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Adaptation, Development and Performance Evaluation of Sorghum Dehuller

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Abstract

The study was conducted at Melkassa Agricultural Research Center's agricultural engineering research process to fabricate and test sorghum dehuller. An electric motor-driven dehuller was developed and tested in the AIRIC workshop using locally available materials. Hopper, barrel, abrasive disk, power shaft, spacers, aspiration unit, frame, and the motor are the main components of the prototype. Sorghum dehulling in Ethiopia is most commonly done traditionally by using a mortar and pestle, which is tedious and time-consuming. In fact, the aim of traditional practice is primarily to remove the unthreshed grain husk determinant factor of injera quality rather than removing seed coat from endosperm. A factorial experimental design was used during performance evaluation by considering grain inlet and outlet openings as factors at three levels. Melkam, widely promoted and available variety at farmers hands, was used for evaluation. A sample with recommendable moisture content was fed into the barrel when the disk attained its maximum rpm and replicated three times. The test result showed an average dehulling efficiency of 92.59%, a dehulling capacity of 18.18 quintals/hr., a throughput capacity of 20.82 quintals/hr., and a cleaning efficiency of 94.43 %.

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Keywords

Sorghum, dehuller, throughput capacity, dehulling efficiency, cleaning efficiency.

Introduction

Sorghum is one of the major cereal crops grown in Ethiopia, with a long history of cultivation. It is an important staple food in many regions of the country due to its nutritional value and ability to withstand harsh environmental conditions. The crop is known for its drought and heat tolerance, making it suitable for cultivation in arid and semi-arid areas.

Sorghum is widely cultivated across different regions of Ethiopia, with a significant portion of agricultural land devoted to its production. It is the major crop in the dry lowland environment which accounts for more than 60 percent of the cultivated land (CSA, 2018). Sorghum is the third most important cereal crop after Teff and Maize both in area and production in Ethiopia. In Ethiopia, sorghum is produced for food, feed, and stalks for fodder and building material. From total cereal crop production sorghum accounts for 12.94% (1.68 million hectares), 13.22% (45.17 million quintals) of the grain production. Average productivity of sorghum was estimated as 26.09 quintals per hectare (CSA, 2022). However, the yield can differ significantly across regions due to farming system, access to improved seeds, fertilizers, irrigation, and good agricultural practices.

After harvesting, sorghum grain undergoes a dehulling process to remove the outer layer, known as the husk or bran. Dehulling is essential as it improves the digestibility of sorghum and enhances its nutritional value. Efficient dehulling process removes high crude fiber and anti-nutritional factors such as tannins and phytic acid. Traditionally, Ethiopians use manual methods for dehulling sorghum, such as pounding the grain in a mortar and pestle or using wooden or stone mills. Of course, the traditional method of dehulling is time consuming and tedious work mostly done to remove pod left on the tip of the grain during threshing operation than removing its anti-nutritional factors.

However, advancement in technology and use of machines specifically designed to remove the husk from the sorghum grains efficiently are best options to minimize drudgery of dehulling and improve utilization of sorghum. Sorghum is not only consumed as a whole grain but it is also processed into flour, which is used in making injera (a traditional Ethiopian flatbread) and other food products.

Dehulling machines play a crucial role in saving time and labor, producing higher quality of sorghum flour for various purposes, including food and beverage production. Dehulling process of sorghum creates additional work load on women in rural area and needs intervention. Using abrasive-type dehuller recommendable for dehulling sorghum and millet is a good solution to minimize drudgery of women, add value and increase utilization of widely produced sorghum grain for injera purpose like tef the precious crop of Ethiopia. *Therefore, development and evaluation of efficient sorghum dehulling machine were the aim of the study.*

Materials and Methods

Materials and Equipments Used

The prototype fabrication and test was conducted at MARC AIRIC workshop. To develop the dehulling machine round pipe steel, galvanized hoolw pipe, sheet metal of different thickness, both hollow and solid round pipes, angle iron, U-channel, abrassive disk, almunium pulley Belt, bolt and nut were used.

Stop watch: was used to record time taken for dehulling each sample grain

Electric digital balance: was used to estimate the dehulled, undehuled, broken and bran component in weight base.

Grain moisture meter: was used to estimate the moisture content sample grain before feeding

Sample poly bags: to collect samples from each treatment from both grain and chaff outlet for further laboratory analysis.

At the very beginning all necessary information related to sorghum dehulling problem were collected. The drudgery of work in traditional dehulling process of sorghum grain and tremendous qualitative and quantitative loss associated with sorghum grain dehulling was assessed via desk review and discussion with concerned bodies further more. Existence of any sorghum dehulling technology in the country else were was assessed. The only dehuller assessed was RIIC dehuller available at MARC sorghum research program. It needs about 8hp for full load continuous mode of operation to rotate disks at 200 rpm. The machine has throughput capacity up to 800kg/hr. (Bassey and Schmidt, 1989). After the operating mechanism and component parts were identified detailed dimension recording and modeling was made for reverse engineering. In line with this material and equipment necessary for the development of prototype dehuller were surveyed in the market, unfortunately the big challenge was un availability of abrasive disk with the same size as one used in the older machine. Based on available material in the market improvement work was done. During the design work throughput capacity, dehulling, cleaning, ease of operation, availability of material in the market were considered to optimize as much as possible.

Main components of the dehuller

Hopper: is made up of steel with pyramidal shape and is positioned at the top of the dehulling barrel opposite side of the grain out let along the grain movement. It is used to hold the grain to be feed in to the barrel at the desired feed rate.

Dehuller barrel: This is semi-cylindrical in shape made from steel sheet metal in which nine (9) rotating abrasive discs mounted on rotating shaft.

Dehuller abrasive disk: nine (9) abrasive disks, separated by spacers made of aluminum, are mounted on a horizontal shaft located through holes on opposite end plates of the barrel. The disks are secured in place so that they cannot slip on the shaft and keep constant clearance between the outer circumference of the disks and the barrel.

Power shaft: there are two shafts made from round solid steel pipe serve as power transmission element for the dehulling operation and fun power source in the aspiration unit.

Spacer and locking nut: Spacer are a component used to maintain constant gap or space between the disk where as end locking nut is a part responsible to fix the whole disk assembly at its better operating position where it was installed.

Aspiration unit: is a part important in separating bran from dehulled grain by suction force from the fun located at one end of dehulling barrel were dehulling process ends.

Frame: is the fixed main part of the dehuller which holds the weight of the machine.

Base: is the bottom part of the dehuller used as foot and dumper of vibration and motion.

Evaluation

Three level (grain inlet openings and three grain out let opening) full factorial design was used for evaluation in three replications resulting in 27 observations. Equal sorghum grain sample was weighted and prepared to feed at different feeding rate, and were fed into the machine to study the influence with continuous mode of operation. Melkam sorghum variety mostly used and available on farmers hand was used during evaluation. Moisture content of sample grain was determined before evaluation is commenced. The grain output and material other than grain output were collected and weighted for all samples using sensitive weighting balance. All necessary data recorded were organized and subjected to statistical analysis using statistix 8 software.

Calculation of performance indicating parameters

The following equations were used to calculate respective performance indicating parameters

Dehulling capacity (DC)

$$DE = \frac{SG}{T} \quad ....1$$

Where: DE: dehulling capacity

SG: sample grain fed in to the machine (kg)

T: time taken to finish the sample(hr.)

Dehulling efficiency (DE): The dehulling efficiency was calculated as:

$$DE = \frac{WDG}{WGF} X100 \quad ....2$$

Where: DE: Dehulling efficiency (%),

WDG: weight of dehulled grain (kg),

WGF: weight of total grain fed (kg)

Cleaning efficiency (CE)

$$CE = \frac{Wt.MOG}{Wt.sample} X100 \quad ...3$$

Where:

CE = Cleaning efficiency (%)

W_{MOG} = weight of material other than grain at grain outlet (kg)

Wt. $_{sample}$ = sample wt. at grain outlet (kg)

Percentage of grain loss at MOG outlet (PL): it was calculated considering the grain come via chaff out let as a loss.

$$PL = \frac{Wt.ofG\ @MOGoutlet}{Wt.sample} X100 \quad ...4$$

Where:

PL = percentage of grain loss (%)

Wt. of $G_{@MOG\ outlet}$ = weight of grain received at chaff outlet (kg)

Wt. $_{sample}$ = Total weight of sample used (kg)

Results and Discussion

Dehulling capacity

From ANOVA table the dehulling capacity of the machine is highly significantly affected by grain inlet opening which determines feed rate and not significant with replication. When the outlet opening increased from O4 to O6 at constant grain inlet opening (h_3) the dehulling capacity increased from 19.2 to 25.9 quintal/hr.

The machine showed grand mean dehulling capacity of 18.18 quintal/hr. and throughput capacity of 20.12 quintal/hr.

Cleaning efficiency

ANOVA table shows that, the cleaning efficiency is highly significant with both feeding rate and drum speed and also significant with the combination replication and drum speed. Increasing the feed rate from 23 to 28kg/min at constant drum speed of 700 rpm cleaning efficiencies decreased from 96.725 to 95.692%, respectively

The cleaning efficiency has increased with increasing grain inlet opening (feed rate) and outlet opening (retention time). That may be because the removed bran and powder is accumulated at the bottom part of the barrel unless it is lifted up by the disk movement and sucked by the fun. Since the disks are arranged in perpendicular position with the direction of grain movement from inlet to outlet opening of the machine has no means of conveying the grain following first in first out principle. This causes filling up of the barrel up to the level the fun can't suck and clean. Then nearly direct grain movement is caused on the top of the barrel where better cleaning opportunity exists. This is confirmed for increased inlet opening and out let opening combination to the maximum h_1O_4 to h_3O_6 resulted increase in cleaning efficiency from 94.70% to 97.0%.

Dehulling efficiency

Dehulling efficiency graph showed decreasing trend as both inlet and grain out let openings increase. It is significantly affected by roughness of the surface of barrel, roughness of disk surface, space between the disks, inlet opening, the amount of grain in the dehulling barrel and grain outlet opening. Maximum dehulling efficiency of 93.53% was obtained at lower grain inlet opening. It can be seen from the result that for increased feed rate the dehulling efficiency was lower indicating that primarily the dehulling action is between grain and rough surface of barrel and disk.

Grain Loss

For this specific activity the total grain loss was estimated by considering the grain received via chaff outlet. For each sample feed the output at chaff outlet was collected and separated by using different sized sieves. The full sized and broken grains are remained on the sieve and weighed by sensitive weighing balance to calculate the percentage of grain lost and broken. In overall the machine has showed average value of loss equal to 13.6 %, the minimum value 9.22% was recorded at minimum grain inlet and outlet combination which is promising result and can be further improved with minor modification work. The graph shows nearly constant relation between cleaning efficiency and loss as the grains are lost via bran outlet by suction force of the fun.

Table.1 Technical specification of electric motor

Model	JIMMA ENT (Made in China)
Type	Three phases
Speed	2880 rev/min
Voltage	380/660V
Power	11 kw or 15 hp
Frequency	50Hz
Weight (kg)	100 kg

Figure.1 Hopper

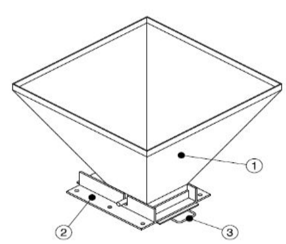


Figure.2

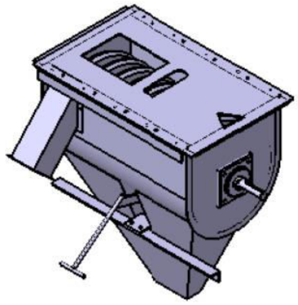
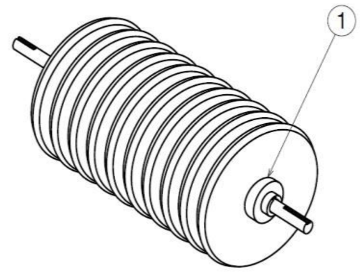
A. Dehulling barrel	**B.** Abrasive disk assembly
	

Figure.3 Fun

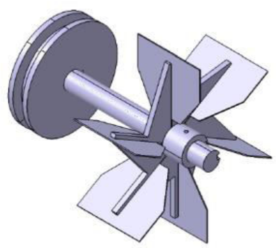


Figure.4

Figure.5

a. Sample preparation	b. Data recording
	

Figure.6

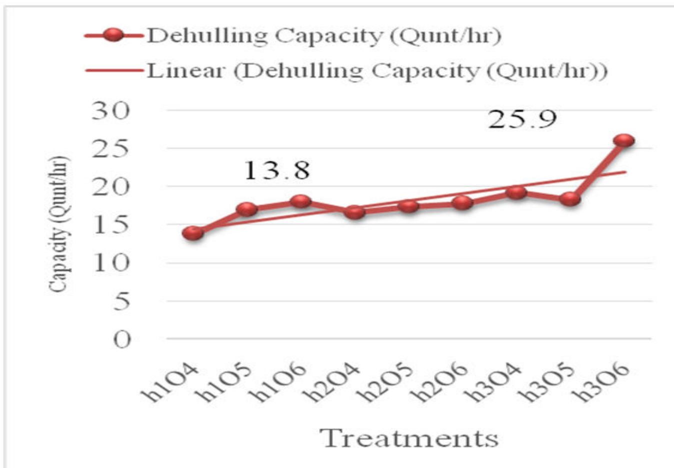


Figure.7

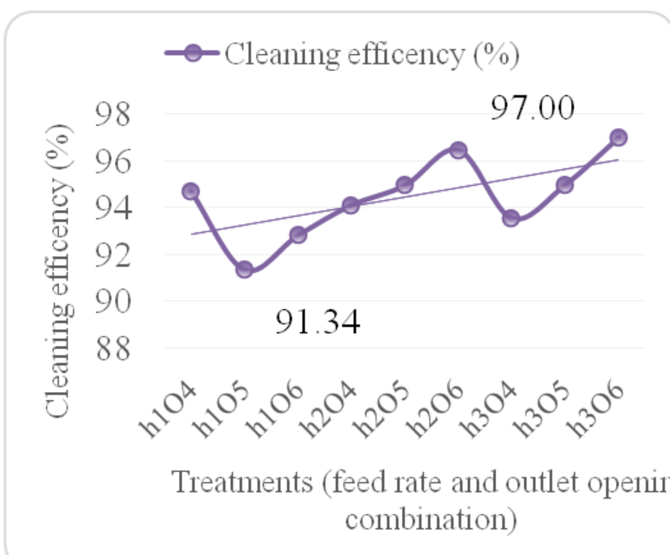


Figure.8

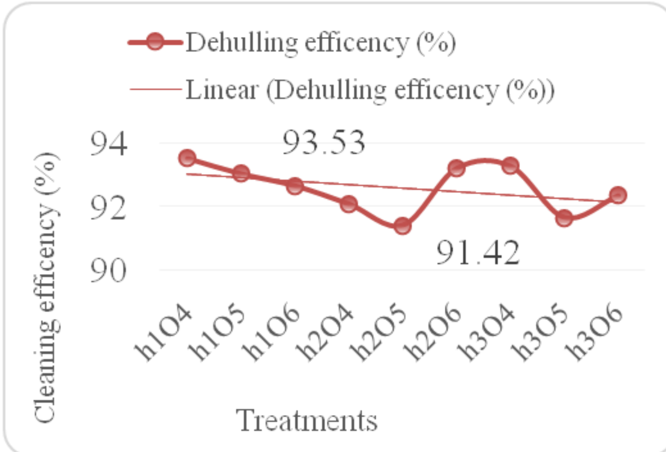


Figure.9

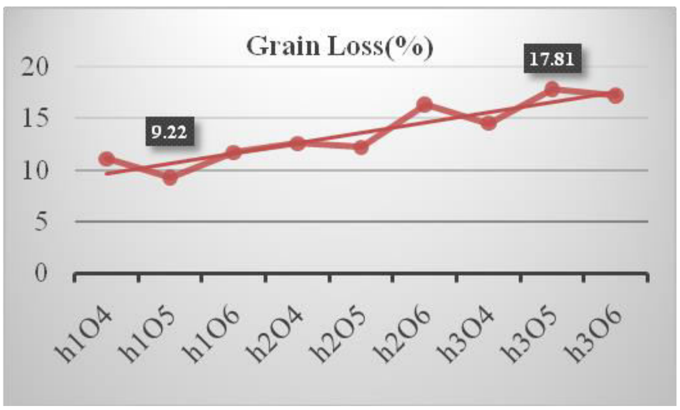


Figure.10 Pictures taken during laboratory analysis

Conclusion

Sorghum dehulling machine was developed and tested to dehull sorghum crop. From the result of the study the following conclusion can be generated: - Minimum total grain loss of 9.22 % was obtained at h1O5 inlet and outlet opening combination and maximum total grain loses of 17.81% was recorded at h1O5 treatment. While minimum dehulling efficiency of 91.67% and maximum value of 93.53% were recorded at h1O4 and h3O5 combinations. The average cleaning efficiency of the machine was seen to be 94.43 % with maximum value of 97.00% recorded at h3O6 combination. Percentage of breakage in steady of dehulling the grain was estimated. Minimum and maximum values were found to be 2.8% at h_3O_6 and 4.92% for h_1O_4 combinations respectively.

As recommendation, as far as the size of the machine was considered it seems very huge due to the appearance of aspiration unit specifically cyclone and dehulling barrel because of the size of the disks used. This requires improvement or modification to down size the machine. The dehulling capacity and efficiency of the machine will be high when optimum feed rate and outlet combination is maintained which needs further refinement work to have best performing machine than what achieved currently. Using different disc speed by steeping pulley may be another option for improvement. High vibration and sound are some points that can damage parts and cause uncomfortable environment for human to work with the machine which needs interference. Accessibility in rural areas where there is no electric power is one of important issues to be addressed through improvement work.

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