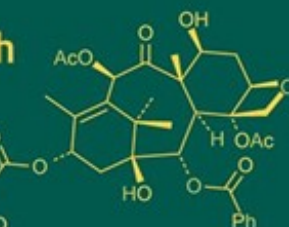
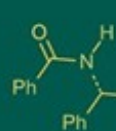
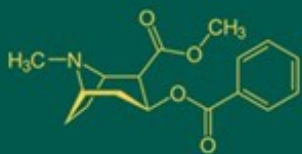


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Impact of mechanical pretreatment on the processing characteristics of kodo millet

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ABSTRACT

Kodo millet (*Paspalum scrobiculatum*) is a nutritionally dense millet grain which comes under difficult-to-dehull millets, yet its wider commercial utilization remains severely constrained by a tightly adhered multi-layered husk and high susceptibility to grain breakage during dehulling. This study investigated the impact of mechanical pretreatment parameters i.e., preprocessing operation prior to dehulling for analyzing the processing characteristics i.e., dehulling efficiency, head recovery and broken percentage with variable rotor speed (250 – 450 rpm) and different moisture content of kodo millet (6 – 12 % w.b.). A small prototype of mechanical treatment system of capacity 5 kg/h was developed by ICAR-CIPHET, Ludhiana. The system consisted of pitch type screw treats for developing cracks on kodo hulls and DC drive with DC motor for rotor speed variables for setting different speeds during entire range. mechanical preprocessing induced deliberate microstructural modifications at the husk-endosperm interface, facilitating husk loosening and significantly improving mechanical grain resistance. Under different treatment conditions i.e., 250 rpm at 9 % moisture content, dehulling efficiency increased by up to 92.75 %, head recovery 62.23 % accompanied by a significant reduction in broken from 10.71 % to 3.92 % compared to untreated controls. Overall, mechanical preprocessing offers an effective, sustainable approach to mitigate milling losses, enhance head recovery yield, and preserve techno-functional traits, providing a robust operational pathway for high-throughput commercial processing of kodo millet.

Keywords: Broken, Dehulling efficiency, Head recovery, Kodo millet, Preprocessing pretreatment, Preprocessing

Introduction

Kodo millet (*Paspalum scrobiculatum* L.) is a climate-resilient small millet cultivated extensively across arid and semi-arid regions of Asia and Africa, primarily within marginal agricultural ecosystems. Recognized globally as a nutrient-dense coarse cereal, kodo millet features a remarkable nutritional architecture characterized by high dietary fiber content (9–14%), well-balanced amino acid profiles, and low glycemic indices, alongside abundant micronutrients like iron, zinc, calcium, and phosphorus. Despite its exceptional nutritional and agronomic virtues, the industrial-scale processing and commercial mainstreaming of kodo millet face persistent structural hurdles. Primary processing—specifically dehulling (decortication)—serves as an obligatory prerequisite before the grain can be rendered suitable for human consumption or downstream product diversification. However, unlike major cereals like wheat or naked millets such as finger millet (*Eleusine coracana*), kodo millet is botanically classified as a "difficult-to-dehull" minor millet. The edible caryopsis is encased in a rigid, fibrous, multi-layered non-edible hull composed of the lemma and palea. This husk structure is tightly bonded to the pericarp and aleurone layer through robust, complex cellulosic and lignified matrix bonds.

Conventional mechanical processing of raw, untreated kodo millet relies heavily on abrasive or shear-based centrifugal dehullers and rubber-roll shellers. Due to the high frictional resistance and stubborn adherence of the hull to the soft starchy endosperm, severe mechanical stresses are transferred directly into the core matrix of the kernel. This mismatch between shear resistance at the surface and internal grain brittleness leads to low single-pass dehulling efficiency, extensive grain pulverization, severe scouring of the nutrient-dense aleurone layer, and unacceptably high broken fractions (often exceeding 15–20%). These high broken yields not only represent direct economic losses for millers and farmers but also accelerate hydrolytic rancidity during post-processing storage through the uncontrolled enzymatic release of free fatty acids from bruised germ lipids. Consequently, designing pre-milling conditioning treatments that weaken the grain coat-endosperm interface without degrading overall kernel integrity is essential for sustainable millet processing. To address these post-harvest bottlenecks, mechanical preprocessing techniques—including different polishing machines—have been explored across cereal grains. While conventional mechanical processes give higher broken during the processing, they are fundamentally energy-intensive, necessitate prolonged processing cycles, and generate effluent waste. In response, modern cereal processing engineering has shifted

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toward mechanical interventions, most notably preprocessing operations prior to dehulling. The mechanical preprocessing system utilizes a progressive-pitch screw conveyor housed within a grooved, stationary barrel to precondition kodo millet prior to primary dehulling. As grains advance along the auger, the decreasing flight pitch and reducing radial clearance generate a controlled volumetric compression gradient, subjecting the tough, multilayered husk to sustain triaxial compressive and frictional shear loads. This mechanical pre-cracking reduces the specific grinding energy and shear forces required in downstream abrasive or centrifugal dehullers, leading to higher de-husking efficiency, lower operational torque, and a marked reduction in kernel breakage. The mechanical interaction between rotor speed variation and grain moisture content resulting in dehulling efficiency methodical investigation. To bridge this operational and scientific gap, the present investigation systematically evaluates the impact of mechanical pretreatment on the processing behavior of kodo millet. Utilizing a bench-scale prototype mechanical treatment system developed by the ICAR-Central Institute of Post-Harvest Engineering and Technology (ICAR-CIPHET), Ludhiana, this study investigates the effects of varying rotor speed (250–450 rpm) and moisture content (6–12 % w.b.) on key milling parameters: dehulling efficiency, head grain recovery, and broken percentage. The findings aim to establish an optimized, low-footprint mechanical preprocessing protocol to minimize post-harvest processing losses, maximize primary recovery yields, and support the broader industrial adoption of kodo millet.

Materials & methods

Materials

Samples

Kodo millet was purchased from the local market and was first cleaned well to remove the extraneous matter before conducting the experiments. The moisture content of the sample was 12.5 % (w.b.). Normally, in the commercial market about 9 % moisture content is common which comes to dehulling to the pulse processor and hence variable moisture content was considered in this study.

Head recovery

Head recovery (from APQ method 104.1, Buridge *et al.* 2001) was defined as the yield of dehulled head kernels as a percentage of original seed weight. It is calculated by the relationship given in Eq. 2.

$$\text{Head recovery (\%)} = \frac{\text{Mass of dehulled whole seeds (g)}}{\text{Initial weight of kodo millet (g)}} \times 100 \quad (2)$$

Broken

Broken is calculated as the weight fraction of the powder and fine broken relative to the total weight of the grain used for dehulling. It is calculated using the relationship given by Eq. (3) (Goyal *et al.*, 2007)

$$\text{Broken (\%)} = \frac{[\text{Weight of powder obtained (g)} + \text{Weight of fine broken (g)}]}{\text{initial weight of kodo millet (g)}} \times 100 \quad (3)$$

Statistical analysis

All the experiments were carried out in triplicates, and the data were represented as mean (Table 1). MS excel was used to fit regression equations.

Results and discussions

Effect of infrared treatment on the kodo millet characteristics

Dehulling efficiency and head recovery

The variation in dehulling efficiency and head millet recovery of 45 kodo millet subjected to different rotor speed (250–450 rpm) and

Mechanical preprocessing system

A customized, mechanical pretreatment prototype was developed and fabricated at ICAR-CIPHET, Ludhiana, equipped with a screw type pitch type rotor with one hp DC motor and DC drive for speed variables. The system accommodated a standardized sample load of 5 kg/h cleaned kodo millet per processing in continuous mode, for efficiency processing of kodo millet.

Methodology

Mechanical pre-treatment

A total weight of 5 kg/h lot cleaned seeds were taken in a single pass for mechanical treatment for specified moisture content. Three levels of rotor speed, viz. 250, 350 and 450 rpm, were applied each at five different moisture content ranging from 6 to 12 % at an interval of 1.5 % w.b.

Dehulling procedure

Dehulling of kodo was performed in rubber roll dehuller developed by ICAR-CIPHET, Ludhiana. Dehulling was done for 10 s in all grain samples and corresponding dehulling fractions were collected and graded as dehulled, unde-hulled and broken. They were weighted separately and noted for further analysis. All samples were studied in triplicates.

Analysis of dehulling characteristics of kodo millet

The dehulling properties of kodo millet were assessed in terms of dehulling efficiency, head recovery and broken.

Dehulling efficiency

Dehulling efficiency was defined as the quantity of total dehulled kernels and broken kernels (except fine broken, powder and husk) that are produced in the dehulling of kodo millet. Head kernels are defined as the kernels retained over sieve no. 14 (BSS mesh). Broken is defined as cotyledon retained on sieve no. 30 and passes through sieve no. 14 (BSS mesh). Fine broken is defined as the broken that passed through sieve no. 30 (BSS mesh). The dehulling efficiency is calculated using the formula given in Eq. 1.

[1].

moisture content (6–12 % w.b.) is illustrated in Fig. 4 and 5. Increasing both rotor speed and moisture content led to a pronounced, statistically significant improvement in dehulling performance compared to the untreated control. The dehulling efficiency increased progressively from baseline levels to a maximum of 84.76% under the

highest thermal intensity condition of 240 V for 7 min. Concurrently, head millet recovery peaked at 58.77% under these identical operational parameters. This synergistic enhancement can be attributed to the rapid radiative surface heating and steep internal thermal gradients established by high-voltage infrared exposure. The resulting differential thermal expansion between the rigid, fibrous lemma and palea and the underlying starchy caryopsis generated sufficient internal shear strain to weaken the interfacial adhesion bonds, promoting clean husk

detachment. Concurrently, controlled infrared energy absorption induced localized annealing and consolidated the endosperm protein-starch matrix, significantly elevating kernel hardness and fracture toughness. Consequently, the grains exhibited greater mechanical resilience against abrasive forces during subsequent mechanical dehulling, driving the substantial gain in whole head grain yield while suppressing kernel fragmentation.

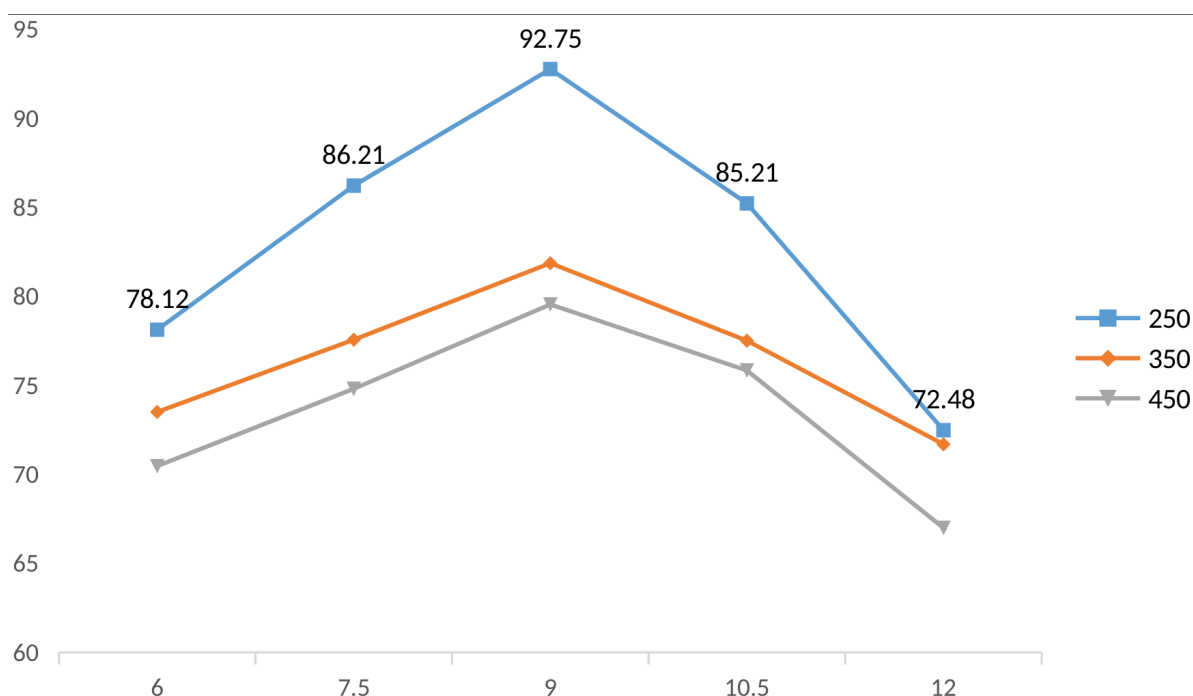


Figure 1. Variation of dehulling efficiency with different shaft speed and moisture content

Head millet recovery

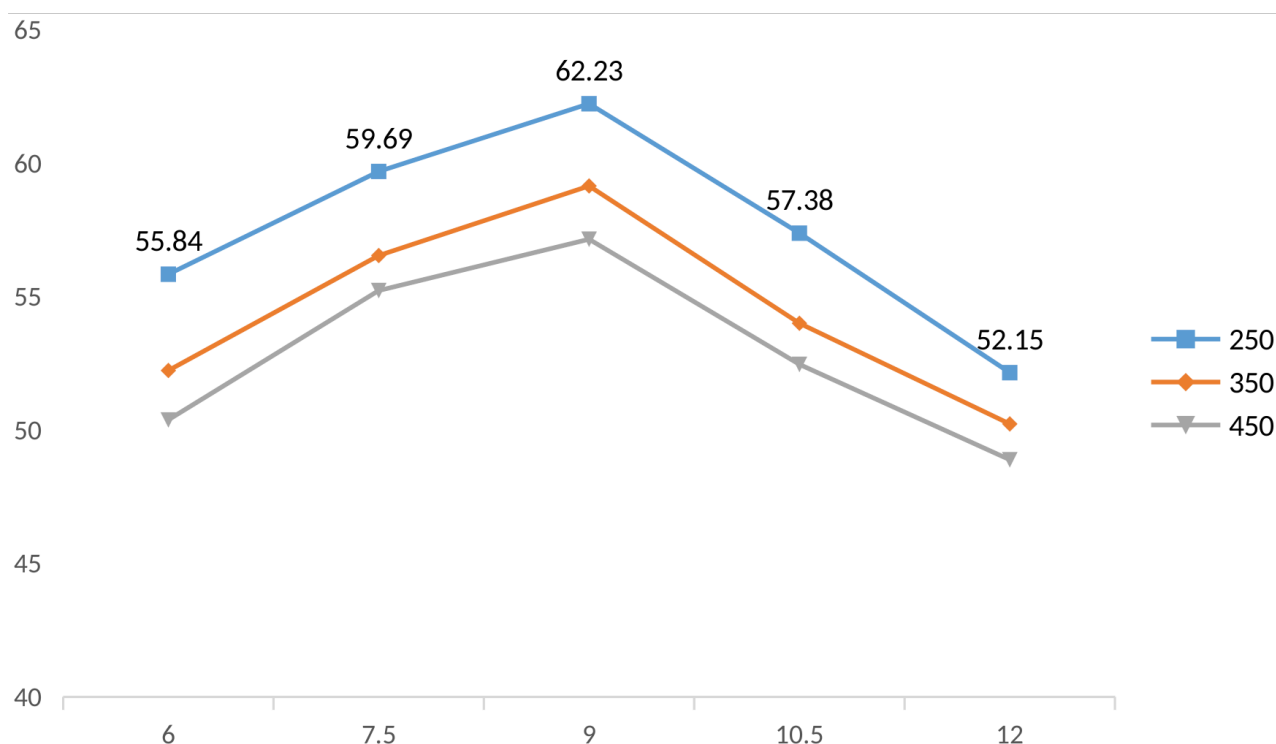


Figure 2. Effect of scratching preprocessing parameters on head millet recovery of kodo millet

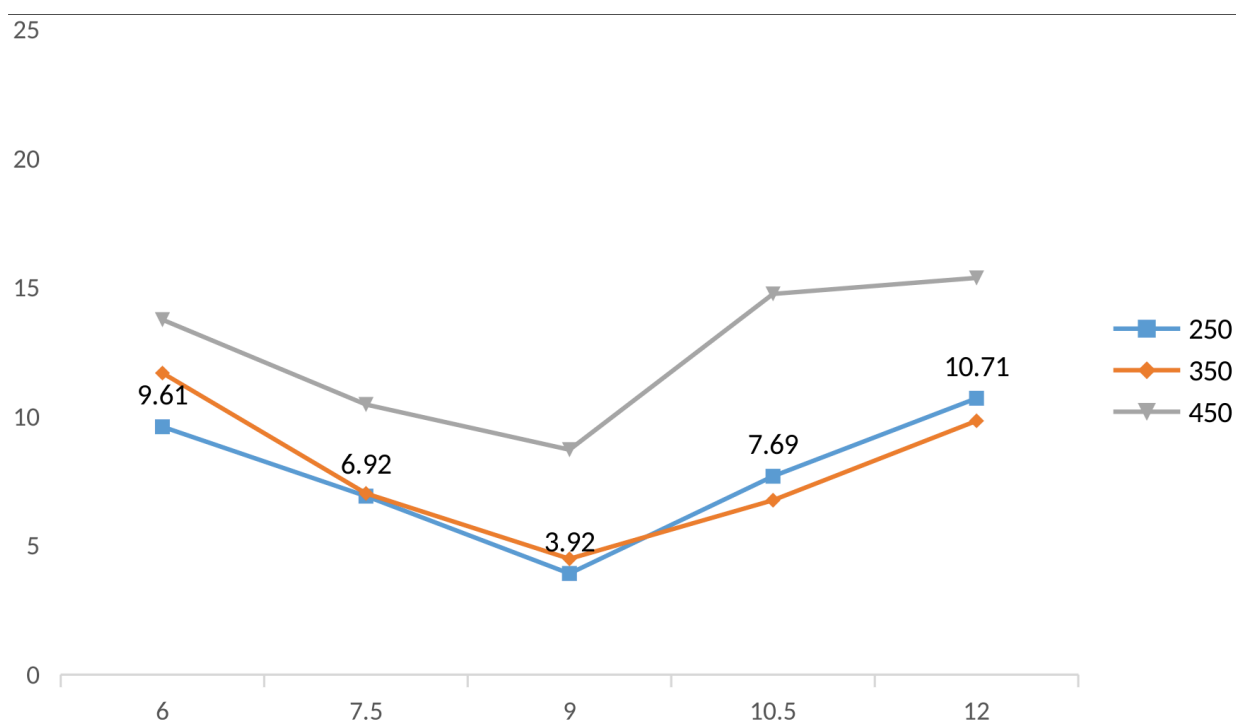
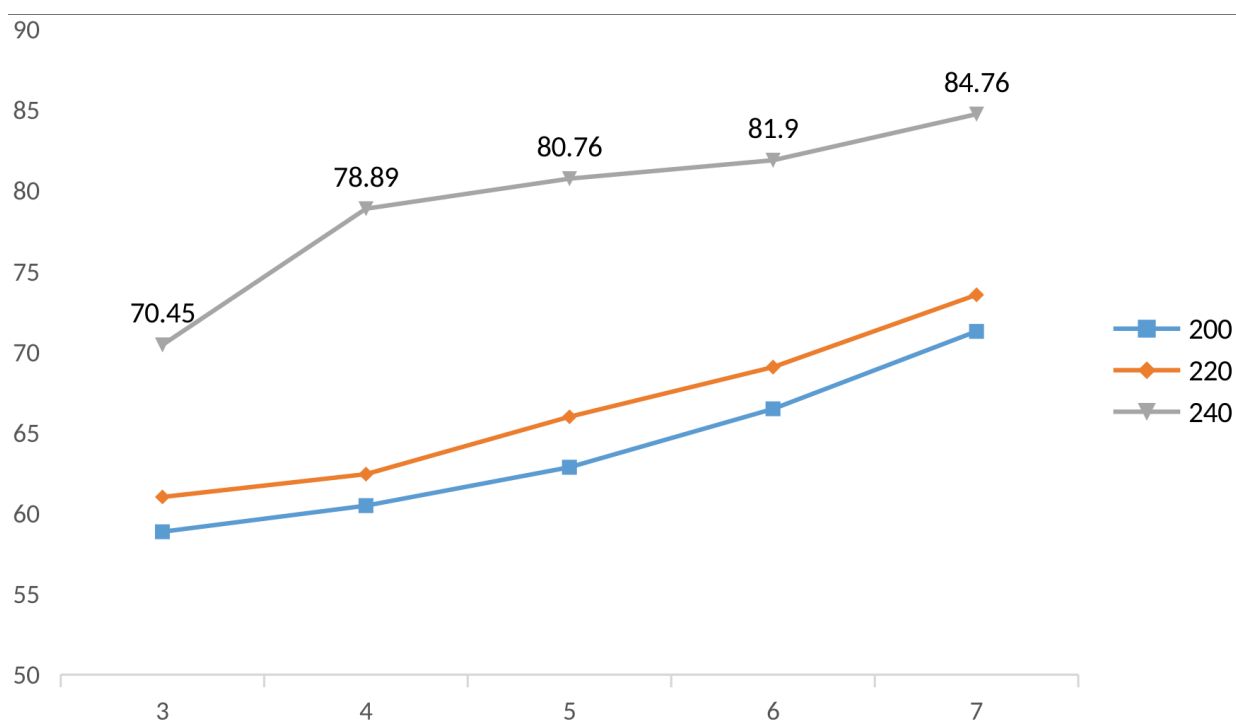
Broken

Figure 3. Effect of scratching preprocessing parameters on broken percentage of kodo millet

Effect of infrared treatment on the kodo millet dehulling**Dehulling efficiency****References**

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