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Development & Performance Evaluation of Pedal Operated Maize Sheller-A Review

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Abstract- This research conducts a literature analysis on maize shelling machines, concentrating on their development and performance assessment. Post-harvest maize procedures are incomplete without the crucial phase known as maize shelling or maize threshing. Detaching the kernels of maize from their cobs is an essential procedure in this process. Currently, there are only a limited number of motorized equipment options accessible on the market. These devices are either driven by tractors or power tillers. Despite the development of many hand-operated maize shellers, these devices can only shell one cob at a time and are not designed for prolonged continuous operation. This research aimed to examine the design of current maize shelling machines and the criteria used to assess their performance. The research aimed to identify the design elements that significantly impact the operating performance of maize shellers.

Keywords: Sheller, maize, moisture contents, performance evaluation.

INTRODUCTION

Maize (Zea mays) is a significant cereal crop that belongs to the grass family (Gramineae) and produces little edible seeds (Aremu et al., 2015). Maize, often referred to as corn, is said to have evolved in central Mexico around 7,000 years ago from a wild grass, which Native Americans then cultivated into a more reliable food source. It is the most well-adapted crop globally, thriving between latitudes 58°N and 40°S of the equator. It is a multifaceted cereal crop, generally referred to as maize in America. The natural attributes of abundant rainfall, elevated light intensities, and optimal temperatures in maize production make it one of the most flexible seed crops globally (Aremu et al., 2015). Maize comprises roughly 72% starch, 10% protein, and 4% fat, providing an energy density of 365 Kcal per 100 g. It is cultivated globally, with the United States, China, and Brazil as the leading producers, collectively generating approximately 563 of the 717 million metric tons annually (Peter and Juan, 2014).

Following wheat and rice, maize ranks as the third most significant cereal grain globally, supplying essential nutrients for both people and animals, and functioning as a fundamental raw material for the manufacture of starch, oil, protein, alcoholic drinks, culinary sweeteners, and, more recently, biofuel. Maize constitutes 15-20% of the total daily caloric intake in the diets of individuals in over 20 developing nations, mostly in Latin America and Africa (as cited by Dauda, 2015). It is used in several ways to mitigate hunger, including pap or ogi, and maize flour (Oriaku et al. 2014).

Approximately 88% of maize grown in Ethiopia is used for consumption, including in its green and dried forms. Maize for industrial applications has further bolstered increasing demand. Minimal maize is now used as feed; nonetheless, this is evolving to accommodate the swiftly expanding urbanization and poultry sector. In contrast to Kenya, which relies heavily on imports for its consumption requirements, Ethiopia has progressively achieved self-sufficiency in maize production since the beginning of this decade and exports surplus quantities to neighboring countries such as Sudan and Djibouti (Tsedeke et al., 2015).

Abebe and Hundie (2006) assert that maize remains a crucial factor in the economic and social development of Ethiopia. Maize, with 8 million smallholder cultivators, is essential to smallholder livelihoods in Ethiopia, surpassing teff at 5.8 million and wheat at 4.2 million. Moreover, maize is the predominant staple crop, yielding 4.2 million tons in 2007/08, in contrast to teff at 3.0 million tons and sorghum at 2.7 million tons (Kindie et al., 2010).

The primary stages in maize processing are harvesting, drying, dehusking, shelling, storage, and milling. Rural farmers must use suitable technologies to optimize profits from their maize cultivation. The transformation of agricultural goods, such as maize, into high-quality forms not only extends their shelf life but also enhances the

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net profits for farmers using mechanized methods for these items. Shelling or threshing is a crucial processing step for enhancing the quality of maize. One of the postharvest issues for maize is shelling. Kaul and Egbo (1985) observed that corn is traditionally shelled by hand or by striking bags filled with maize cobs with wooden flails. The conventional techniques for shelling maize are inefficient, perilous, and characterized by considerable toil (Oriaku et al., 2014).

The majority of farmers in Ethiopia shell dried cobs by repeatedly striking them with a club while contained in sacks, open barrels, or laid on a plastered floor, either inside or outdoors (Ashwin and Shaik, Nyongesa and Patil et al., 2014). This procedure inflicts harm on the kernels and is laborious and time-consuming. Another conventional way for shelling maize involves manually rubbing the cobs against each other or directly extracting the kernels by pushing them between the thumb and palm. Moreover, the majority of mechanical shellers were designed for multi-grain threshing or shelling, resulting in significant damage to maize seeds and fragmentation of the cob. To mitigate the laborious process of traditional maize shelling, which involves beating cobs with sticks and manual rubbing, and to ensure product quality, the utilization of a mechanical sheller, such as a maize shelling machine with optimally designed components to minimize crop damage, is essential.

LITERATURE REVIEW

Maize shelling is a postharvest procedure that involves the removal of maize seeds from the cob. This method may be executed in the field or inside the storage environment (Nwakire et al., 2011). Thus, maize shelling is an essential stage in the conversion of maize into various end products, including flour. The methods of maize shelling may be categorized based on the automation technology used. Optimal shelling occurs at a moisture level of around 13% (Ashrae, 1998). Shelling is an essential process used to maximize space and enhance the management of grains.

The most straightforward traditional technique for shelling maize involves exerting pressure with the thumbs on the kernels to detach them from the ears. A common and simple method of shelling is friction between two ears of maize. These methods need considerable work. An employee can hand shell just a certain amount of kilograms every hour. The shelling of maize may be performed more efficiently by striking a bag filled with ears or heads with a stick. Maize and sunflowers may be threshed by friction against a coarse surface. Minor equipment, sometimes fashioned by local artisans, are sometimes used for the hand shelling of maize. Using this equipment, a worker can shell between 8 and 15 kg of maize per hour (Patil et al., 2014; John et al., 1989). When draught animals are available and significant quantities of maize exist, threshing may be performed by attaching the animals to threshing tools and allowing them to traverse the grain in the field (Onwualu et al., 2011).

Manual shellers, sometimes crafted by local artisans, enhance the efficiency and speed of maize ear shelling. These are offered in many configurations, some engineered to support a motor; they are often actuated by a handle or a pedal. The operation of manual shellers often requires just one person. Producing between 14 and 100 kg/min, they are optimally engineered for the demands of small-scale production. Hand-operated rotating maize shellers are considered suitable for small and marginal farmers for maize shelling, especially for seed production, since they cause less grain damage than power-operated maize shellers (Ashwin and Shaik, 2014).

The engine-driven method employs mechanical assistance for maize shelling. It is recommended that mechanical shellers accelerate the shelling of maize to reduce postharvest deterioration, since manual shelling methods are insufficient for commercial purposes (Nwakaire et al., 2011).

At now, many compact maize shellers using rotating cylinders of peg or bar types are accessible on the market. Their output varies from 500 to 2000 kg per hour, and they may be driven by a tractor's power take-off or have a standalone engine; power requirements vary from 5 to 15 hp according on the equipment used (Nyongesa, 2009). The main aim of design is to achieve optimum machine performance. The factors influencing maize shelling efficiency may be classified into machine parameters and crop characteristics. Engineering design considerations also impact the design of mechanical shellers. The factors include the design of the power transmission shaft, key, selection of the prime mover, type of pulley, appropriate chain drive design, and choice of suitable bearing support (Danfulani, 2009).

Physical and Mechanical Characteristics of Maize The significant crop metrics include moisture content, biometric qualities including grain size, grain cob ratio, grain bulk density, sphericity, angle of repose, terminal velocity, one thousand grain mass, and porosity. To treat maize seeds, particularly during threshing, it is essential to ascertain certain physical qualities, which are mostly influenced by moisture content. The properties encompass dimensions (size, shape), bulk density, porosity, coefficient of static friction, volume, weight, specific gravity, density, surface area, angle of repose, and angle of internal friction; their practical utility in machine and structural design processes and control engineering has been highlighted (as cited by Dauda, 2015).

Coskun et al. (2006) determined the physical qualities of sweet corn seeds in relation to moisture content, which ranged from 11.54% to 19.74% (dry basis). The mean dimensions were 10.56 mm in length, 7.91 mm in breadth, and 3.45 mm in thickness, with a moisture content of 11.54% (dry basis). The moisture content ranged from 11.54% to 19.74% (d.b.). Research on rewetted sweet corn seeds indicated that the thousand seed mass increased from 131.2 to 145.5 g, the projected area from 59.72 to 75.57 mm^2, the sphericity from 0.615 to 0.635, the true density from 1133.8 to 1225.5 kg m^{-3}, the porosity from 57.48% to 61.30%, and the terminal velocity from 5.56 to 5.79 m s^{-1}. The bulk density decreased from 482.1 to 474.3 kg m-3 as the moisture content increased from 11.54% to 19.74% (dry basis). The static coefficient of friction for sweet corn seed exhibited a linear rise across four structural materials: rubber (0.402-0.494), aluminum (0.321-0.441), stainless steel (0.267-0.401), and galvanized iron (0.364-0.477) as the moisture content rose from 11.54% to 19.74% (d.b.).

El-Fawal et al. (2009) established a database including the physical and technical features of grains from many primary and widely-used feed and industrial crops. The examined crops are fennel flower, rice (Giza 101), rice (Giza 177), broad bean, corn (hyb. 310), corn (hyb. 352), wheat (Giza 9), and wheat (Giza 168). Their selection was predicated on current cultivation areas and anticipated future growth for each type. Numerous physical properties, such as grain dimensions (length, width, and thickness), thousand grain weight, bulk density, sphericity percentage, projected area, as well as mechanical properties including angle of repose and coefficient of friction, alongside aerodynamic properties like terminal velocity, drag coefficient, and Reynolds number, were assessed at a storage moisture content of 7-12% (wet basis). The findings indicated that the use of stainless steel or galvanized iron in the production of seed hoppers for planting machines, silos, and storage containers with a 400 side tilt facilitates the effortless sliding of grains. The physical characteristics of seeds are crucial for selecting appropriate separation and cleaning equipment, and the primary dimensions were taken into account while choosing and developing the optimal size of screen perforations.

Tarighi et al. (2011) examined the physical and mechanical characteristics of maize seeds in relation to moisture content, which ranged from 5.15% to 22% (dry basis). The average length, breadth, thickness, and arithmetic diameter grew by 6%, 2.2%, 1.66%, and 3.3%, respectively, with rising moisture content. Within the moisture range of 5.15 to 22% (d.b.), the findings indicated that the thousand seed mass escalated from 267.7 to 305.8 g, porosity augmented from 31.41 to 45.98%, the static angle of repose increased from 42 to 57 degrees, and the coefficient of friction on compressed plastic, plywood, and galvanized iron sheet surfaces rose from 0.36 to 0.67, 0.36 to 0.60, and 0.38 to 0.57, respectively. The bulk density decreased from 679.1 to 632 kg m-3, but the actual density escalated from 999.33 to 1170.49 kg m-3.

Montellano et al. (2012) established the mechanical parameters of maize grains and olives necessary for discrete element method (DEM) simulations. The Discrete Element Method (DEM) is a numerical approach especially developed for simulating the mechanical behavior of granular materials. This study presents the experimental assessment of values for many microscopic parameters, including particle density, modulus of elasticity, coefficient of restitution for particle walls, and particle-particle interactions.

SUMMARY

Numerous authors' reports suggest that maize exhibits fluctuating production demand globally, since it serves as a diverse source of nutrition for both people and animals, in addition to being a raw material for various industries. In addition to increased production demand, excellent postharvest production often requires well-engineered shelling equipment. Shelling is the primary postharvest process in which grains are detached from ear heads using traditional methods, hand-operated mechanical shellers, and power-operated shellers. The analysis of research data indicates that the conventional method of maize shelling causes significant harm to the maize grain and entails considerable labor. Various mechanical shellers have been invented and developed to mitigate the issue. The operating efficiency of these shellers has been enhanced by meticulously assessing the crop and machine characteristics.

The physical and mechanical qualities of the crop together influence the performance of the cylinder. The physical properties of agricultural products, such as grain dimensions (length, width, and thickness), bulk density, true density, sphericity percentage, projected area, porosity, moisture content, and mechanical properties (angle of repose and coefficient of friction), along with aerodynamic properties (terminal velocity, drag coefficient, and Reynolds number), are essential for machine design. Consequently, these properties are examined individually due to the irregular shapes and size variability of agricultural products.

Moreover, relevant machine parameters influencing the design, performance, and assessment of shellers encompass the cylinder type, feed rate, concave length, concave clearance, concave hole size, concave rod clearance, fan speed, sieve oscillation frequency, and cylinder peripheral velocity.

The amalgamation of machine and crop data meticulously assessed by many researchers to evaluate the sheller's performance includes shelling efficiency, grain loss, grain damage, output capacity, cleaning efficiency, power demand, and threshing recovery.

Consequently, kernel moisture content significantly impacts kernel damage (Mahmoud and Buchele, 1975; Chowdhury and Buchele, 1976; Hamid et al., 1980; Ajav and Igbeka, 1995; Abba and Atiku, 2010; Naveenkumar, 2011; Naveenkumar and Rajshekarappa, 2012; Shaik, 2014; Oriaku et al., 2014). The studies indicated that mechanical kernel damage escalated significantly with rising moisture content above about 20%; nevertheless, maize shelled at moisture levels much below 20% still experienced substantial damage.

Mahmoud and Buchele (1975), Chowdhury and Buchele (1976), Kravchenko and Kuceev (1979), and Nalbant (1990) indicated that the peripheral velocity of the cylinder in a maize sheller, which achieves enhanced cleaning and shelling efficiency, ranges from 7 to 11 m/s.

Joshi (1981), Gupta et al. (1985), Shaik (2014), and Sachin (2016) said that the intensity of the shelling process is regulated by the cylinder velocity and the clearance between the cylinder and concave. The clearance at the front of the concave is around 20 to 30 mm. Kustermann (1987), Hamid et al. (1980), and Wacker (2005) determined that axial feeding, where the cob's axis is parallel to the cylinder's axis, results in less damage to the corn kernel compared to feeding at an angle.

Results and Discussion

To mitigate the issue of power scarcity in rural and semi-urban regions, human intervention is necessary. A pedal-operated maize shelling machine was created to provide ease of use, minimal maintenance, and to address food safety and hygiene concerns. Initial drawing and design schematic A preliminary drawing was created prior to the real design of the machine to develop the strategy. Comprehensive elucidation of the operation of a pedal-operated maize shelling apparatus The energy necessary for pedaling to operate the machine was derived from the leg, lower back, abdominal, and thigh muscles. The individual stayed sitting and started pedaling using plastic pedals. A specifically engineered rubber seat was included into the machine to facilitate optimal body balance for the user throughout the exercise.

The energy from the pedals was conveyed by a chain and sprockets constructed from cast iron. An iron chain served as the pedal chain, positioned horizontally on the sprockets at both the pedal end and the main shaft. A shelling device was installed at the terminus of this shaft. The maize feed was manually supplied to the shelling equipment. Upon initiating pedaling, the pedal side chain and sprocket engage the main shaft, facilitated by bearings, therefore causing the shelling unit to rotate. The maize cobs engage with the teeth of the shelling unit and are extricated from the cob. The dehusked corn was then gathered at the exit. Operational Principle The transmission system delivers the essential motion necessary for the operation of the machine. The motion and torque are conveyed by a chain, sprocket, and bearings to the shaft connected to the sheller, which is equipped with shelling teeth. The maize, together with the cobs, is manually inserted into the shelling portion of the machine. The spinning sheller is accessed inside the de-cobing teeth by the operation of the sheller. The teeth exerted a constant impact force on the whole corn, effectively detaching the grains. Due to the teeth being inclined at a ratio of 1:2 (outward to inward), the whole maize progresses down the length of the sheller in a forward motion until it reaches the cob outlet. Prior to the maize reaching this stage, almost all the grains (seeds) were extracted. The impact of the teeth may result in some cobs being fractured, while both broken and intact cobs emerge down the spout. The cleaned maize is then sent into the receiver, where it is gathered for further processing activities. Evaluation of manufacturing operations The factors evaluated for manufacturing activities were the availability of raw materials and the viability of production processes. Sheller Sheller was a component of the shelling unit, responsible for the shelling of maize. Chain and sprockets Chains and sprockets were used for power transfer. A single pair of chain and sprockets was used on the pedal side to link the main shaft. Spatial requirements The machine's floor area needed for operation and storage was 4800 cm² [120 cm (length) × 40 cm (breadth)]. Empirical findings The average weight of one cob is 167 grams. Provide 180 kilograms Average shelled grain weight: 58.86 kg Average unshelled and damaged grain: 1.13 kg Average time required for shelling one cob is 9 seconds. Average time required for the replacement of maize cobs is 2 seconds. Shelling efficiency: 98.10% Calculation of machine capacity: Average time needed for shelling one cob = 9 seconds. One minute of maize/cob shelling yields 1.02 kg. For one hour, the shelled maize/cob weighs 61.2 kg. Consequently, machine capacity ranges from 58 to 62 kg/hr. The machine's capacity, taking into account one-third.

Figure.1 Front view of pedal operated maize sheller

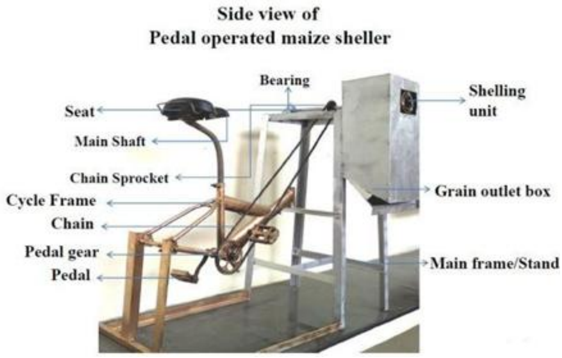

Figure.2 Side view of pedal operated maize sheller

This chapter presents the discussion regarding the findings of the study. A pedal operated maize shelling machine was designed and developed . The machine was pedal operated and could be operated at various r.p.m manually. The capacity of machine varied from 58-62kg/h at 10% moisture content and at different speed of operation. The capacity of machine was maximum 348 - 372kg/day considering 1/3rd of the rest given to farmer, with maximum shelling efficiency and cleaned outlet grain 98.10 (%) and minimum mechanically damaged and unshelled grain i.e. less than 1.88%.

An increase in the proportion of unshelled grain leads in a drop in the shelling efficiency of the sheller, while a rise in the percentage of damaged grain renders the grains more vulnerable to microbial and fungal infestations, leading to grain loss during storage. A research conducted by Sahil et al. revealed that the minimum grain damage percentage (1.712%) occurred at a moisture level of 16%, while the maximum grain damage percentage (2.606%) was seen at a moisture content of 20%. Increased grain moisture results in the adherence of grains to the cobs, causing damage due to impact inside the machine.

The conventional technique of maize shelling imposes significant labor on the farmer and requires excessive time for the shelling process. Consequently, the pedal-operated maize sheller has a straightforward design, is economically viable, and can be effectively used by small and marginal farmers. Even untrained laborers may work without harming their hands, since the revolutions per minute of the shelling unit are manually regulated. The sheller may be used in the field, yards, or farmhouse without the need for a power supply. The pedal-operated maize sheller demonstrated a machine capacity of 58-62 kg/h and achieved a shelling efficiency of 98% during testing. The engineered sheller is economically viable, at a price of Rs. 2,000/-.

Conclusion

The corn is usually shelled by hand. This process involves rubbing maize against another until the grains are detached from the cob; this traditional shelling technique is very laborious, inefficient, and time-consuming, resulting in poor production. The electrically powered maize sheller needs electrical energy for operation and entails a substantial capital expenditure relative to traditional shelling techniques; yet, the electricity supply in rural regions is sometimes unreliable. Therefore, a creative concept or product that is practical, safe, economical, and efficient for the Indian farmer was necessary. Considering the existing circumstances, a continuous, high-capacity, pedal-operated maize shelling machine was conceived, manufactured, and evaluated using RSM techniques. The influence of operational factors on response variables was examined. The primary criteria for optimization were machine capacity, mechanically damaged grain, and shelling efficiency. The moisture content did not influence the capacity of the pedal-operated maize shelling machine. The operational speed and machine capacity have shown a consistent and significant rise. The machine's capacity was at its peak when the shelling disc's revolutions per minute were at their highest. The moisture content did not influence the capacity of the pedal-operated maize shelling machine; nevertheless, a rise in operational speed resulted in a consistent and significant enhancement in the machine's capacity. The machine's capacity reached its maximum when the shelling disc's revolutions per minute (r.p.m) were at their peak, demonstrating an upward trend with higher operational speed.

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