Review article

Hydrothermal treatment: a critical review on improving milling efficiency using the parboiling process for pearl millet

Abstract:

Hydrothermal treatment, particularly through the parboiling process, has emerged as a critical method for enhancing milling efficiency in pearl millet. This review provides a comprehensive analysis of the various aspects related to parboiling as a means to improve the quality and yield of milled pearl millet grains. The review begins by elucidating the significance of milling efficiency in pearl millet processing, considering its nutritional value and widespread consumption in regions such as sub-Saharan Africa and Asia. 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. Key factors influencing milling efficiency, such as soaking temperature, duration, and steaming conditions, are thoroughly examined based on recent research findings and empirical evidence. The review highlights the critical role of gelatinization in starch transformation, protein denaturation, and fiber preservation during the parboiling process, contributing to improved milling outcomes. 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 pearl millet. 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. The review concludes by outlining future research directions and practical considerations for optimizing the parboiling process in pearl millet production. 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 pearl millet. In summary, this critical review provides valuable insights into the role of parboiling as a transformative technique for enhancing milling efficiency in pearl millet processing, offering implications for research, policy, and practice in the domains of food security, nutrition, and agricultural development.

Keywords: food security, nutrition, and agricultural development, pearl mellet

INTRODUCTION

Food safety remains a significant challenge in Africa and worldwide. Agriculture constitutes the predominant economic sector in sub-Saharan Africa, engaging 70% of rural populations who depend on it for their livelihoods. The diets of African peoples primarily rely on vegetable sources, particularly cereals, among which pearl millet (Pennisetumglaucum) stands out as one of the most extensively cultivated cereal crops in tropical and developed countries.

According to Reddy et al., pearl millet is cultivated across approximately 27 million hectares in some of the harshest tropical environments of sub-Saharan Africa and Asia. It serves as a versatile crop, utilized for food, fuel, and feed. In Senegal, cereals predominantly constitute staple foods, accounting for 65% of energy sources and 61% of protein intakes, with pearl millet representing over 60% of cereal production.

Nutritionally, pearl millet is distinguished by its high micronutrient content, particularly calcium and iron, as well as its high dietary fiber content. Pearl millet grains are richer in proteins and essential amino acids compared to other cereals. Their nutraceutical value, attributed to high dietary fiber, phytochemicals, and low glycemic index, has garnered increasing attention.

Pearl millet is commonly used in feed after decortication, a processing operation that reduces vitamin content due to low milling yield and high breakage rates. The percentage of broken grains is a critical factor in evaluating dehulling capability. Parboiling, a processing technology commonly applied to paddy milling, enhances milling efficiency and reduces breakage.

Parboiling involves three fundamental steps: soaking to absorb water, steaming to gelatinize the starch in the endosperm, and drying before milling. This process transforms starch into an amorphous form and hardens the endosperm, making it translucent and resistant to breakage during milling. Parboiling enhances milling yield, reduces nutrient losses during milling and cooking, increases grain resistance to insect attacks, and improves nutritional quality.

While information on parboiling millet is limited, it has been primarily reported for finger millet and little millet grains. Further research and application of parboiling techniques to pearl millet could offer significant benefits in terms of improved milling efficiency, reduced nutrient losses, and enhanced food safety across Africa and beyond.

METHODOLOGY

Millet Parboiling Process:

The millet parboiling process was conducted in four steps, with all procedures carried out in triplicates:

1. Soaking: Initially, 7 kg of whole millet grains were soaked in 10.5 liters of water using a kettle. The soaking was performed at increasing temperatures of 60°C, 70°C, 80°C, and 90°C for four hours. Following soaking, the grains were cooled to room temperature within the covered kettle.

2. Pre-drying: Subsequently, the steamed paddy underwent pre-drying in sunlight for approximately one hour. This step aimed to reduce water content to facilitate gelatinization during the subsequent steaming process.

3. Steaming: The soaked grains were steamed utilizing a parboiling system, which comprised a container resembling a bucket. The bottom and lower quarter of the container's perimeter were perforated, with a kettle made of cast aluminum mounted atop. Steaming was conducted for a duration of fifteen (15) minutes.

4. Drying: Following steaming, the paddy underwent further drying in sunlight for an additional hour. Final drying occurred in the shade for three days before the husking process. Moisture content was determined using a moisture meter, with residual moisture levels between 10% and 12% achieved.

Milling/Decortication: The decortication process was executed using a huller. Abrasive grinding wheels, rotating at 1300 rpm, facilitated abrasion of the outer layers through friction against the moving grains' mass. Millet grains remained in the husking chamber of the decorticator for three minutes, a crucial period for achieving sufficiently husked grains. The husked grains were then separated from bran within a chamber. Following decortication, whole millet grains were segregated from broken grains using a vibrating screen. The milling millet yield and the proportion of broken grains were calculated. The milling millet yield, expressed as a percentage, represents the ratio of the weight of husked grains to the weight of unhusked grains.

Physicochemical Analysis: The millet underwent analysis for moisture, protein, fat, ash, fiber, and mineral content utilizing classic methods of the Association of Official Analytical Chemists (AOAC). Moisture content determination involved drying the sample in a GENEQ-inc incubator at 105 ± 2°C until a constant weight was attained. Protein content was determined via the Kjeldahl method (n x 6.25). Ash content was determined by incinerating the sample residue for four hours at 550°C in a muffle furnace (Heraeus). Crude fiber content was determined through segmental warm digestion of the defatted sample, followed by acidic and basic hydrolyses and EDTA complexation. Mineral elements (Fe, Zn, Mg) were determined from the incinerated ash, dissolved in HCl, and analyzed using Atomic Absorption Spectrometry (AAS) as per AOAC methods (Hitachi Z6100, Tokyo, Japan).

Millet Parboiling Optimization and Effects:

Milling Millet Yield:

The milling millet yield of unparboiled samples stood at 74.37%. Parboiled samples exhibited higher yields compared to unparboiled millet, with rates of 88.21%, 89.79%, and 89.55% recorded for 60°C, 70°C, and 80°C respectively. Notably, these temperatures yielded similar results and surpassed the yield of millet parboiled at 90°C (83.69%). The enhancement in milling yield is attributed to gelatinization and starch compaction during steaming, reinforcing the grain structure and reducing breakage during milling. The temperatures 60°C, 70°C, and 80°C emerged as optimal for millet parboiling, aligning with findings from previous studies.

Percentage of Broken Millet Grains:

Parboiled millet exhibited significantly reduced percentages of broken grains compared to untreated millet (14% at 90°C vs. 23.34% untreated). At 60°C, 70°C, and 80°C, broken grain proportions were 1.81%, 1.79%, and 1.82% respectively, with no significant differences observed between them. Beyond 80°C, the broken proportion increased, albeit remaining lower than unparboiled millet. Gelatinization of starch during soaking (60°C to 75°C) and subsequent drying contributed to grain compaction, enhancing resistance to milling and reducing breakage.

Effect of Parboiling on Physicochemical Composition:

Parboiled millet displayed moisture levels below the recommended 13% for pearl millet, with parboiled samples exhibiting lower moisture content compared to unparboiled ones. Protein content increased in parboiled millet due to enhanced protein preservation during parboiling, with temperatures up to 60°C considered optimal. Similarly, fiber content increased in parboiled millet, contributing to grain hardness and resistance to milling. Ash content was higher in parboiled samples, attributed to reduced dehulling impact. Mineral composition (Fe, Zn, Mg) remained stable across parboiled samples, indicating minimal nutrient loss. Optimal soaking temperatures of 60°C, 70°C, and 80°C were identified for millet parboiling.

Nutritional Benefits: Parboiling offers not only improvements in milling quality but also significant nutritional benefits. The preservation of proteins and fibers during parboiling contributes to the overall nutritional value of millet, making it a valuable dietary staple.

Cultural and Economic Implications: In regions where millet serves as a dietary staple, such as sub-Saharan Africa, optimizing parboiling techniques can have profound cultural and economic implications. Enhanced milling quality and nutritional retention ensure food security and livelihood sustainability for communities reliant on millet production.

Sustainability: Parboiling contributes to sustainability in agricultural practices by reducing waste and maximizing the utilization of millet grains. By minimizing nutrient losses and enhancing milling efficiency, parboiling aligns with sustainable agriculture principles, promoting resource efficiency and environmental stewardship.

Future Research Directions: Continued research into millet parboiling techniques can further refine and optimize the process, considering factors such as variations in millet varieties, environmental conditions, and consumer preferences. Additionally, exploring innovative technologies and methodologies can advance parboiling practices to meet evolving food safety and nutritional standards.

Knowledge Sharing and Capacity Building: Knowledge dissemination and capacity building initiatives are essential for promoting the adoption of optimized parboiling techniques among farmers and agricultural stakeholders. Training programs, workshops, and outreach efforts can empower communities to implement best practices in millet processing, enhancing food security and economic resilience.

In conclusion, millet parboiling represents a promising avenue for improving milling quality, nutritional retention, and sustainability in millet production systems. By leveraging the benefits of parboiling and fostering collaboration across sectors, stakeholders can contribute to the advancement of millet processing practices and the well-being of communities dependent on this vital crop.

Conclusion:

Parboiling improves millet milling quality and nutritional retention. Optimal conditions for millet parboiling involve soaking at 60°C or 70°C for 4 hours, followed by 15 minutes of steaming. This process enhances milling yield, reduces broken grains, and minimizes nutrient losses during milling. Careful control of parboiling parameters is essential for maximizing millet quality and nutritional satisfaction, particularly for the GB 87-35 millet variety.

In conclusion, the optimization of millet parboiling techniques holds significant promise for enhancing milling quality, nutritional retention, and sustainability in millet production. Through meticulous control of parboiling parameters, including soaking temperatures, duration, and steaming processes, substantial improvements in milling millet yield and reductions in broken grains can be achieved. The physicochemical composition of parboiled millet, characterized by preserved proteins, fibers, and mineral elements, underscores its nutritional value and dietary significance.

Moreover, the cultural, economic, and environmental implications of optimized millet parboiling cannot be understated. In regions where millet serves as a dietary staple, such as sub-Saharan Africa, advancements in parboiling techniques contribute to food security, livelihood sustainability, and agricultural resilience. By minimizing nutrient losses, reducing waste, and maximizing resource utilization, parboiling aligns with principles of sustainable agriculture, promoting environmental stewardship and economic prosperity.

Future research endeavors should focus on refining parboiling methodologies, exploring innovative technologies, and addressing variability across millet varieties and environmental conditions. Knowledge dissemination and capacity building initiatives are essential for fostering adoption of optimized parboiling practices among farmers and agricultural stakeholders. Through collaborative efforts and shared expertise, the potential of millet parboiling to improve food safety, nutritional quality, and economic livelihoods can be fully realized.

In essence, millet parboiling represents not only a technical advancement in grain processing but also a pathway towards a more resilient, inclusive, and sustainable agricultural future for communities worldwide. By embracing the principles of optimization, innovation, and collaboration, stakeholders can unlock the full potential of millet as a vital crop for global food security and well-being.

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