Infrared Radiation: A Breakthrough Technique for Efficient Dehusking and Enhancing Nutritional Quality of Millets

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Millets are small–seeded, drought–resistant cereals that have been cultivated for thousands of years, particularly in regions with arid and semi–arid climates of Africa and Asia (Shahidi & Chandrasekara, 2013). As awareness of the benefits of under–utilized millet grains grows, there is a renewed interest in millet production, which had been declining due to a primary focus on cereal crops like rice and wheat. Millet ranks as the sixth most widely produced grain globally, with an estimated production of 29.62 million metric tons (Mt) in the 2023–24 period. India leads the world in millet production, accounting for 41% of global output, followed by Niger, China, and other countries (U.S. Department of Agriculture, 2023). Major millet varieties include pearl millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*), and finger millet (*Eleusine coracana*). Minor millets consist of barnyard millet (*Echinochloa frumentacea*), foxtail millet (*Setaria italica*), kodo millet (*Paspalum scrobiculatum*), little millet (*Panicum sumatrense*), and proso millet (*Panicum miliaceum*) (Geervani & Eggum, 1989).

Millets have gained attention in recent years due to their health benefits, including their low glycemic index, which helps in managing blood sugar levels. These are highly regarded for their rich nutritional profile, offering significant amounts of protein, dietary fiber, vitamins, and essential minerals (Saxena et al., 2018). Additionally, millets are rich in antioxidants, promoting cardiovascular health. With the rising focus on sustainable agriculture and the need for climate–resilient crops, millets are being recognized as a valuable addition to global food systems, offering both nutritional benefits and an opportunity to promote food diversity and combat malnutrition.

Dehusking is a crucial process in grain processing, involving the removal of the outer, protective husk from grains such as millets. This tough, fibrous layer is not digestible and can make the grain unpalatable and difficult to process. By removing the husk, the edible part of the grain is exposed, making it suitable for human consumption (Singh et al., 2024). The dehusking process not only makes the grain more palatable but also improves its texture, making it more appropriate for various culinary uses. Moreover, dehusking enhances the nutritional benefits of millets. This husk also contains anti–nutritional factors, like tannins, trypsin inhibitor or protease inhibitors, saponins, haemagglutinin, phytates or phytic acid, oxalates, or oxalic acid, glucosinolates and gossypol (Dey et al., 2022). These anti–nutrients form complexes with macro molecules like protein and micronutrients like iron, calcium, and zinc and reduce their solubility and bioavailability (Balasubramanian, 2013).

Dehusking of minor millets poses significant challenges due to the tight adherence of the husk to the grain. This strong attachment is attributed to the presence of polysaccharides, such as cellulose and hemicelluloses, which form a robust matrix, combined with the moisture that further enhances the adhesion of the husk to the millet kernel. As a result, conventional dehusking methods can be quite difficult and less effective for these small grains. Therefore, it is required to give proper pretreatment for loosening of husk prior to milling.

Hydrothermal treatment is a standard, commercially used treatment for kodo millet. This treatment typically involves a series of steps: soaking the millet at various temperatures and durations, steaming under different pressures and times, finally drying through methods such as sun or shade drying (Agarwal et al., 2016). These processes can be carried out individually or in combination. Despite its widespread use, hydrothermal treatment has several drawbacks. It is labor–intensive, energy–consuming, and costly, often leading to undesirable flavors and colors in the grains. Additionally, the soaking phase can make the millet susceptible to microbial contamination and result in slightly moist flour, which can reduce its shelf life. Therefore, exploring alternative, energy–efficient techniques is essential to mitigate the lengthy processing times and minimize quality deterioration (Sunil & Chacko, 2018).

As alternative heat sources, infrared radiation is used one of the minimal heat treatments used to aid in dehusking process of millets. Infrared (IR) radiation heating is an effective technique for dehusking millets, due to its ability to interact specifically with the grain's outer layers. Infrared radiation operates in a wavelength range from 700 nm to 1 mm. The mechanism behind IR heating involves the absorption of IR radiation by the millet grains, particularly the moisture and organic compounds present in the husk. When the millet is exposed to IR radiation, the energy is absorbed by the outer husk, causing rapid heating and subsequent expansion (Kate & Sutar, 2018). The absorbed energy increases the temperature of the husk and the moisture contained within it. This localized heating leads to the formation of steam or vapor pressure within the husk, creating a pressure differential between the inside of the husk and the external environment.

As the internal pressure builds up, the husk begins to soften and separate from the seed. The process of thermal expansion and steam generation weakens the adhesion between the husk and the kernel, making it easier to remove the husk mechanically. Additionally, the high temperatures achieved during IR treatment can alter the physical properties of the husk, reducing its toughness and making it more pliable. This facilitates the removal of the husk through subsequent mechanical processes such as rubbing or friction. In addition to enhancing dehusking efficiency, IR treatment also increases head rice yield and reduces the percentage of broken grains. This is due to protein denaturation, partial starch gelatinization, and structural changes in the millet (Kumar et al., 2022).

IR energy not only improves dehusking efficiency but also enhances the proximate composition of the grains, including moisture content, protein, fat, fiber, ash, and carbohydrates, as well as bioactive compounds such as total phenolic content, total flavonoid content, and DPPH scavenging activity. Additionally, it reduces anti–nutritional factors and shortens cooking time compared to conventional treatments like parboiling and soaking. The IR treatment induces fissures in the endosperm due to thermal gradients and internal stresses from rapid moisture expansion and localized heating. These fissures facilitate more efficient moisture penetration, leading to quicker internal hydration and softening of the grains (Lang et al., 2022).

The efficiency of infrared heating for dehusking millet depends on several factors, including the intensity of the IR radiation, the duration of exposure, and the specific wavelength of the IR radiation used. By optimizing these parameters, it is possible to enhance the dehusking process, improving yield and quality while reducing the energy consumption and time required compared to traditional methods.

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