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D Shashikalabai

Associate Professor
ICAR-All India Coordinated
Research Project on Post Harvest
Engineering and Technology
(AICRP on PHET), University of
Agricultural Sciences (UAS),
Gandhi Krishi Vignana Kendra
(GKVK), Bengaluru, Karnataka,
India

M Manjunatha

Research Engineer and Head
ICAR-All India Coordinated Research
Project on Post Harvest Engineering
and Technology (AICRP on PHET),
University of Agricultural Sciences
(UAS), Gandhi Krishi Vignana Kendra
(GKVK), Bengaluru, Karnataka, India

GN Supriya

Ph.D. Scholar Department of
Agricultural Extension and
Communication, Anand Agricultural
University (AAU), Anand, Gujarat,
India

K Amaresh Kumar

Professor and Extension Leader
Staff Training Unit (STU), University of
Agricultural Sciences (UAS), Gandhi
Krishi Vignana Kendra (GKVK),
Bengaluru, Karnataka, India

Veena R

Senior Technical Officer
ICAR-All India Coordinated Research
Project on Post Harvest Engineering
and Technology (AICRP on PHET),
University of Agricultural Sciences
(UAS), Gandhi Krishi Vignana Kendra
(GKVK), Bengaluru, Karnataka, India

Corresponding Author:

D Shashikalabai

Associate Professor
ICAR-All India Coordinated
Research Project on Post Harvest
Engineering and Technology
(AICRP on PHET), University of
Agricultural Sciences (UAS),
Gandhi Krishi Vignana Kendra
(GKVK), Bengaluru, Karnataka,
India

Emerging trends in parboiling of small millets: A sustainable route to improved grain quality- A review

D Shashikalabai, M Manjunatha, GN Supriya, K Amaresh Kumar and Veena R

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Abstract

Millets are strategic for food and livelihood security particularly for dryland farmers. Direct dehulling of small millets often results in significant nutritional losses because the process removes portions of the bran and germ, which are rich in dietary fiber, minerals, vitamins, and bioactive compounds. Parboiling is an effective pre-processing technique that facilitates the migration of water-soluble nutrients into the endosperm while strengthening the grain structure. Parboiling of small millets has emerged as a promising pre-processing technology that enhances grain quality, nutritional value, and post-harvest stability while supporting sustainable food processing. Hydrothermal treatment or parboiling significantly improves the milling properties of minor millets by enhancing milling recovery, dehulling efficiency, and reducing broken yield. Parboiled grain is more resistant to breaking under abrasive as well as friction milling conditions than raw grain. Parboiling offers a scientifically proven approach to address these challenges. By inducing starch gelatinization and structural hardening of the endosperm, parboiling enhances grain integrity, significantly reduces breakage during milling, and improves head rice yield. Furthermore, the review explores the effects of parboiling on reducing grain breakage, enhancing milling yield, and minimizing nutrient losses, thereby optimizing the overall milling efficiency of small millets.

Keywords: Parboiling, Pretreatment, Processing and Dehulling

Introduction

Small Millets includes finger millet (ragi), kodo millet (kodo), foxtail millet (kangni), barnyard millet (sawan), proso millet (cheema), and little millet (kutki). Millets are strategic for food and livelihood security particularly for dryland farmers. They are climate-resilient and highly nutritious, contributing positively to local agro-ecosystems. Despite their benefits, millet consumption has declined due to the labor-intensive nature (drudgery) of their preparation. Millet consumption is mostly limited to traditional consumers and cultivation areas, leading to underutilization. To boost millet demand, it is essential to involve all stakeholders across the production-to-consumption value chain as well numerous food uses of millets. However, it has been confined only to traditional consumers; limited especially to areas of their cultivation, and still have remained underutilized. The global production of millets increased from 27.71 million metric tons (MMT) in 2021-2022 to 32.09 MMT in 2022-2023. Among these, India accounted for 42% (32.51 MMT) and held the top position in global millet production, with Niger and China ranking second and third respectively (Singh *et al.*, 2024a)^[13, 16]. This growth reflects the rising recognition of millets as vital crops for food security, nutrition, and climate resilience, particularly in regions where millet cultivation faces challenges. Providing an affordable, healthy, and nutritious diet to all populations is a critical step towards this goal. Millets, often referred to as nutri-cereals, possess significant potential to address food insecurity and malnutrition due to their high nutritional value and adaptability to diverse agro-ecological conditions (Nanje Gowda *et al.*, 2022).

Parboiling

Hydrothermal treatment, particularly through the parboiling process, has emerged as a critical method for enhancing milling efficiency in small millets. Parboiling as a means to improve the

quality and yield of milled millet grains. Considering its nutritional value and widespread consumption in India. It then delves into the principles underlying the parboiling process, including soaking, steaming, and drying stages, and their impact on the physicochemical properties of millet grains. Furthermore, the review explores the effects of parboiling on reducing grain breakage, enhancing milling yield, and minimizing nutrient losses, thereby optimizing the overall milling efficiency of small millets. It discusses the implications of parboiling on nutritional quality, food safety, and economic viability, underscoring its potential to address challenges in millet processing and promote

sustainable agricultural practices. It emphasizes the importance of interdisciplinary collaboration, knowledge exchange, and technology transfer to realize the full benefits of hydrothermal treatment in improving milling efficiency and enhancing the value chain of small millets. In summary, this critical review provides valuable insights into the role of parboiling as a transformative technique for enhancing milling efficiency in millet processing, offering implications for research, policy, and practice in the domains of food security, nutrition, and agricultural development.

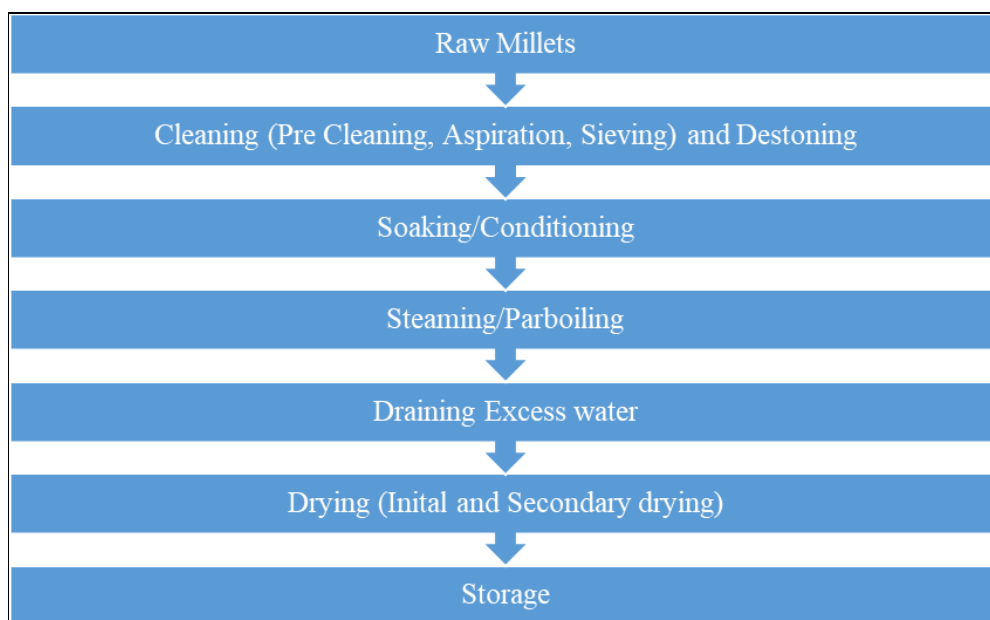


Fig 1: Process flow chart for Parboiling of small mill

The scientists involved in conducting parboiling research systematically investigated the parboiling and dehulling of small millets and their findings has been given below.

Akhil *et al.* (2021) ^[1] examined the effect of parboiling on foxtail millet de-husking, finding an increase in head grain yield from 63% to 77.5% and a reduction in broken grains from 18.5% to 2.5%. Singh *et al.* (2024) ^[13, 16] reported that hydrothermal pre-treatments improved the dehulling and polishing efficiencies in Kodo millet, resulting in higher head grain yield and lower broken percentage. Thus, parboiling is an effective pre-treatment to enhance millet milling properties (Kabui K.K. and Athmaselvi, 2024) ^[6].

Hydrothermal treatment significantly improves the milling properties of minor millets by enhancing milling recovery, dehulling efficiency, and reducing broken yield. For example, kodo millet soaked at room temperature for 24 hours followed by steaming at 1 kg/cm² for

5 minutes achieved about 57% milling recovery, while browntop millet treated similarly but steamed for 15 minutes reached approximately 70% recovery was reported by B. Kalpana *et al.*, 2017-18. An experiment was conducted by Visvanathan and Balkrishna in the year 2024 ^[11, 19] found that increasing the severity of hydrothermal treatments, particularly soaking at 60°C followed by steaming at 1 kg/cm² for 20 minutes (T9 treatment), optimized milling yield for little and barnyard millets. For pearl millet, soaking in water at 60-70°C for 4 hours followed by steaming at 100°C for 15 minutes improved grain processing depending on grain morphology (Sene *et al.*, 2018) ^[14]. These treatments affect starch gelatinization and retrogradation, leading to improved water absorption,

digestibility, texture, and nutrient availability, thus enhancing the suitability of millets for various applications. Kodo millet was subjected to more severe hydrothermal treatments like hot water soaking followed by steam cooking. During hot water soaking @ 75°C for 3.5 h, the grains got hydrated quickly and also while steeping itself they absorbed relatively more water. Some starch granules might have been gelatinized at this soaking temperature even before steam treatment, ultimately enhancing the severity of heat treatment. This resulted in increased head yield, milling recovery, dehulling efficiency and reduced grain breakage for hot water soaked millet when compared to room temperature water soaked millet. Similar results were reported for paddy by Ali and Bhattacharya (1969), Pillaiyar and Mohandoss (1981) and Raghavendra and Jualino (1970).

Kodo millet soaked in hot water @ 75°C and subsequently steamed @ 1kg/cm², for

15 min was considered to be more suitable, since the colour of the milled rice was lighter and a part from better milling characteristics. In case of hot water soaked (72°C for 3.5 h) kodo millet grains, steaming pressure @ 1kg/cm² for 15 min was found to be best owing to high dehulling efficiency, high head yield and lower broken.

Rajashekar *et al.* (2018) stated that finger millet grains were soaked in two different temperatures of 30°C and 70°C with 24 and 1 hour 45 minutes soaking times respectively and the same was reported by Ushakumari, 2009. A water bath was used for soaking finger millet at 70°C and good quality plastic containers were used to soak the grains at 30°C. Grains after soaking were immediately subjected to steaming at

steaming pressures of 1, 1.5 and 2 kg/cm² in order to get the grains completely gelatinized. Rathore and Singh (2017) revealed that, the impact of hydrothermal treatment on pearl millet showed the highest milling yield obtained by soaked for 4 hours, steamed at 12.33 minutes and 393.23 kPa of pressure. Hydrothermally treated millet contains 65.4% yield with 15.5% moisture content that was tempered with 5% more water at the first stage and 4% more at the second.

The efficiency of dehulling, dehushing, and polishing in millets is strongly influenced by pretreatment methods, particularly those involving moisture conditioning and thermal processing. These treatments modify the physical and structural properties of the grain, facilitating easier separation of the husk and improving milling performance for individual millets is given in Table 1. (Singh S. M. *et al.*, 2024) ^[13, 16]

Table 1: Effect of pretreatment on dehulling/dehushing and polishing of millets

Type of millet	Pretreatment Conditions	Highlighted results	References
Foxtail	Moistening the hydrothermally treated grain with 6% water and tempered for 5 to 10 min.	Decortication yield was increased from 45% to 85%.	Shobana & Malleshi
Little	Boiling in water for 20 mins and sun drying.	Obtained 83% dehushing efficiency and 60.60% milling efficiency.	Ravindra <i>et al.</i>
	Soaking in 2% lime water for 2 h and sun drying.	Obtained 82% dehushing and 66% milling efficiency.	Ravindra <i>et al.</i>
Pearl	Parboiling	Observed 65.40% head grain yield.	Rathore & Singh
Kodo	Soaking for 2 h and shade drying for 5 h	Found 75.29% dehushing efficiency of 14% moisture content grain.	Nayak <i>et al.</i>
Pearl	Modified parboiling (12 h soaking, 5 min boiling, and air dried 24-48 h till 11%-13% m.c.).	Obtained 78% decortication yield.	Bora <i>et al.</i> ^[2]
Little	Soaking (4 h), 15 min steaming at 100°C, and hot air drying (45°C) until the grain reaches 11% m.c. (d.b).	Observed 96.72% dehulling efficiency and 70.21% milling efficiency.	Sahoo <i>et al.</i> ^[15]
Foxtail	Soaking (5), steaming (10 min), and drying at 50 °C for 2 h (till 12% m.c).	Head yield increased from 63% to 77.50%.	Akhil <i>et al.</i> ^[1]
Finger	Soaking for 2.1 h at 44°C followed by steaming at 110°C at 5 psi. For 5 min in a scientific autoclave, followed by oven drying.	Head yield increased from 70% to 86% while broken percentage decreased from 15% to 1.30%.	Kaur <i>et al.</i>

Parboiling or hydrothermal treatment of foxtail and little millet grains is done for gelatinizing the starch granules. These treatments significantly reduce the number of breakages during milling by imparting extra strength to the grains and improve the retention of nutrients compared to raw grains of the same variety was reported by Araullo *et al.*, (1985).

Parboiled grain is more resistant to breaking under abrasive as well as friction milling conditions than raw grain. The fissures of the grains are filled during parboiling, resulting in less breakage

during milling. Akhil *et al.* (2021) ^[1] investigated the effect of parboiling on de-husking of foxtail millet. It was found that the head grain yield of the millet increases from 63% to 77.5% and the broken yield reduced from 18.5% to 2.5% after the parboiling treatment. (Kabui KK, Athmaselvi KA. 2024) ^[6]. Considering several advantages of hydrothermal treatments on the milling qualities of grains particularly paddy, the following preconditioning treatments were imposed on little and foxtail millets is given in Table 2:

Table 2: Details of different pretreatment adopted for Little and Foxtail Millet experiment

Treatment	Pretreatment	Drying
T1	Soaking in boiling water for 20 min	Sun drying
T2	Soaking in water for 24 h + open steaming for 15 min	Sun drying
T3	Soaking in water for 24 h + steaming at 1 kg/cm ² for 10 min	Sun drying
T4	Hot water soaking at 70°C + open steaming	Sun drying
T5	Hot water soaking at 70°C + steaming at 1 kg/cm ² for 10 min	Sun drying
T6	Soaking in water for 10 min + open steaming for 15 min	Sun drying
T7	Soaking in water for 10 min + steaming at 1 kg/cm ² for 10 min	Sun drying
T8	Control without any pre-treatment i.e. raw grain	Sun drying

(R. Chandru *et al.* 2008 XXVII Annual Workshop Dec-17-20, UAS, Bangalore)

Foxtail, little, kodo and brown top millets were selected and treatments were imposed on these millets. The detailed treatment is as follows i. e., a) Soaking in boiling water (100°C) for 10 min and sun drying. b) Soaking at room temperature (28-30°C) for 10 min. followed by open steaming for 15 min. and sun drying. c) Soaking at room temperature (28-30°C) for 15 min. followed by open steaming for 10 min. and sun drying. Soaking at room temperature (28-30°C) for 24 hours followed by open steaming for 10 min. and sun drying. d) Dipping in 2% lime solution for 2 hours followed by sun drying was conducted by Kalpana *et al.*, 2016.

Browntop millet is emerging as a nutritionally superior millet with significant health-promoting properties; however, its large-

scale utilization is severely constrained by processing challenges. The grain is characterized by nearly seven tightly bound husk layers, making manual dehulling inefficient, with traditional methods yielding only 40-50 kg of rice from 100 kg of raw grain. Unlike other millets, existing milling technologies are not well suited for browntop millet, leading to excessive grain breakage and reduced recovery. This limitation is primarily due to the absence of standardized and optimized parboiling treatments that can modify the grain structure to withstand milling stresses.

Structurally, browntop millet has multiple hull layers and a relatively small endosperm surrounded by a thin bran layer, which makes it highly susceptible to breakage during

mechanical processing. Additionally, the outer layers contain anti-nutritional factors such as tannins and phytates. Tannins are concentrated in the outermost layers and are partially removed during dehulling, whereas phytates are distributed in inner layers and are more resistant to removal. These compounds reduce mineral bioavailability, hinder protein digestion, and may cause gastrointestinal discomfort. Therefore, effective pre-processing is essential not only to facilitate dehulling but also to improve nutritional quality.

Parboiling offers a scientifically proven approach to address these challenges. By inducing starch gelatinization and structural hardening of the endosperm, parboiling enhances grain integrity, significantly reduces breakage during milling, and improves head rice yield. Furthermore, it promotes the migration of water-soluble nutrients into the endosperm and helps reduce anti-nutritional factors, thereby improving both nutritional value and digestibility. Parboiling also enhances shelf life by inactivating enzymes responsible for rancidity and reducing susceptibility to pest infestation. Tatapudi, P. P. P. R., and Sharada, S. (2023)^[20] reported that browntop millet dehulling is one of the most critical steps in essential processing that removes and separates inedible husk from the edible portion of the grain as minor millets husk is highly cellulosic and firmly attached to edible portion. As existing technologies are unable to yield better solutions. Application of hydrothermal treatment and mechanical stress for a short duration by means of abrasive dehuller are the pre-treatments selected to soften the husk prior to dehulling. Despite its proven benefits in major cereals and other millets, systematic studies and continuous processing systems for parboiling of browntop millet are currently lacking. Given the small grain size, variability in raw material due to agro-climatic conditions, and post-processing storage issues, there is a critical need to develop a standardized, scalable, and continuous parboiling technology tailored specifically for browntop millet. The process of parboiling and the associated quality parameters are yet to be studied for further adoption and towards utility for the millets. (Rangaraju *et al* 2024)..

Significance of parboiling

Further, the presence of anti-nutritional compounds such as tannins and phytates, which significantly limit nutrient bioavailability and consumer acceptance when appropriate pre-processing is absent. Hydrothermal interventions, particularly parboiling, offer a scientifically validated pathway to overcome these constraints by facilitating husk loosening, enhancing grain integrity, minimizing breakage, and improving micronutrient retention and shelf stability. However, the absence of standardized, continuous, and scalable parboiling systems tailored specifically for small millets represents a critical research and engineering gap. Establishment of Continuous line for Parboiling of Small Millets is essential to reduce post-harvest losses, This process, strengthen millet-based enterprises, and contribute to national priorities such as nutritional security, climate-resilient agriculture, and doubling farmers' income. Without such targeted and science-driven intervention, the full potential of millet will remain unrealized, limiting its contribution to sustainable food systems and public health.

- Improve milling efficiency and head rice recovery
- Reduce grain breakage during processing
- Enhance physico-chemical, functional, and nutritional properties
- Reduce anti-nutritional factors
- Improve shelf life of processed products
- Minimize drudgery and processing time

- Promote value addition and diversification of millet-based products

Conclusion

pre-treatment technologies, particularly parboiling, represent a critical intervention for improving the processing efficiency, nutritional quality, storage stability, and commercial value of small millets. Optimized parboiling significantly enhances dehulling and milling performance while minimizing grain breakage, reducing post-harvest losses, and preserving essential nutrients and bioactive compounds through improved nutrient retention within the endosperm. Moreover, parboiling improves the functional properties of millet flour, including water absorption capacity, cooking performance, shelf life, and textural attributes, thereby expanding its suitability for the development of high-quality, value-added, and ready-to-cook food products. The integration of scientifically optimized parboiling protocols also supports sustainable processing by improving resource-use efficiency, reducing processing losses, and increasing the economic viability of millet-based value chains. As the demand for climate-resilient, gluten-free, and nutrient-dense cereals continues to grow, parboiling has emerged as a sustainable processing technology capable of enhancing both the nutritional integrity and industrial applicability of small millets.

Furthermore, continued advancements in process optimization, equipment design, and integrated pre-treatment technologies will facilitate the production of safe, functional, and consumer-acceptable millet-based foods while strengthening food security and nutritional outcomes. Therefore, the widespread adoption of standardized and sustainable parboiling technologies will be instrumental in maximizing the nutritional, functional, and commercial potential of small millets and supporting resilient agricultural and food processing systems for future generations.

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