Review Article
The J. Res. PJTAU 53 (1&2) 1-5, 2025

POST-HARVEST PROCESSING METHODS OF MAJOR MILLETS: A COMPREHENSIVE REVIEW

R. VASANTHA[1] and M. GIRIJA SRI[2]
[1]Extension Education Institute, PJTAU, Rajendranagar, Hyderabad
[2]College of Agriculture, PJTAU, Rajendranagar, Hyderabad

Date of Receipt: 09-01-2025 Date of Acceptance: 27-02-2025

ABSTRACT

Post-harvest processing plays a vital role in improving the quality, nutritional value, shelf life, and marketability of millets, which are increasingly recognized as climate-resilient and nutrient-rich cereals. This review synthesizes recent national and international research on the major post-harvest processing methods employed for millets, including harvesting, threshing, drying, cleaning, grading, storage, dehulling, pearling, polishing, and milling. Scientific processing technologies significantly reduce quantitative and qualitative post-harvest losses while enhancing grain recovery, processing efficiency, and consumer acceptability. The review highlights the importance of harvesting at physiological maturity, controlled drying, efficient cleaning and grading, scientific storage, and modern dehulling and milling techniques in preserving nutritional quality and minimizing processing losses. Furthermore, emerging technologies such as moisture conditioning, hydrothermal pretreatment, solar-assisted drying, and mechanized processing improve nutrient retention, reduce antinutritional factors, and support the development of value-added millet products. The review also emphasizes the role of post-harvest technologies in strengthening millet value chains, promoting entrepreneurship among women Self-Help Groups (SHGs) and Farmer Producer Organizations (FPOs), and enhancing food and nutritional security. Overall, adopting scientific post-harvest processing practices is essential for maximizing the economic potential, sustainability, and commercial utilization of millets while meeting the growing demand for healthy and functional foods.

Key Words: Millets, post-harvest processing, Value addition, Dehulling and milling, Food and nutritional security.

Millets have re-emerged as one of the most important climate-resilient cereal groups in the twenty-first century because of their ability to support sustainable agriculture, nutritional security, and diversified food systems. For several decades, global agricultural policies favoured rice, wheat, and maize, resulting in a decline in millet cultivation, consumption, and research. However, the increasing incidence of climate change, water scarcity, micronutrient malnutrition, and lifestyle-related diseases has shifted scientific attention toward underutilized cereals, particularly millets. The declaration of 2023 as the International Year of Millets (IYM 2023) by the United Nations has further accelerated global research on millet production, post-harvest technologies, food processing, value addition, and commercialization, millets are no longer viewed merely as subsistence crops but as strategic commodities capable of contributing to climate-smart agriculture, healthy diets, and sustainable food systems. Mahajan *et a*l. (2024) sustainable post-harvest processing technologies such as dehulling, germination, fermentation, extrusion, roasting, and puffing play a central role in enhancing nutrient bioavailability while reducing antinutritional compounds. value addition through scientific processing technologies not only enhances the marketability and nutritional quality of millet-based products but also creates opportunities for rural entrepreneurship, particularly among women-led Self-Help Groups (SHGs) and Farmer Producer Organizations (FPOs). ICAR-IIMR (2023).

Growing popularity of millets is closely associated with changing consumer preferences toward healthy, functional, and sustainable foods, modern consumers increasingly demand foods rich in dietary fibre, natural antioxidants, plant proteins, essential minerals, and bioactive compounds while preferring gluten-free and minimally processed products. Jacob *et al*. (2024). millets meet these nutritional and functional requirements because they possess superior nutritional profiles compared with refined cereals and are increasingly incorporated into value-added food products. Siroha and Bangar (2024). Due to the low glycaemic index, high dietary fibre content, and abundance of phenolic compounds in millets make them particularly suitable for the dietary management of diabetes, obesity, cardiovascular diseases, and

Email: girijasri444@gmail.com

other metabolic disorders regular millet consumption contributes to improved metabolic health and supports the prevention of several non-communicable diseases.

Despite the outstanding nutritional and agronomic advantages of millets, their utilization remains constrained by several post-harvest challenges like small grain size, hard outer layers, variable moisture content, and the presence of antinutritional factors such as phytates, tannins, and enzyme inhibitors adversely affect processing efficiency, mineral bioavailability, and consumer acceptability. Mahajan *et al.* (2024). Inadequate post-harvest operations, particularly improper harvesting, drying, cleaning, dehulling, storage, and milling, contribute significantly to quantitative and qualitative grain losses, thereby reducing both nutritional quality and market value, improving post-harvest management through scientific processing technologies is fundamental to enhancing millet utilization, reducing post-harvest losses, and strengthening the millet value chain. (Mittal *et al.,* Sindhu *et al.* (2024). modern processing technologies not only improve grain quality and storage stability but also facilitate the development of a wide range of value-added products that increase consumer acceptance, create rural employment opportunities, and improve the profitability of millet-based enterprises. Hemasankari *et al.* (2023).

Harvesting of Major Millets

Harvesting is the first and one of the most crucial operations in the post-harvest management of millets because it determines grain quality, storage stability, milling efficiency, and the suitability of grains for further processing and value addition. Harvesting at the correct stage of physiological maturity minimizes field losses and ensures maximum retention of nutritional and physical quality. Premature harvesting often results in immature grains with high moisture content, poor grain filling, and low milling recovery, whereas delayed harvesting increases shattering losses, insect infestation, bird damage, fungal infection, and weather-induced deterioration (Anandhara makrishnan *et al.*, 2022; FAO, 2023) harvesting well-matured panicles of finger millet followed by proper post-harvest handling improved grain quality and enhanced the suitability of finger millet for processing into value-added products such as flour, malt, and bakery products and harvesting at optimum maturity produced grains with better storage stability and processing characteristics compared with immature grains Chandra *et al.* (2018) and pearl millet production systems in West Africa, reported that harvesting at physiological maturity significantly reduced field losses and preserved grain quality under rainfed conditions. Their study highlighted that delayed harvesting exposed grains to rainfall and mould development, leading to reduced market value,grain moisture at harvest strongly influenced subsequent drying efficiency and milling recovery harvesting at appropriate physiological maturity reduced kernel cracking during drying and improved head grain recovery after dehulling, proper harvesting combined with immediate post-harvest drying maintained the physicochemical characteristics of millet grains and reduced deterioration during storage. Mechanization has become an important area of research to reduce labour shortages and minimize harvest losses. evaluated small-scale harvesting technologies for millets in India and reported that mechanized harvesting significantly reduced labour requirements, harvesting time, and grain shattering compared with conventional manual harvesting,modern harvesting equipment not only improves operational efficiency but also minimizes mechanical damage to grains, thereby enhancing the quality of raw material entering the post-harvest processing chain, harvesting practices also influence microbial contamination and grain safety Dinesh *et al.* (2025) immediate harvesting followed by rapid drying reduced fungal colonization and minimized the risk of mycotoxin contamination in stored millet grains , integrating proper harvesting schedules with scientific post-harvest handling practices contributes significantly to food safety and long-term storage stability. Harvesting major millets when grains attain physiological maturity and panicles become completely dry to ensure maximum grain recovery and minimize storage losses. ICAR-IIMR (2023)

Threshing

Threshing is a crucial post-harvest operation that determines grain recovery, quality, and milling efficiency. Traditional methods such as beating and trampling are labour-intensive and often result in grain breakage and post-harvest losses (Yadav *et al.*, 2016). To overcome these limitations, a cleaner-cum-pearler that improved grain recovery while reducing impurities and kernel damage was developed Tejaswini *et al.* (2018). Similarly,mechanical threshers enhanced threshing efficiency and minimized grain losses through proper machine adjustmentSingh *et al.* (2015) and maintaining optimum grain moisture, reduced kernel breakage during threshing Patel and Naik (2022). mechanized threshing integrated with cleaning significantly improves grain quality, reduces labour, and enhances milling recovery and overall post-harvest processing efficiencyDayakar Rao *et al.* (2022).

Drying

Drying is one of the most important post-harvest operations because it reduces grain moisture to safe levels, thereby preventing microbial spoilage, insect infestation, and quality deterioration during storage. Traditional sun drying is widely practiced due to its low cost; however, it is highly dependent on weather conditions and often results in uneven drying, contamination, and nutrient losses (Anandha ramakrishnan *et al.*, 2022). To overcome these limitations, drying finger millet to safe moisture levels before milling improved flour stability, storage quality, and the suitability of grains for value-added products. Chandra *et al.* (2018) controlled drying following germination enhanced protein digestibility while reducing phytate content and improving mineral bioavailability.Nithiyanantham *et al.* (2019). Working on solar drying, solar-assisted drying preserved colour, functional properties, and nutritional quality more effectively than conventional open sun drying. Kaur *et al.* (2023). moisture conditioning followed by controlled drying before dehulling significantly improved milling recovery and reduced kernel breakage in kodo millet.Kabui and Athmaselvi (2024) maintaining grain moisture at approximately 10-12% through appropriate drying methods enhances storage stability, minimizes post-harvest losses, and improves milling efficiency and the quality of value-added millet products.

Cleaning

Cleaning is an essential post-harvest operation that removes dust, stones, chaff, immature grains, weed seeds, and other foreign materials, thereby improving grain quality, food safety, and processing efficiency. Effective cleaning before milling enhances flour quality by eliminating impurities that adversely affect processing, storage, and consumer acceptability (Malleshi, 2016). The integration of cleaning and pearling operations increases grain recovery, minimizes foreign matter, and improves overall processing efficiency in finger millet (Tejaswini *et al.*, 2018). Air-screen cleaning before polishing ensures uniform grain flow through the processing system, reduces machine wear, and enhances polishing efficiency in foxtail millet Kaur *et al.* (2023). The use of a double-head dehuller equipped with an aspirator and cyclone separator efficiently removes husk particles and light impurities from several small millets while maintaining high grain recovery (Hemasankari *et al.*, 2024). Integrating air-screen cleaners, destoners, and aspirators before dehulling further minimizes kernel damage, improves processing efficiency, and produces cleaner grains suitable for storage, milling, and value-added product development (Mittal *et al.*, 2024).

Grading

Grading is an important post-harvest operation that separates millet grains based on size, density, colour, and physical quality, thereby improving processing efficiency and market value. size grading of foxtail millet before polishing improved grain uniformity, reduced kernel breakage, and enhanced polishing efficiency.Kaur *et al.* (2023) uniform grain size significantly improved the performance of abrasive and centrifugal dehullers by ensuring consistent grain flow and reducing mechanical losses. Mittal *et al.* (2024) density grading effectively removes immature and shrivelled grains, thereby improving the quality of processed millet products. Dayakar Rao *et al.* (2022) colour sorting efficiently removed discoloured and damaged grains, enhancing consumer acceptability and food safety.Anandharamakrishnan *et al.* (2022) proper grading before processing improves milling recovery, storage quality, and market price while providing superior raw material for value-added millet products. Furthermore, FAO (2023).

Storage

Storage is a critical post-harvest operation that preserves grain quality and minimizes quantitative and qualitative losses during the storage period. Reducing grain moisture to approximately 10-12% before storage effectively minimized fungal growth and insect infestation, properly dried finger millet-maintained flour quality and storage stability for longer periods than inadequately dried grains. Chandra *et al.* (2018) hermetic storage effectively reduced insect infestation and prevented moisture absorption, thereby maintaining grain quality without chemical protectants.Anitha *et al.* (2022).ICAR-Indian Institute of Millets Research (2023) recommended scientific storage structures with proper aeration and moisture management to reduce post-harvest losses.FAO (2023) concluded that integrating moisture control, hermetic storage, and regular monitoring significantly improves grain safety, extends storage life, and preserves the nutritional quality of millet grains.

Dehulling of Major Millets

Dehulling is one of the most important processing operations because it removes the inedible husk while improving the cooking quality and processing characteristics of millet grains. Abrasive dehullers provide higher dehulling efficiency with lower grain losses than conventional methods. Hemasankari *et al.* (2024) developed a double-head dehuller for small millets and demonstrated that it achieved higher dehulling efficiency and grain recovery while reducing processing time, hydrothermal pretreatment followed by dehulling significantly improved kernel recovery and reduced grain breakage in kodo millet.centrifugal and impact dehullers substantially increased processing capacity compared with traditional dehulling methods.Dayakar Rao *et al.* (2022) optimized dehulling effectively removed the husk while retaining most of the nutritional components, thereby improving both consumer acceptability and processing efficiency.

Pearling and Polishing of Major Millets

Pearling and polishing improve the appearance, cooking quality, and consumer acceptability of millet grains by removing portions of the bran layer, optimized polishing conditions significantly improved surface finish and reduced grain breakage in foxtail millet.Kaur *et al.* (2023) increasing the degree of polishing reduced dietary fibre, minerals, and phenolic compounds because these nutrients are concentrated in the outer layers of the grainthen controlled pearling improved processing efficiency while minimizing nutrient losses. Mittal *et al.* (2024) moderate polishing offers a balance between improved consumer preference and nutritional retention. Anandha ramakrishnan *et al.* (2022)

Milling of Major Millets

Milling converts millet grains into flour which is suitable for preparing a wide range of traditional and value-added products, proper milling of finger millet produces stable flour suitable for bakery products, malt, and other value-added foods. Chandra *et al.* (2018). It also improved flour digestibility and functional properties.Nithiyanantham *et al.* (2019) roller milling produced finer flour with better functional characteristics than conventional stone milling. Kaur *et al.* (2023)and alsomodern milling technologies significantly improved flour recovery, reduced kernel losses, and enhanced product quality.Mittal *et al.* (2024)so, selecting an appropriate milling technique is essential for preserving nutritional quality, improving flour functionality, and maximizing milling recovery for the development of high-quality millet-based products.Anandharamakrishnan *et al.* (2022).

CONCLUSION

Post-harvest processing is essential for improving the quality, nutritional value, shelf life, and marketability of millets. Scientific operations such as timely harvesting, efficient drying, cleaning, grading, storage, dehulling, pearling, and milling significantly reduce post-harvest losses while enhancing grain recovery and consumer acceptance. Emerging technologies further improve processing efficiency, nutrient retention, and value addition, supporting the production of diverse millet-based foods. Promoting modern post-harvest technologies among farmers, women Self-Help Groups (SHGs), and Farmer Producer Organizations (FPOs) can strengthen millet value chains, increase rural income, ensure food and nutritional security, and contribute to sustainable, climate-resilient agricultural development.

REFERENCES

Anandharamakrishnan, C., Rawson, A., & Sunil, C. K. (Eds.). (2022). Handbook of millets: Processing, quality, and nutrition status. *Springer.*

Anitha, S., Kane-Potaka, J., Tsusaka, T. W., Botha, R., Rajendran, A., Givens, D. I., & Subramanian, S. (2022). Can millet consumption contribute to improved nutrition and sustainable diets.*Frontiers in Sustainable Food Systems, 6*, Article 876612.

Chandra, A., Singh, A. K., & Mahto, B. (2018). Processing and value addition of finger millet to achieve nutritional and financial security-Case study. *International Journal of Current Microbiology and Applied Sciences, 7*(11), 2901–2910.

Dayakar Rao, B., Tonapi, V. A., Satyavathi, C. T., & Malleshi, N. G. (2022). Millet processing technologies for value addition. ICAR-Indian Institute of Millets Research, Hyderabad.

Dinesh, G., Krishna, A. S., Kumar, Y., Joshi, T. J., & Rao, P. S. (2025). Postharvest processing of millets: Advancements & entrepreneurship development opportunities. *Future Postharvest and Food, 2*, 108–123.

Food and Agriculture Organization of the United Nations. (2023). Millets and sustainable food systems. FAO.

Hemasankari, P., Rao, B. D., Malathi, V. M., Kiranmai, E., &Rathnavathi, C. V. (2023). Value addition in millets through agricultural processing techniques. *Indian Farming, 73*(1), 107-109.

ICAR-Indian Institute of Millets Research. (2023). Millet processing and value addition manual. ICAR–Indian Institute of Millets Research, Hyderabad.

Jacob, J. J., Veda Krishnan, V., Antony, C., Bhavyasri, M., Aruna, C., Mishra, K. M., Nepolean, T., Satyavathi, C. T., &Visarada, K. B. R. S. (2024). The nutrition and therapeutic potential of millets: An updated narrative review. *Frontiers in Nutrition*, 11, Article 1346869.

Kabui, G. P., &Athmaselvi, K. A. (2024). Effect of moisture conditioning and dehulling on milling quality of kodo millet (*Paspalum scrobiculatum*). *Journal of Food Measurement and Characterization*.

Kaur, R., Sharma, S., & Kaur, M. (2023). Advances in drying technologies for millets: Effects on nutritional and functional properties. *Journal of Food Process Engineering, 46*(9), e14473.

Mahajan, M., Singla, P., & Sharma, S. (2024). Sustainable postharvest processing methods for millets: A review on its value-added products.*Journal of Food Process Engineering,* 47(1), e14313.

Malleshi, N. G. (1997). Nutritional and technological characteristics of small millets and preparation of value-added products. *Indian Food Industry, 16*(1), 23-28.

Mittal, S., Panghal, A., Kumar, N., *et al.* (2024). Review on millets dehulling and pearling technologies and machinery. *Journal of Food Process Engineering, 47*(7), e14611.

Nithiyanantham, S., Kalaiselvi, P., &Mahomoodally, M. F. (2019). Nutritional and functional roles of millets-A review. *Journal of Food Biochemistry, 43*(7), e12859.

Patel, K. K., & Naik, R. K. (2022). Studies on performance parameters for development of finger millet thresher. *International Journal of Plant & Soil Science, 34*(24), 900-907.

Sindhu, M., *et al.* (2024). Millets in Indian perspective: Importance, processing and value addition-A review. *Plant Science Today*.

Singh, K. P., Poddar, R. R., Agrawal, K. N., Hota, S., & Singh, M. K. (2015). Development and evaluation of multi millet thresher. *Journal of Applied and Natural Science, 7*(2), 939-944.

Siroha, A. K., &Bangar, S. P. (2024). Processing technologies and value addition of millets for functional food applications: Recent advances. *Journal of Food Science and Technology*.

Tejaswini, V. V., Bhaskara Rao, D., Lakshmipathy, R., & Kumar, S. (2018). Development and evaluation of cleaner-cum-pearler for finger millet. *International Journal of Current Microbiology and Applied Sciences, 7*(11), 1819-1830.

Yadav, O. P., Mathur, B. K., & Manga, V. K. (2016). Path analysis of pearl millet yield and yield components under moisture stress. *Annals of Arid Zone, 32*(1).