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Research Article

Development and Performance Evaluation of Grain De-Huller

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About Article

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ABSTRACT

Manual de-hulling of different grains has been a time-consuming and tedious operation. From locally available and low cost motorized grain de-huller was therefore developed, fabricated and evaluated on different grains. The de-hulling operation of the machine is achieving by combination of abrasive and impact forces. The machine consists of a hopper, a de-hulling unit consisting of a shaft with Beater arrangement on it and which rub the grains against cylinder and grain to grains, an outlet for collection of de-hulled and a frame made of rectangular pipe mild steel. Rice, wheat, Oat and barley were the grains used for evaluating the performance of machine. Besides de-hulling operation the machine also tested on splitting of di-cotyledon such as bean, pea and lentil. The average de-hulling Capacity and efficiencies of the machine were 215 kg /hr and 86.22 %, 243 kg/hr and 91.01 %, 204 kg/hr and 90.94 %, and 282 kg/hr and 97.87%, on rice, wheat and barley oat grains respectively.

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1. INTRODUCTION

Wheat, barley rice and oat are major grains for food security in Ethiopia. Due to their economic importance, significant efforts have been taken to improve the production. Despite the increase in production, limited effort has been taken to improve these crops processing technologies, particularly, for small scale rural farmers. Rice, oat and Barley intended for human consumption needs to be de-hulled. Producers and consumers of different grains face a daily task of de-hulling the grains manually before being able to prepare the daily meal. In Ethiopia, de-hulling process is commonly accomplished either by hand pounding of tempered grain using pestle and mortar or mechanically using rubbing type de-hullers. These methods are slow, time consuming and laborious process which is done by women.

Successful development of an efficient small-scale de-huller for different grains which can overcome the problems associated with current de-hullers will eliminate much of the daily drudgery that is currently associated with the traditional processing of different grains in rural areas and hence increase the acceptability of products. Therefore, the introduction of such de-hullers will be complimenting the indigenous technology and hence will have a higher chance of being adopted compared to other types of de-hullers. Therefore, in this study, abrasive, a low cost power operated machine and portable for de-hulling grains was designed, constructed and tested for its efficiency with the objectives of to develop, construct the grain de-huller and evaluate the performance of the developed machine.

2. LITERATURE REVIEW

A grain de-huller, also known as a grain hulling machine, is an agricultural instrument used to remove the outer husk or hull of grains and seeds. This technique, known as de-hulling or hulling, is an important step in preparing grains for human consumption and other purposes. De-hulling is a vital step in the preparation of grains for consumption and processing. It entails removing the outer husk or hull from grains. The performance of grain de-hullers is critical for the efficiency and quality of the de-hulling process. This review looks at several research on the performance of various grain de-hullers, with an emphasis on efficiency, efficacy, and effects on grain quality.

2.1. Advantages of Grain De-hulling

Improved Edibility and Nutritional Value: Removing the hull makes grains more pleasant and digestible. It also improves nutrient availability (FAO, 2015).

Better Processing Efficiency: De-hulled grains are easier to process in later stages, such as milling and grinding, resulting in higher-quality finished goods (FAO, 2015).

Increased Market Value: Because of their superior quality and appropriateness for direct consumption, de-hulled grains frequently command higher market prices than unprocessed grains (Mehta, 2018).

Reduced Bulk and Weight: By removing the husk, grains can be stored and transported more efficiently and cost-effectively (FAO, 2015).

Time and Labor Savings: Mechanized de-hulling decreases the time and labor necessary.

Time and Labor Savings: Mechanized de-hulling significantly reduces the time and labor required compared to traditional methods (EIAR, 2021).

Consistency and Quality: Machines provide a more consistent and higher-quality product, which is crucial for both local consumption and export markets (EIAR, 2021).

Economic Impact: By improving the efficiency of grain processing, mechanized de-hulling supports the agricultural economy and helps farmers increase their income (IFPI, 2020).

2.2. Grain De-hulling Practice in Ethiopia

Grain dehulling is a crucial practice in Ethiopia, especially for key crops including wheat, oats, barley, and sorghum. Traditional methods, such as mortar and pestle or manual threshing, are widely utilized. However, there has been a steady transition to mechanical de-hulling in order to enhance efficiency and product quality.

2.3. Types of Grains De-hullers

i. Mechanical De-hullers

Mechanical de-hullers are the most often used type in the grain processing business. These de-hullers use physical force to separate the hulls from the grains. Mechanical de-hullers' performance is determined by a variety of elements, including the de-huller's design, grain type, and grain moisture level.

Mechanical de-hullers, such as the impact and abrasion de-hullers, are popular due to their high throughput and low operating costs, according to Sharma and Gupta (2015). The impact de-huller removes hulls using centrifugal force, making it useful for grains such as barley and rice. The abrasion de-huller, on the other hand, uses abrasive surfaces to scrape the hulls off the grains, making it appropriate for grains with tougher husks, such as millet. According to Mehta (2018), mechanical de-hullers are classified into four categories.

A. Impact de-hulling machines use impact force to shatter the hulls of grains. The grains accelerate against a hard surface, shattering the hulls.

B. Abrasion De-hullers: These devices use abrasive surfaces to remove hulls from grains. The grains are scraped against abrasive surfaces to remove their outer coats.

C. Centrifugal De-hullers: These machines use centrifugal force to separate the hulls and grains. The grains are spun at high speeds, causing the hulls to separate due to force.

D. Roller De-hullers: These devices use pairs of rollers to crush and shear the grains' hulls. The rollers may be adjusted to apply the necessary amount of pressure to remove the hulls without damaging the grains

ii. Pneumatic Dehullers

Pneumatic dehullers use air pressure to separate the hulls and grains. These dehullers are very effective on grains with lightweight or brittle hulls. The airflow rate and chamber design influence the performance of pneumatic de-hullers.

According to Martinez *et al.*, (2018), pneumatic de-hullers provide a gentle de-hulling technique that reduces grain breakage while preserving kernel integrity. This qualifies them for high-quality grain processing, where preserving the entire grain is critical (Martinez *et al.*, 2018).

iii. Hydrothermal De-hullers

Hydrothermal de-hullers use heat and moisture to soften the hulls before mechanical removal. This approach works particularly well for grains with extremely hard or sticky hulls. Hydrothermal de-hullers operate best when temperature and moisture levels are precisely controlled.

According to Kaur *et al.* (2019), steam de-hulling improves de-hulling efficiency for difficult grains like sorghum. By softening the hulls, these de-hullers reduce the mechanical effort required, resulting in lower grain breakage rates and higher overall output.

2.4. Factors Affecting De-hulling Performance

2.4.1. Grain Type and Condition

The kind of grain and its state have a big influence on how well it dehulls. Dehulling grains with tougher hulls or more moisture content takes more effort. Preconditioning grains by varying their moisture content can improve dehulling efficiency and lower energy usage, according to studies by Oluwole *et al.* (2014).

2.4.2. De-huller Design and Settings

Performance is greatly influenced by the de-huller's design, which includes the kind of de-hulling mechanism and the operational parameters (such as pressure and speed). To get the best results, de-hullers must be calibrated and maintained properly. In order to maintain high de-hulling efficiency and product quality, Singh and Verma (2016) stress the significance of routine maintenance and suitable settings.

2.4.3. Processing Environment

The efficacy of dehulling can also be impacted by the processing environment, which includes humidity and ambient temperature. To ensure efficiency, the de-hulling process may need to be adjusted in extreme situations. Controlled processing settings can result in more consistent de-hulling outcomes and higher-quality grains, according to research by Kim and Park (2017).

3. METHODOLOGY

3.1. Study Area

The prototype was produced in Asella Agricultural engineering research center and primary testing of the machine was done at the center. Finally the testing of machine was done at Lemu Bilbilo wereda of Arsi zone. This study area is located between 7°10' 14''- 7°40' 20''N latitudes and 39°4' 59''- 39°38' 56''E longitudes and Mixed farming system is the main economic activity practiced in Lemu-Bilbilo district (Sime *et al.*, 2014).

3.2. Material Selection

The materials would be critically considered based on strength, availability, durability and corrosiveness to prevent machine damage, ease construction work and maintenance and prevent rusting or corrosion of the machine parts hence, mild steel angle iron -would be used for the frame and Shaft and bitter made of sheet metal and round bar for the de-hulling chamber.

3.3. Design Consideration

A number of points would be considered during the development. Such points include the cost of construction, power requirement of the machine and labour requirement in operating the machine. Also considered in the design would be the ease of replacement of component parts in case of damage or failure. The design considerations included economy and ergonomics, machine efficiency and product quality, simple operational and maintenance requirements to meet the need of local farmers and small scale industrialist, portability and detachability for easy transportation and low grain damage.

3.4. Selection of Shaft Diameter

The feed pellet making has one main shaft for die pellet and its diameter determined using maximum shear stress theory (Khurmi & Gupta, 2005; Nwaigwe *et al.*, 2012).

$$d^3 = \frac{16}{\pi \tau_{\max}} \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \qquad (1)$$

where: d is diameter of the shaft (m), Mt is torsional moment (Nm), Mb is maximum bending moment (Nm), Kb is combined shock and fatigue factor applied to bending moment, Kt is combined shock and fatigue factor applied to torsional moment, τ_{max} is allowable stress (55 MPa for shaft without key way and 40 MPa for shaft with key). For rotating shafts, when load is suddenly applied (minor shock): Kb = 1.2 to 2.0; Kt = 1.0 to 1.5. It must be noted that factor safety need to be considered in actual design work.

On performing subsequent calculations the shaft of 40 mm diameter selected.

3.5. Determination of Power

The power required to operating the machine was considered to be the sum of powers required to drive the pellet roll assembly, the die plates assemble and the loads on them and power required to overcome frictional resistance. The total power (Pt) required for the pelleting processes was determined by using the Equation given by Nduka *et al.*, (2012).

Pt=P+10%P (10% is possible power loss due to friction drive) (2)

Where: Pt = total power required to drive the machine,

P = (Ti − Tj) V for die plate rotation, Ti = tight side tension of belt drive wheel belts and Tj = slack side tension of belts and V = speed of belts .

On performing subsequent calculations the motor of 15 HP was selected to serve the purpose.

3.6. Determination of Pulley Diameter

Selection of pulleys and belts The machine required two pulleys; one pulley mounted on the die shaft and one on electric motor as main drive. One belt was used to transmit power from electric motor to the die shaft. Due to its availability and low cost aluminum pulleys were selected. To the beginning the diameter of the pulley on electric motor shaft was 100 mm and speed 1800 rpm. So According to Sharma and Aggarwal (2006) as cited by Abayineh and Abebe (2015) the diameter of pulley on die shaft, center distance between pulleys, belt length and belt speeds on the other shaft were calculated as follows:

$$D_1 N_1 = D_2 N_2 \qquad (3)$$

$$C = \frac{D_1 + D_2}{2} + D_1 \qquad (4)$$

$$V = \frac{N2\pi D2}{60000} \quad (5)$$

$$L = 2C + 1.57(D_1 + D_2) + \frac{(D_2 - D_1)^2}{4C} \quad (6)$$

Where: D_1 and D_2 = diameters of driving and driven pulleys (mm), N_1 and N_2 = rpm of driving and driven pulleys, C = center distance between two adjacent pulleys (mm), L = length of belt (mm) and V = speed of belts (m/s)

So by performing subsequent calculation, 210 mm pulley diameter on shaft, 255 mm center distance between two pulleys, 1020 mm length of belt were obtained.

3.7. Grain De-hulling Technology Description

The prototype of a grain de-hulling would be designed for de-hulling of different grain and it is batch type. The portable prototype of a grain de-hulling was designed for de-hulling up to 25 kg of Grains at once operational time and having overall dimensions was 920*1370*1000 mm. The major components of the de-huller technology are the frame, power (motor or engine), power transmission (belt and pulley), de-hulling part (cylinder, shaft and blade), flange bearing. Figure 1 shows technology constructed and evaluated in the experiments.

3.8. De-hulling Mechanisms

The de-hulling operation of the machine is achieving by abrasive and rotation forces and batch type. The de-hulling process was accomplished through abrasion between grain and grain, grain and de-huller cylinder surface and beater attached to shaft. The jostling and rubbing of individual grain particles against each other and against the de-huller cylinder and shaft attached beater surface as the shaft rotates help to create the friction necessary to remove the already loosen seed coat from the grain. As the motor/engine on, it transmits the motion to pulley through beater attached to shaft. The shaft rotational speed ranging between 1800 and 1850 rpm. This range was sufficient to achieve high de-hulling efficiency. The beater was adjusted on shaft at 200 mm distance on the same side of shaft and 100 mm distance on opposite side of shaft which gave the best de-hulling with maximum removal of the seed coat and minimal kernel breakage (Figure 1).

a) Isometric view b) Photographic view b) Exploded view

Figure 1. The developed de-huller machine (1. Frame, 2. Cylinder, 3. Side plate, 4. Flange bearing, 5. Hopper, 6. Outlet plate, 7. Pulley)

Table 1. The grain de-hulling technology consists of the following main parts and specifications

Part Name	Materials made up of	Specification
Hopper	Sheet metal 1.5 mm	(400 * 450)2 mm
Cylinder	Sheet metal 3 mm	$\pi r^2 h$ = (0.42π*0.8)
Shaft	Round bar	Ø = 40mm and length 100 cm
Pulley	Cast iron	Ø = 21 cm double line
Frame	Rectangular pipe	(4*60)mm
Beater	Stainless steel	(8*30*170) mm, # 9
Flange bearing	Flange bearing 207	#2
v-belt	B-51	#2

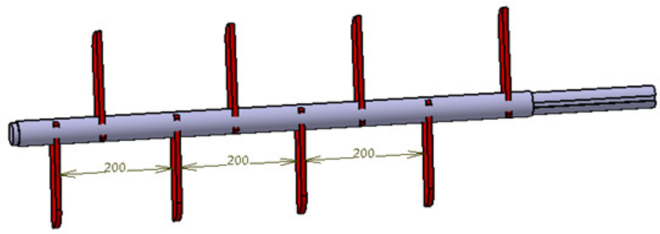

Figure 2. Shaft and Beater arrangement.

3.9. Sample Preparation

The grain de-hulled machine was evaluated with grains such as rice, oat, barley and wheat. Pulses such as bean, pea and lentil also prepared to test effect of machine on de-hulling and splitting efficiency. The sample was procured from local market for the test in center and collected from the farmers for the further evaluation of the machine at site. The moisture content of grain was taken according to farmers' trend. Wheat and barley de-hulled with and without soaking water. The required moisture content was achieved by soaking with water. But all the other selected grains were tested without soaking water as it is as farmers' trend.

3.10. Performance Evaluation

The performance evaluation of the grain de-huller would be made on the basis of the following parameters; De-hulling efficiency, Percentage of breakage, De-hulling capacity.

According to Lazaro *et al.*, (2014), de-hulling efficiency and percentage of breakage was calculated as-

$$DE = \frac{N_{GO}}{N_{GF}} X100\% \qquad (1)$$

$$BE = \frac{N_{GB}}{N_{GF}} X100\% \qquad (2)$$

Where:

DE is the De-hulling efficiency (%)

NGO is weight of grain at outlet (kg)

NGF is the weight of grain fed into the machine (kg)

BE is percentage of breakage (%)

NGB is the weight of broken grain (kg).

Whereas de-hulling capacity of the grain de-huller was calculated as

$$D_c = \frac{N_{GF}}{t}$$

Where:

D_c- de-hulling capacity (kg/hr),

t – Recorded time of de-hulling

4. RESULT AND DISCUSSION

Seven types of grains such as rice, barley, oat and wheat from monocot and pea, bean and lentil from dicot were poured into the hopper while the machine was running to evaluate the de-hulling efficiency, de-hulling capacity and percentage of breakage as well splitting efficiency of the pulses. In order to determine the percentage of breakage three samples was taken randomly from the test run and the de-hulled seeds, the seed broke were separated from de-hulled grains weighed separately and recorded.

4.1. Effect of Soaking Grain on De-hulling

Grain de-hulling process is intended to reduce a labor demand and drudgery while improving feed intake and feed use efficiency. As shown in table 1 the mean grain de-hulled of both wheat and barley grains was increased from 18.44 to 19.57 Kg and 18.8 to 19.82 Kg as water used for soaking increased from 1 to 2 lit respectively. By increasing water to three liters the de-hulling of grain also increase to 19.84 kg and 19.94 on wheat and barley respectively. No changes were occurred by adding extra water on de-hulling in 20 kg of wheat and barley. When subjecting the data to Analysis of Variance there are significant pairwise differences among the means of de-hulling grains with soaking in with 1 lit and 2 lit. But there is no significance difference between mean of de-hulling grain with soaking of grain in 2 and 3 liters on both wheat and barley.

4.2. De-hulling Efficiency

Table 2 indicates that barley has slightly the higher Means of de-hulling efficiency and when described figuratively it was recorded as 94, 99.08 and 99.77 % at soaking of grain with 1, 2 and 3 liters of water respectively. Similarly, means of de-hulling efficiency of wheat were 92.22, 97.87 and 99.18 % at 1, 2 and 3 liters respectively. This means that the grains type affects significantly to the study of de-hulling efficiency. This due to the thick cover hull of the barley, this protect grain from breakage and loss during the experiment.

4.3. Effect of Soaking Grain on De-hulling Capacity

As shown from table 2, it was observed that when the machine was loaded by the grains, soaking of grain with 3 liters of water has highest the de-hulling capacity of 611.48 kg/hr followed by 2 liters which is 482.6 kg/hr. and then 263.1 kg/hr. at 1 liter on wheat grain. Similarly on barley grain, de-hulling capacity were 218.5, 429.8 and 558.5 kg/hr when the grain soaked with 1, 2 and 3 liters of water for three minute respectively. Subjecting the data to Analysis of Variance shows means of the de-hulling capacity of machine on wheat and barley grain were significant at 5 % level of significance. This means that the de-hulling machine can has a highest de-hulling capacity when 3 liters of water used for soaking grains this is due optimum moisture content of the grain reached. No significance changes would occur further increasing of water for soaking on de-hulling capacity. According to Lazaro etal, 2014 it was very important to make sure all surface moisture is absorbed before the grain is fed into the de-huller so as to avoid introducing excessive moisture into the de-huller, as this might have led to crushing problem.

Table 2. Summarized Performance evaluation result of the de-hulling machine on wheat and barley with soaked water at different level.

Parameters	Wheat						Barley					
	1 lit	**2 lit**	**3 lit**	**Mean**	**CV**	**SEM**	**1 lit**	**2 lit**	**3 lit**	**Mean**	**CV**	**SEM**
DC (kg/hr)	263.1	482.6	611.48	452.39	2.97	7.77	218.5	429.8	558.5	402.27	6.7	15.57
DE (%)	92.22	97.87	99.18	96.42	0.75	0.42	94	99.08	99.77	97.59	0.84	0.47
Amount (kg)	18.44	19.57	19.84	19.28	0.75	0.08	18.8	19.82	19.94	19.52	0.84	0.09
Time (min)	4.21	2.44	1.95	2.86	2.91	0.05	5.17	2.78	2.14	3.36	5.22	0.1

The mean followed by same letter in the column has no significantly different, DC- de-hulling capacity, DE- de-hulling efficiency.

4.4. Percentage of Breakage

As shown in figure 2 percentages of breakage for both wheat and barley grains were decreases with increasing water used for soaking in three minute. Soaking of wheat with 3 lit of water for three minute results 0.82 % of breakage. When soaking of wheat with 2 and 1 lit of water for three minute percentage of breakage were 2.13 and 7.78 % respectively. Whereas soaking of barley with 1, 2 and 3 lit of water for three minute percentage of breakage was recorded as 6, 0.5 and 0.3 % respectively. The finding has similar result with Tamiru etal, 2019 studied that percentage of breakage was decrease as moisture content increase on coffee bean.

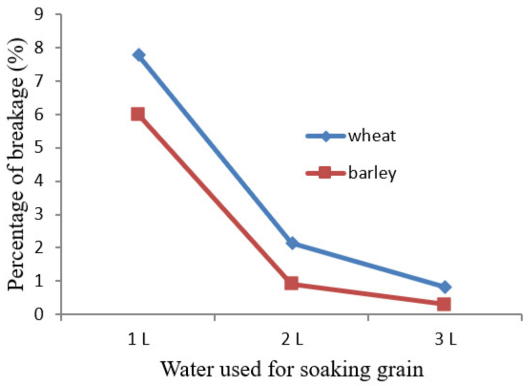

Figure 3. Percentage of breakage of grain (wheat and barley)

Table 3. Performance result of machine on different grains without soaking with water

Parameters	Grains					
	Rice	Wheat	Barley	Oat	CV	SEM
De-hulling capacity (kg/hr)	215.52	243.44	204.67	282.68	2.97	7.77
De-hulling efficiency (%)	86.22	91.01	90.94	97.87	0.75	0.42
Percentage of breakage (%)	47.56	14.5	11.71	8.97	0.75	0.08

As shown from the Table 3. de-hulling capacity of the machine on rice and oat was 215 and 282 kg/hr respectively. One of the special properties of oat observed during the evaluation, when soaking with water it make de-hulling operation difficult and it take long period of time and the color appearance was also not attractive. Moreover it did not de-hull. The percentage breakage of the machine on rice was 47.56 % this figure looks high but better than when compared to rice purchased on local market for consumption purpose.

4.5. Performance of Machine of Splitting of Dicot

Based on the result found it break instead of splitting which not recommended. So the developed machine must incorporate with other mechanism in order to split effectively.

5. CONCLUSION

The performance of grain dehullers is influenced by various factors, including the type of dehuller, grain characteristics, and operational settings. Mechanical dehullers are widely used due to their efficiency and cost-effectiveness, while pneumatic and hydrothermal dehullers offer advantages in preserving grain integrity and processing tough grains, respectively. Further research and technological advancements in dehuller design and operation can lead to improved deh-ulling efficiency and grain quality.

A grain de-hulling machine was developed and evaluated. Based on the result, the following conclusions were drawn:

- The average de-hulling efficiency of the machine was 96.42 and 97.59 % on wheat and barley grain respectively.
- The maximum de-hulling capacity of the grain de-huller was about 452.39 and 402.27 kg/hr on wheat and barley respectively.
- The maximum percentage of breakage was 3.58 and 2.27 % on wheat and barley grain respectively.

6. RECOMMENDATION

- The developed grain de-hulling machine had good de-hulling capacity, de-hulling efficiency and small percentage of breakage which means that it was accepted
- Therefore, it was recommended that due to its good performance gained, this grain de-huller was appropriate for medium farmers, job seeker with association.

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