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A review on factors affecting Dehusking operation of different agricultural products

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Abstract

Dehusking is the one of the important secondary processing operations which is used to remove outermost layer in seed processing. Present review explores the different factors influencing dehusking operations of agricultural products. The significance of different product parameters *viz*., size, shape, hardness, texture, moisture content and machine parameters *viz*., feed rate, machine clearance, machine speed, speed difference, type of mechanism for achieving efficient dehusking is crucial. The effect of different pre-treatments like chemical or enzymatic pre-treatment, thermal pre-treatments like parboiling, steaming and soaking also found to help in improve dehusking process. Understanding of these factors is essential for optimizing dehusking operations, to achieve higher dehusking efficiency and get a higher yield.

Keywords: Dehusking, machine factors, product factors, pretreatments, performance

1. Introduction

Dehusking is the unit operation in which outermost layer of seeds usually husk or hull is removed from inner seed by mechanical action. There are several different mechanisms to detach husk from kernel i.e. rubber roller dehusker, concave type dehusker, hollander type dehusker, centrifugal sheller, under runner type dehusker, air jet-based polisher, tangential abrasive dehuller device (TADD). Basic principles governing these dehusking machines are 1) compression and shear in rubber roller and concave type dehusker, 2) abrasion and friction in hollander type dehusker tangential abrasive dehuller device and 3) impact and friction in centrifugal type sheller (Chakraverty and Singh, 2014) [4].

Dehusking operation and its efficiency can be governed by several factors. Pre-treatments such as conditioning, chemical treatment *viz*., enzymatic pretreatment *viz*., xylanase, pectinase and cellulase in pigeon pea dal (Sangani *et al*., 2014; Dabhi *et al*., 2019) [23, 6] and thermal treatments like steaming (Opoku *et al*., 2003) [20], parboiling (Undre *et al*., 2017) [25] and microwave (Moses *et al*., 2015) [13] also used to make improvement in the dehusking operation. Other than pre-treatment, there are other factors which may be product specific or dependent on dehusking machine. Products parameters *viz*., moisture content, type of varieties, size and shape of product, primary processing of seeds influence the yield and efficiency of the machine. The machine parameters *viz*., type of dehusking machine, clearance, sieve size, processing speed, speed ratio, feed rate, orientation of fed material also found to impact the dehusking operation.

Objective of this paper is to highlight the different works based on different pretreatment for improvement of dehusking operation and effect of different parameters affecting the dehusking process.

2. Effect of different pre-treatments on dehusking of agricultural products

Moisture content plays significant role in dehusking or milling process. The layer between grain seed and husk is attached with hemicellulose which might result in husk to be separated not easily. Addition of moisture into the grain helps in loosening the bond between the husk and seed as husk softens. This addition of moisture can be facilitated by conditioning the seeds in controlled humidity or giving thermal treatments *viz*., parboiling and steaming followed by drying to safe moisture content. Increasing the moisture content can led to decrease in the yield of fine particle size from dehusked products (Schorno *et al*., 2019) [26]. The conditioning of seeds beyond optimum moisture levels might lead to negatively impact the dehusking process. Longer thermal treatment duration may lead to seeds become softer which can increase the broken percentage of seeds.

Ogunsola *et al.* (2022) [16] found that longer soaking times (from 2 to 6 hours) increased the moisture content and the weight of dehulled soybeans. It was found that soaking led to more weaking of bond between hulls and cotyledons of soybeans resulted in improved dehulling efficiency. The best results, with an 81.8% efficiency, were achieved with 6 hours of soaking and a 600rpm operating speed. Okonkwo *et al.* (2019) [17] conducted a locust bean dehulling experiment with a boiling pre-treatment for varying durations (1 to 4 hours). It was found that as boiling time increased, the dehuller's throughput capacity decreased. The seed quality initially improved from 1 to 2 hours of boiling but worsened when boiling exceeded 2 hours. Dehulling efficiency increased with longer boiling times. The labor required per kilogram of seeds decreased from 1 to 2 hours of boiling but increased beyond 2 hours. Adekanye *et al.* (2019) [2] improved the dehulling efficiency of a locally made locust bean dehuller by steaming the seeds for four hours. This softening process made the seeds less brittle, resulting in a substantial efficiency boost from 10.25% to 93.58%. However, the higher moisture content decreased the dehulling rate, which dropped from 0.58 kg/min to 0.05 kg/min.

The radiation energy from the microwaves can be applied as a heating medium for faster drying of conditioned seeds. The penetration of microwaves might lead to uniform drying and increase thermal expansion gradient of seeds followed by contraction of seed and seed coat with much less energy (Schirack *et al*., 2007) [24]. Oomah *et al.* (2014) [18] found that treating the dry beans with microwaves at 2450 MHz from 3 min to 6 min led to increase in the yield dehulled seeds. Microwave treatment also enhanced the flavor profile of beans. Moses *et al.* (2015) [13] carried out dehulling of pigeon pea with microwave pre-treatment at different power (90, 270, 450, 630 and 810 W). There was an increase in dehusking efficiency, splits yield, seed coat yield with increase in microwave power up to 630 W. The microwave exposure of 630 W for 90 s was found to be the optimized treatment for maximum dehulling efficiency (70%) and minimum dehulling loss (0.18%).

Several enzymatic pretreatments have been carried out specially on legumes whose seeds coats require multiple processing steps which take much more time (4-5 days) to process. The choice of enzymes depends on the chemical composition and binding material at the interface between the seed coat and cotyledon (Dabhi *et al*., 2022) [7]. Enzymatic treatments also found to improve cooking quality and reduce cooking time. Sangani *et al*., (2014) [23] optimized a minimum cooking time of 21.91 minutes at enzyme concentration of 37.8 mg/100 g dry matter, incubation time of 8.69 hours, incubation temperature at 48.5°C, and tempering water pH at 5.49. The enzyme-treated dhal showed a 19.77% reduction in cooking time compared to oil-treated dhal. Dabhi *et al.* (2019) [6] found that enzyme pretreatment improved hulling efficiency by 2.44%, increased protein content by 6.77%, and reduced cooking time by 1.50 minutes compared to traditional oil pretreatment.

3. Effect of different parameters on dehusking of agricultural products

3.1 Product parameters

The size and shape are one of the product parameters which become critical during the dehusking operation. Subramanian *et al*., (1990) [29] compared the different seeds size for dehulling sunflower seeds. They found that shelling efficiency and percent fines were increased with increase in seed size. The texture of the outer husk of the product influences dehusking. Hard husks require more force and time, while softer husks are easier to remove. The chemical composition of husk and seed affects dehusking. Enzymes can break down bonds in the husk, and the presence of compounds like tannins can impact the process. Some products have natural gums or adhesives made up of different polysaccharides and hemicellulose that bind the husk tightly with kernels. Understanding these adhesives is crucial for choosing the right dehusking method, which may involve enzymes or chemicals to weaken the adhesion. Shahin *et al*. (2012) [27] used image analysis to predict dehulling efficiency with comparing plumpness (thickness/diameter) of lentils seeds. They found that dehusking efficiency decreased with decrease in plumpness in flat samples. While, there was an increase in dehusking with decrease in plumpness in plump seeds.

3.2 Machine parameters

Different machine parameters like feed rate, direction of feed, machine clearance, machine speed, speed difference, type of mechanism can affect the performance of the machine. The slower feed rate may result in higher retention time of seed in dehusking mechanism which may improve dehusking efficiency. However, keeping the lower feed rate also reduce lower dehusking capacity. The force required to be generated for detaching the husk may be not be effective at slower feed rate. Increasing the feed rate usually results in more breakage of seeds due to more interparticle friction between seeds. Adejuyigbe and Bolaji (2005) [1] found that increasing the feed gate from 15 to 40 mm led to increase in dehusking efficiency and decreased further with further increase in feed gate. Therefore, it is necessary to optimize the feed rate in dehusking process. Increase in dehulling time also attributes to positive increase in yield (Oomah and Mazza, 1997; Mridula *et al*., 2013) [19, 14].

The orientation of feed also influenced the dehusking ability of the machine. Edukondalu (2014) [8] evaluated the effect of different roller angle (0 to 50°) and three feed rate (20, 25 and 30 kg/h The husking ratio was significantly influenced by the roller angle, with a positive correlation observed up to 45°, after which it decreased. The highest husking ratio (yield of whole seeds) was 88.31%, achieved at a 40° roller angle with a feed rate of 25 kg/h. The vertical feeding was found most suitable as it was found to reduce the specific energy required to rupture the husk and seed (Baker *et al*., 2012) [3]. Chen *et al.* (2019) [5] investigated how feeding direction angle (0° to 90°) affect rice dehusking and breakage. They found that a vertical feeding direction (0°) resulted in the best hulling yield (98.5%) and the least rice kernel breakage (2.3%).

Selection of optimum machine clearance can enhance the dehusking parameters. Adjustment of machine clearance in dehusking machine should be such that it can create suitable compression force to dehusk the smallest seed size. The smaller clearance hinders the passing of seeds and may choke the mechanism while larger clearance reduces dehusking efficiency and yield of dehusked product. Powar *et al.* (2019) [21] found that decrease in concave clearance and pearling sieve size and increase in drum speed increased the pearling efficiency.

Another critical factor is the machine speed (rpm). The machine speed or roller speed optimized for the dehusking machine should match the power requirement of the machine. The force exerted by dehusking mechanism on the product largely depends on the machine speed. The faster moving speed attributes to the lower retention time of the seeds which contributes to reduced dehusking efficiency and yield. However, increasing the machine speed also found to increase the specific energy consumption. Firouzi *et al.* (2010) [9] found that increasing roller speed from 1.5 m/s to 5 m/s reduced broken rice from 18.83% to 9.97%. The husking index initially rose from 1.5 to 2.9 m/s and then declined beyond 2.9 m/s. Sinha *et al*. (2011) [28] assessed a tamarind dehuller cum deseeder, varying dehulling ring clearance (3-4 cm) and feed rate (4-6 kg/min). Increased feed rate enhanced dehulled yield. Dehulling efficiency rose with 4-5 kg/min feed rate and 3-4 cm clearance, peaking at 79.99% with 4 cm clearance and 5 kg/min feed rate.

Speed difference are between rollers are usually kept in the rubber roller type dehusking machines. The speed difference between faster and slower roller moving towards each other are kept to create a greater shear force which helps in easy dehusking of the products. Usually the minimum speed difference between faster and slower roller in rubber roller dehusking machine is kept at least 2.5 m/s (Chakraverty and Singh, 2014) [4].

Selection of materials involved in dehusking mechanism is also an important factor which affect the operation. Baker *et al.* (2012) [3] found the effect of different rubber material on dehusking of paddy. They found that the dehusking is not only dependent upon the coefficient of friction between paddy and roller surface but surfaced material also. The dehusking was positively increased with the increase of hardness of rubber due to smaller area of contact with greater pressure. Radwan *et al.* (2007) [22] compared the different materials and standardized the treatment for dehulling of prototype at 5200 rpm and 6 vanes of spinning of disc. The dehusking efficiency at this standardized treatment for wood, iron and aluminium was 38.8%, 81.2% and 89.8%, respectively.

Thus, the selection of different machine parameters become crucial for optimization of dehusking process. The choice of right parameters can be based to interface between the product conditions and dehusking mechanism.

4. Development and performance evaluation of different dehullers

Gesudaraj *et al.* (2012) [10] developed a rubber roller dehusking machine for foxtail millet (Figure 1). The machine's performance was tested under various conditions, including different roller speeds, feed rates, and millet varieties. It was found that dehusking efficiency decreased with higher feed rates and lower roller speeds. The highest dehusking efficiency (81%) was achieved at the lowest speed (640 rpm) and the slowest feed rate (150 kg/h) for the RS-118 millet variety. In contrast, head yield increased with higher feed rates and speeds. The optimized parameters for dehusking were a roller speed of 740 rpm and a feed rate of 150 kg/h.

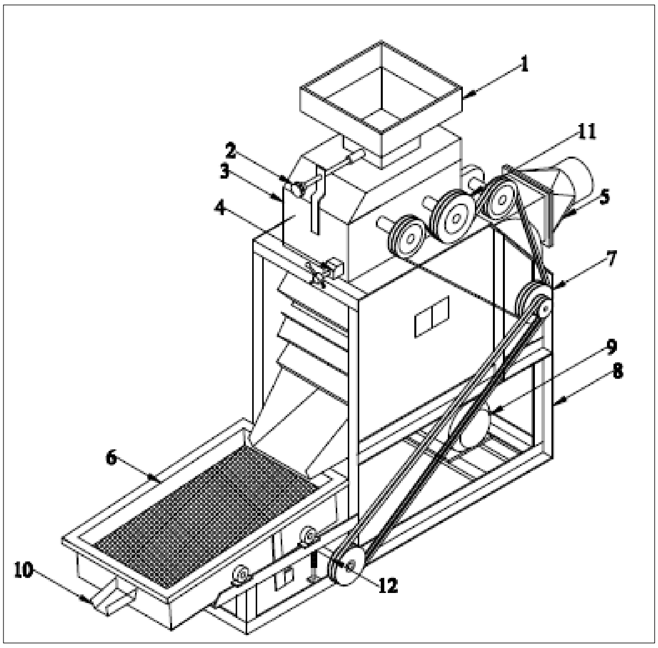

Fig 1: Isometric view of developed dehusker (Gesudraju *et al*., 2012) [10]

Gojiya *et al.* (2022) [11] developed dehuller for sesame seeds (Figure 2). They found that dehulling efficiency increased with higher dehuller speed, longer soaking time, and extended dehulling time. The optimal dehulling efficiency, reaching 79.29%, was achieved with a soaking time of 120 minutes, a dehuller speed of 150 RPM, and a dehulling time of 6 minutes in this developed sesame dehuller. On the other hand, the lowest mean dehulling efficiency of 41.84% was observed at a dehuller speed of 100 RPM, a soaking time of 40 minutes, and a dehulling time of 4 minutes.

Krishnappa *et al*. (2022) [12] developed a dehusking machine for foxtail millet, featuring knurling and rubber rollers (Figure 3). They tested various knurled roller types and feed rates (100, 200, and 300 kg/h). Lowering the feed rate resulted in higher dehulling efficiency and head yield. The diamond-type knurled roller at a 100 kg/h feed rate achieved the highest dehulling efficiency (82.24%), while the angular-type knurled roller at a 300 kg/h feed rate had the lowest efficiency (72.22%). Maximum head grain yield (97.82%) was obtained with the diamond-type knurled roller at 300 kg/hr feed rate, while the lowest yield (90.81%) was from the straight-type knurled roller at 100 kg/h feed rate. Power consumption increased with higher moisture content and feed rates. The recommended settings are a feed rate of 100 kg/h and using a diamond-type knurled roller.

Fig 2: Developed sesame dehuller (Gojiya *et al*., 2022) [11]

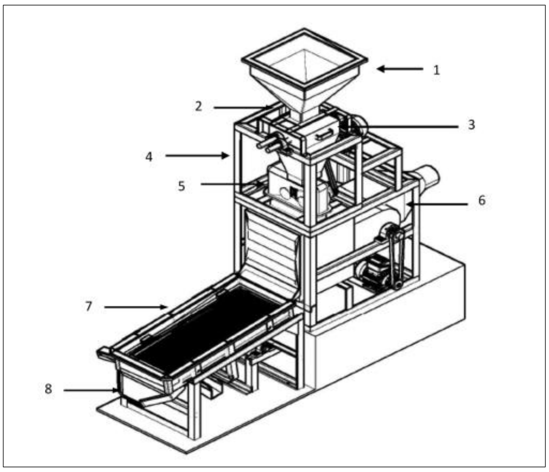

Fig 3: Developed miller dehuller (Krishnappa *et al*., 2022) [12]

5. Conclusion

Dehusking is a vital process to remove the outer seed layer. Various machines use different principles, and factors like pre-treatments, product characteristics, and machine parameters which impact dehusking efficiency. Optimization of these factors is crucial for effective dehusking of various seeds and products.

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