$$

$$\text{Residual husk percentage (\%)} = \frac{\text{Weight of hull retained (g)}}{\text{Weight of sample (g)}} \times 100$$

$$\text{Dehulling efficiency (\%)} = \frac{\text{Weight of sample - Weight of unhulled grain retained (g)}}{\text{Weight of sample (g)}} \times 100$$

$$\text{Dehulling (\%)} = \frac{\text{Weight of hulled grain retained (g)}}{\text{Weight of sample (g)}} \times 100$$

$$\text{Head rice} = \frac{\text{Weight of dehulled whole kernels (g)}}{\text{Weight of sample (g)}} \times 100$$

$$\text{Coefficient of wholeness kernel} = \frac{\text{Weight of whole kernel (g)}}{\text{Weight of dehulled (g)}} \times 100$$

$$\text{Milling efficiency} = \frac{\text{Co.eff of wholeness * Dehulling efficiency}}{\text{Weight of sample (g)}} \times 100$$

Calculation of spatial properties

The pretreated barnyard millet grains were collected after dehulling and evaluated for spatial properties. Projected area to largest area (mm^2), intermediate (mm^2) and small dimensions (mm^2), critical projected area (mm^2), radius minimum (mm) and maximum (mm) were calculated using following equations as per Abhishek *et al.* (2021).

$$P\,(Max) = \frac{\pi \times L \times W}{4}$$

$$P\,(Int) = \frac{\pi \times W}{4}$$

$$P\,(s) = \pi \times T \times W$$

$$CPA = \frac{Pm + Pi + Ps}{3}$$

$$R\ min = \frac{W}{2}$$

$$R\ max = \left[W^2 + \frac{L^2}{4}\right] /2W$$

Calculation of functional properties

The pre-treated grains were evaluated for pH and other functional properties like water holding capacity, swelling power, water solubility index and water absorption capacity were calculated.

Determination of pH

The pH of the millet flour was determined by the method of Jackson (1973). Three grams of flour was mixed in 30ml of distilled water and placed in a shaker for thirty minutes at 150 rpm. The supernatant was decanted into a beaker and pH was read using pH meter after calibrating with pH 4.0 and 7.0 buffers.

Water holding capacity

One gram of flour was accurately weighed into a pre-weighed centrifuge tube, to which 10 ml of distilled water was added. The contents were then vortexed vigorously for 1 minute to ensure thorough mixing. After standing at room temperature for 30 minutes, the mixture was centrifuged at 3000 rpm for 15 minutes. The supernatant (unabsorbed water) was carefully removed and the tube was weighed again. The water holding capacity of the flour was calculated based on the increase in weight using the following formula:

$$\frac{\text{Weight of tube with sample and water retained} + \text{Weight of tube with sample}}{\text{Weight of sample}} \times 100$$

(Mesias and Morales, 2017).

Swelling power (SP) and water solubility index (WSI)

Swelling power (SP) was determined following the method of Awoyale (2020). Approximately 1 g of the sample was mixed with 10 ml of distilled water and cooked in a water bath maintained at 60°C for 30 minutes. The resulting slurry was then centrifuged at 3000 rpm for 15 minutes. The wet sediment was carefully weighed to determine the swelling power. The supernatant was transferred to a petri dish and evaporated on a hot plate. The petri dish was then dried in a hot air oven at 105°C, cooled and reweighed to assess the water solubility index (WSI). Swelling power and solubility were calculated using the corresponding formulas:

$$\text{Swelling power} = \frac{\text{Weight of wet residue (g)}}{\text{Weight of sample}} \times 100$$

$$\text{Water solubility index} = \frac{\text{Solids in dried supernatant (g)}}{\text{Weight of sample}} \times 100$$

Water absorption capacity (WAC)

Water absorption capacity was assessed following the method described by Kadan *et al*. (2008). One gram of flour was placed into a pre-weighed centrifuge tube and 10 ml of distilled water was added. The suspension was allowed to stand at room temperature for 2 hours with occasional stirring. Thereafter, the mixture was centrifuged at 300 rpm for 10 minutes.

$$\text{WAC (g/ml)} = \frac{\text{Weight of wet sediment (g)}}{\text{Dry weight of flour (g)}}$$

Statistical analysis

All the numerical data were expressed as the mean±SD of triplicate measurements and statistical analysis was done using paired sample t-test for control and treated samples for the grains in SPSS software.

RESULTS AND DISCUSSION

Indian millets are broadly classified into major and minor types on their grain and consumption patterns. Major millets have a physiological structure where the bran forms the outer layer, covering the endosperm. In contrast, minor millets possess an additional protective layer, featuring a hard, indigestible hull. Dehulling is a key technique in the early stages of the grain processing, involving the removal of the outer layer, whether it be the hull or pericarp. Although no definitive standard exists for the extent of outer layer removal, the hull content and pearl millet typically ranges from 1.5 to 30%. Excessive dehulling beyond this limit can lead to the loss of essential nutrients such as minerals, protein and fiber (Rani *et al.*, 2018). The hull percentage can be recognized as a relevant criterion and it plays subsidiary role in evaluating the current study and measuring the efficiency of its output.

Evaluation of dehulling quality

The quality of dehulling was evaluated by removing the hull and collecting dehulled grains with the objective of minimising coarse grits and maximising head rice yield. This assessment was carried out for barnyard millet control and pre-treated grain samples and the results are presented in Table 1.

Grain retention percentage indicates the percent of grains that withstand the dehulling process and remain intact after processing. No significant variation was observed among the barnyard millet samples ($p>0.05$), indicating statistical insignificance. The lowest grain retention (%) was for A6 sample while the highest was observed for the A4 sample compared to the control. Notable, the A4 sample exhibited the highest dehulling efficiency, reflected in the greater proportion of dehulled grains obtained, whereas the A6 sample yielded more head rice. Residual husk percentage is the expression of husk left over after processing and generally indicates better husk removal. It generally influence dehulling quality, milling efficiency and final output. The husk percentage was obtained more in A4 sample compared to control barnyard millet and was significantly different (5% level).

Dehulling efficiency explains how the pre-treatment effected outer husk removal and as high as it escalates indicate better removal ability of husk removal. Significant differences in dehulling efficiency were observed for the A4 and A6 samples at the 5% level and for the A2 sample at the 1% level, when compared with the control. Dehulled kernel output was significantly higher for A4 samples

whereas head rice yield was high for A6 samples. In contras, the co-efficient of wholeness kernel and milling efficiency were significantly higher for A2 samples. This might be due to high proportion of intact grains improving product quality and better kernel output. Similar results were observed in little millet (Swapna *et al.,* 2020), for minor millets (Dayakar *et al.*, 2019), for kodo and little millets (Shashikumar *et al.*, 2023).

The spatial properties given in Table 2 refer to their size, shape and distribution characteristics, which influence processing efficiency, milling performance and food quality. The projected area (mm^2) define the maximum surface area of grain projected from top and A4 has highest maximum projected area and smallest for A2 sample and the values has no significant variation among barnyard millet control and pre-treated samples ($p>0.05$), indicating statistical insignificance. Similar trend was observed for projected intermediate surface area. Smaller grain dimension grains remain critical in processing efficiency. Among the control and pre-treated samples of barnyard millet A4 sample has significantly (5% level) wider grain width that could influence dehulling and milling performance and A2 remain smallest keeping it more compact. The critical projected area refer to minimum surface area required for efficient processing technologies. This parameter remain crucial in determining grain's interaction with machinery during processing. A4 sample of barnyard millet showed slight resistance to mechanical pressure and differed from control sample (5% level) whereas remaining sample has no variation resulting statistically insignificant. Minimum (mm) and maximum radius (mm) values depicted A2 sample was the smallest and A4 sample appeared elongated and rounder in shape (Abhishek *et al.,* 2021).

Evaluation of functional properties

In Table 3 the values expressing acidity or alkalinity was evaluated by pH of the flour. The pH of the control and pre-treated millet samples revealed that they were slightly acidic and the values were statistically insignificant. Water holding capacity of the sample indicate the ability of grain's moisture retention making it ideal for various food applications. Highest water holding capacity was reported for A6 sample and lowest for control sample. This pre-treatment might have left the samples soft-textured and enhanced moisture retention significantly among treatments. Furthermore, superior water holding observed in wheat-maize blends compared to gram-maize blends attributing to differences in molecular structure (Kathuria *et al.*, 2021) and water absorption trend can be affected by irradiation (Kaushik *et al.*, 2021). Swelling power indicate the ability of starch granules to expand and water solubility

Table 1: Dehulling quality of barnyard millets.

Grains	Grain retention (%)	Residual husk percentage (%)	Dehulling efficiency (%)	Per cent of dehulled	Head yield (%)	Co-efficient of wholeness kernel	Milling efficiency
BY-C	71.51±1.42	22.43±1.12 ^{NS}	88.79±0.67	60.30±2.08	57.90±1.70	62.87±0.92	55.81±0.78
BY-A2	73.68±1.39 ^{NS}	24.28±1.13 ^{NS}	93.54±0.63***	67.22±1.69*	61.97±1.81*	99.43±0.34***	93.0±0.94***
BY-A4	74.79±2.88 ^{NS}	29.56±4.22*	93.98±0.19*	68.77±2.96***	62.86±2.24*	86.69±4.74**	81.47±4.31***
BY-A6	70.81±5.40 ^{NS}	24.73±1.19 ^{NS}	93.51±0.32*	64.32±5.29***	68.16±2.21**	86.02±5.48**	80.43±4.94***

NS- Not significant; *Significant at 0.05 level; **Significant at 0.01 level.

Table 2: Spatial properties of barnyard grain samples.

	Projected area (mm^2)	Projected area intermediate dimension (mm^2)	Smaller dimension (mm^2)	Critical projected area (mm^2)	Radius min (mm)	Radius maximum (mm)
BY-C	2.24±0.37	1.26±0.13	1.35±0.26	1.62±0.25	0.81±0.08	1.05±0.09
BY-A2	1.87±0.39 ^{NS}	1.13±0.21 ^{NS}	1.15±0.29 ^{NS}	1.39±0.28 ^{NS}	0.72±0.13 ^{NS}	0.97±0.10 ^{NS}
BY-A4	2.68±0.30 ^{NS}	1.40±0.09 ^{NS}	1.78±0.24*	1.96±0.19*	0.90±0.05 ^{NS}	1.15±0.06 ^{NS}
BY-A6	2.34±0.23 ^{NS}	1.29±0.07 ^{NS}	1.46±0.13 ^{NS}	1.70±0.13 ^{NS}	0.82±0.04 ^{NS}	1.07±0.05 ^{NS}

NS- Not significant; *Significant at 0.05 level; **Significant at 0.01 level.

Table 3: Functional properties of barnyard grain samples.

	pH	WHC (%)	Swelling power (%)	Water solubility index (%)	Water absorption capacity (g/ml)
BY-C	5.88±0.02	99.52±0.09	122.73±0.17	4.98±0.29	2.17±0.31
BY-A2	5.89±0.20 ^{NS}	102.21±0.11***	132.26±0.33***	6.99±0.20**	2.13±0.34 ^{NS}
BY-A4	5.89±0.13 ^{NS}	130.14±0.10***	147.03±0.29***	6.97±0.23**	2.42±0.13 ^{NS}
BY-A6	5.85±0.05 ^{NS}	139.93±0.65***	161.30±0.42***	6.97±0.50**	2.53±0.19 ^{NS}

NS- Not significant; *Significant at 0.05 level; **Significant at 0.01 level.

index explain the liberation of water soluble compounds into water and the results were significantly different from control sample. In both the parameters, the values of control sample revealed that it had lowest hydrating property and reduced solubility. Water absorption capacity that influenced cooking time and it was reported highest for A6 and A4 sample that can lead to flour utilisation in softer textured foods and control and A2 sample can result in developing firmer textured product (Mane *et al.*, 2022).

CONCLUSION

Despite its small size, barnyard millet grain exhibited diverse and significant variations when subjected to specific pre-treatments. The pre-treated barnyard millet grains were evaluated for dehulling properties, spatial and functional properties. A2 and A4 samples displayed high milling efficiency and whole kernel recovery indicating better grain integrity after processing. A6 grain resulted in highest head rice yield that remained grains intact whereas control has lower retention and reduced performance in expelling dehulling indices. Dehulling efficiency was higher for pre-treated samples compared to control. Spatial properties of the grain revealed that A4 has the largest grain dimensions compared to other samples. A6 has the highest water holding capacity and swelling power making it ideal in developing rehydrated formulations, A4 in processed foods application, A2 has good hydration whereas control sample was best suited for snacks. Among the pre-treated samples A2 sample was reported dominant among the other pre-treated samples.

ACKNOWLEDGEMENT

Not applicable.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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