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Research Article

Performance Evaluation of the Melkassa-Made Engine-Driven Maize Sheller

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Abstract

The strategy of Ethiopian mechanization is to minimize postharvest loss. The methods of crop production were traditional. It involves high drudgery, low quality and quantity, time-consuming, and inefficient operation. To minimize loss, the sheller, thresher, and storage developed. But the performance was not clearly determined for researchers and manufacturers for selection and multiplication. The target of this research was the evaluation of Melkassa maize Sheller. It was conducted at three levels of feed rate: 7500, 6500, and 500 kg/hr., and speed: 700, 650, and 600 rpm. The moisture is 14 percent and maize LIMU variety. Split plot design of feed rate as the main factor and drum speed as a sub factor. The maximum shelling capacity of 6608.9 kg/h was achieved at a feed rate of 750 kg/h and a speed of 700 rpm. Where the minimum obtained at 5000 kg/hr and a speed of 600 rpm is 4242.27 kg/hr. The highest efficiency was 99.9 percent, the maximum breakage was 1.06 percent. The maximum fuel consumption is 2.347214 L/hr. The machine can significantly reduce drudgery and save time, energy, and cost of operation. As a suggestion, if engine changed to tractor attached will increase the requisition of technologies.

Keywords

Capacity, Efficiency, Fuel, Performance and Sheller

1. Introduction

Ethiopia is a developing country in Africa, with a much faster rate of population growth than food grain production growth [1]. The Ethiopian economy is based on agriculture and currently, crop production in Ethiopia has a significant effect on the gross domestic product (GDP), which is mostly covered by cereal crops. Cereal crops are the principal crops, which cover around 87.42% of the total area of crop production in Ethiopia [2]. Cereal crops are the principal crops, which cover around 87.42% of the total area of crop production in Ethiopia. From the cereal, there are five major crops, mostly dominated by stable foods. These are: maize, wheat, sorghum, tef, and barley [3, 4].

Maize (Zea mays) is a cereal crop that originated in Mexico and Central America. It is a member of the Poaceae family's Maydae tribe [5, 6]. According to [7], after rice and wheat, maize is used for food in different countries, and its source of protein results in stable human food, giving nourishment to both people and animals. In Ethiopia, the maize production system became popular and is increasingly popular from time to time due to the sack of food security [8]. Maize is currently grown by more than 9 million smallholder families in Ethiopia, which is more than any other crop.

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Maize is a major commodity in grain crops, providing 17–60% of people's daily source of protein and vitamin A, which are essential for human growth, the immune system, and eye health [8].

The Ethiopian crop production system practiced is in traditional ways. Without machinery or mechanization in Ethiopia, according to the current status, the agriculture operations challenge human survival. To increase crop production the machinery can improve working conditions and time lags, and it can motivate the farmers willing to drive Ethiopia's agricultural policy changes and boost crop productivity [7]. The government is allocating significant resources to increase agricultural productivity and to alter the country's agricultural situation [2]. According to [9], the weighted mechanizations index reveals that mechanically operated operations in the Amhara region, SNNP regions, Oromia region and Tigray regions account for 4.35 percent, 4.38 percent, 12.1%, and 3.48 percent, respectively.

Post-harvest loss has a significant impact on cereal crop yields. The losses happen during the harvesting, transporting, and seed storage operations [10]. During maize production, planting, harvesting, shelling, drying, husking, and storing are where obtained. Shelling operations can be obtained in traditional and mechanized methods [10]. The process of shelling maize challenges the farmers due to high drudgery and a lack of technologies. The shelling maize human power operated first the maize was dried [11]. Traditional shelling is costly, laborious, and time-consuming. When drafting animals, they are losing high quantities of maize [12]. This method can damage the kernels and is time consuming. Another traditional maize shelling technique is to rub the maize cobs together by hand or to remove kernels directly by pressing them between the thumb and palm [11]. Furthermore, the majority of mechanical Sheller's were designed for shelling operations, which can cause significant damage and loss of maize seeds [11].

To improve productivity, reduce drudgery, save time, save energy, and access the technologies, maize sheller 8HP engine-driven Melkassa Agricultural Engineering Research develops maize sheller. The goal was to reduce the loss and improve working conditions for small and medium farmers. Maize Sheller engines driven for small and medium farm scales are designed and manufactured. Melkassa Agricultural Engineering Research develops the maize sheller for the shelling operation. The maize shelling capacity, shelling efficiency, and cleaning efficiency are not clearly known to be recommended and reported. According to the [13] suggestion the machine can significantly reduce the human labor and stress involved in shelling maize, as well as the time spent on shelling operations on farms.

Therefore, the goal of this research was to conducting the and testing the Melkassa developed maize Sheller for determination shelling performance, identification of the best feed rate, and drum speed for researchers and future scientists, to know the shelling for inducers to select the machine and to access the Sheller technologies for local manufacturers, and for NGOs to open the door for demonstration.

2. Materials and Methods

2.1. Experimentation Sites

The machine where installed Melkassa Agricultural Research Centre (MARC). The study was carried out at Ethiopia's Oromia regional state's Melkassa Agricultural Research Centre. The machine performance was conducted at Ayehu Farm, which is located in Amhara Region (Western Gojam), 400 km from Addis Ababa, and the area of the farm is 5,204 ha and the annuals rainfall on averages was 1,100mm, and the temperature on average is Min. 13 ℃ and Max. 28 ℃.

2.2. Materials

The material used is Melkassa-developed engine-driven maize sheller. It was found at Melkasa agricultural engineering research works, and the description of the machine is shown below. Parts of the Sheller are: A represents the Hopper, B represents the Hopper Threshing Cylinder, C represents the Hopper Concave/punched thick sheet metal, D represents the Hopper Sieves and Blower/Aspirator, E represents the Hopper Cob Outlet, F represents the Hopper Main Shaft, G represents the Pulley, I represents the Hopper Engine Stand, and J represents the Hopper grain outlet.

Figure 1. *Melkassa developed engine driven maize Sheller.*

The Melkasa Engine-Driven Maize Sheller Machine Description and Principles of its Operation with Parts at Figure 1 are described. The schematic diagram of the Melkassa developed maize sheller. Details of the specifications of the sheller are shown in Table 1. The sheller is a simple to operate, maintain, and compact machine operated by engine power, and it can be transported from farm to farm.

Table 1. *Description details of the engine driven Melkassa maize sheller.*

Item.	General Dimensions Overall length	Unit
1	Overall width and Overall height	1.65m and 1.5m
2	Total weight	155kg
3	Transmission Power source	Belt, pulley
4	Huma power needed to assist	Human power

2.3. Material Used for Testing

The materials used for performance evaluation are listed below. Sensitive moisture meter, taco meter, cylinder gauge, oven dry, balance, grain collector package, different wrenches, caliper, tap meter and fuel are used.

2.4. Experimental Procedures

Moisture content during threshing and shelling operations testing performance conducted after the crop planted had harvested and dried with in moisture content ranged from 12 to 14.5 percent, making it suitable for shelling. The crop types were Melkassa-II varieties for maize shelling performance tested. During the performance testing, factorial design was used to know the impact of speed and feed rate on shelling capacity, efficiency and seed breakage for confidentially speaking the shelling performance. There are three levels of drum speed: 600, 650, and 700 rpm, with feed rates of 80 kg/sec, 100 kg/sec, and 120 kg/sec.

$$\mathrm{Mwb} = \frac{\mathrm{wI-wD}}{\mathrm{wi}}\mathrm{x100} \quad (1)$$

Where: Mwb, is represents the moisture percentage, WI, where represented the initial weight of the sample in grams, and WD, represented the dried weight in grams. According to [14], suggestions for determine the damaged grain, two 100-gram samples were collected from the threshed grains.

$$\text{Damaged grain (\%)} = \frac{\text{Mass of grain breakage in KG}}{\text{Total Mass of grain sample in kg}}\ x\ 100 \quad (2)$$

$$\text{Feed rate of shelling} = \frac{\text{amount of biomass in KG}}{\text{time taken to shell in minute}} \quad (3)$$

$$\text{shelling effciency} = \frac{\text{total mass of shelled grain}}{\text{total mass of (shelleled+unshelled)}}\mathrm{x100} \quad (4)$$

According to the studies [15, 16] the range of speed for threshing cereal crops was 500 rpm to 1200 rpm and the drum speed was 500–750 rpm and for sorghum at 700–100 rpm.

2.5. Statistical Analysis

The statistical difference between the treatment means was assessed for significance at the 5% level and separated using the least significant difference (LSD). The degree of significance (P) for this relationship was determined using an F-test and analysis of variance, and depending on crop analysis of variance (ANOVA) is used to examine under different treatments (version 3.4.3, 2018).

3. Results and Discussions

The parameters of Melkassa-made maize Sheller are: moisture, fuel consumption, breakage, grain out through the cob outlet, grain out through the blower, capacity, cleaning efficiency, and shelling efficiency. After taking the raw data, we calculate the analysis of variance, mean separation, regression, and correlation of shelling capacity, breakage, grain out through the blower, grain out through the cob outlet, and cleaning and shelling efficiencies. Performance evaluation result of the Melkasa maize Sheller on feed rate and drum speed has significant effect on shelling performance ($p < 0.05$). The maximum shelling capacity was recorded at feed rate 750 kg/hr. and the drum speed of the shelling capacity was 6608.90, and the minimum shelling resulted at 5000 kg/hr with a drum speed of 600 rpm, as shown in the table below.

Table 2. *Result of Sheller performance at different feed rate and drum speeds.*

Feed rate (kg. hr^{-1})	Drum speed (Rpm)	Capacity (kg.hr^{-1})
7500	700	6608.90[a]
7500	650	6579.01[a]
7500	600	6515.84[a]
6500	700	5536.01[ab]
6500	650	5325.00[ab]
6500	600	4967.16[ab]
5000	700	4800.34[bc]
5000	650	4461.94[c]
5000	600	4242.27[cd]

The shelling capacity from the liner regression model which is direct related to the feed rate and drum speeds with model are the shelling capacity (kg/hr) ~ 0.8020 (feed rate. hr^{-1}) + 4.0666 drum speed (rpm) - 2277. The seed breakage of the Melkassa maize Sheller shown as it is non-significant ($p > 0.05$). The effect of fed rates and drum speeds on maize

Sheller with related to seed breakage shown on the table below.

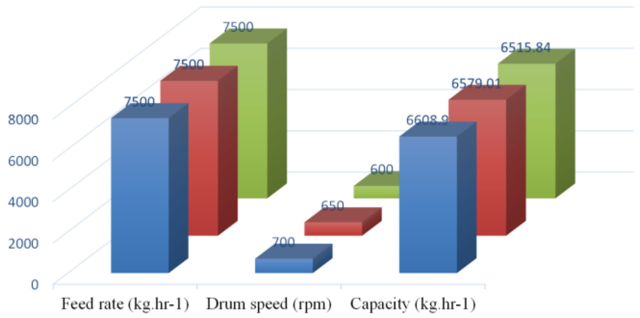

Figure 2. Figure of shelling capacity at the same feed arte and different drum speed.

Figure 2. Represented he relationship of feed rate (kg.hr^{-1}) and the drum speed rate (Rpm) on the shelling capacities. From the graph the feed rate had direct relationship with shelling capacity. Also the drum speed had direct relationship on the shelling capacity. This trends also the same as [17, 18]. To increases thresher or Sheller performance feed rate, moisture content, drum speed, and crop variety are the main parameter.

Table 3. Result of seed breakage at different feed rate and drum speeds.

Feed rate (kg.hr$^{-1)}$	Drum speed (rpm)	Seed breakage (%)
7500	700	1.067^{a}
7500	700	0.93^{ab}
7500	700	0.911^{ab}
6500	650	0.645^{bc}
6500	650	0.622^{c}
6500	650	0.53^{cd}
5000	600	0.465^{de}
5000	600	0.234^{e}
5000	600	0.2241^{e}

The feed rate and drum speed had no significant effect on shelling efficacy ($P > 0.05$). The result was shown below on the table, and the minimum value of shelling performance was 99.4 percentage at fed rates 5000 kilogram per hour with drum speed 600 Rpm resulted, and the maximum shelling efficiency resulted at 750 kg.hr^{-1} feed rate with 650 rpm drum speed was 99.74 percentage.

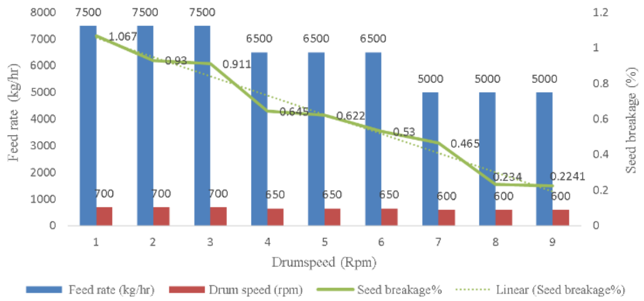

Figure 3. Graph of feed rate and drum speed effect on the seed breakage.

Figure 3. Represented that the effect drum speed and feed rate on the seed breage.one type of Sheller performance parameter was seed breakage. From the above the seed breakage increases as the drum speed increases. This trends was he same as the maize Sheller testing results which almost recommended results was achieved [17]. As the suggestion of different researcher and testing protocol as the seed breakage as the parameter the seed breakage for stationery thresher or Sheller should be not more than 2 percent.

Table 4. Result of shelling efficiency at different feed rate and drum speeds.

Feed rate (kg.hr^{-1})	Drum speed (rpm)	Shelling Efficiency (%)
7500	650	99.74 ^{a}
7500	650	99.74^{a}
7500	650	99.74^{a}
6500	700	99.6^{ab}
6500	700	99.6^{ab}
6500	700	99.6^{ab}
5000	600	99.4^{ab}
5000	600	99.4^{ab}
5000	600	99.4^{ab}

The feed rate and drum speed had non-significant effect on fuel consumption the feed rate ($P > 0.05$). The minimum value of fuel consumption was 1.316533 litre per hour at 5000 kg.hr^{-1} and drum speed 700 rpm and the maximum rate of fuel consumption was 2.347litre per hour at feed rate was 7500 kg/hr with drum speed 700 rpm and the additional information shown below.

Table 5. *Result of Sheller fuel consumption at different feed rate and drum speeds.*

Fed rates ($kg.hr^{-1}$)	Drum speeds (Rpm)	Fuel consumptions $ltr.hr^{-1}$
7500	700	2.347000 ^{a}
7500	650	2.199667 ^{a}
7500	600	2.052667 ^{a}
6500	600	1.885667 ^{ab}
6500	650	1.781667 ^{ab}
6500	700	1.663333 ^{ab}
5000	650	1.476000 ^{b}
5000	600	1.402053 ^{b}
5000	700	1.316533 ^{b}

The sheller was evaluated at three levels of feed rate and drum speed to identify Sheller performance. The feed rate level and influence of conveyor feed on shelling performance are assessed by threshing and shelling efficiency (%), threshing and shelling capacity, percentage of grain damage (%), fuel consumption (fc), ergonomics, risk protection, and total manpower engaged in the threshing operation. According to the results of the analysis, the effects of feed rate and drum speed had a significant effect on shelling capacity ($p < 0.05$).

Figure 4. *Picture taken during performance evaluation of maize Sheller.*

4. Summery and Conclusion

Melkassa developed the maize sheller as a simple way of operation for maize shelling, efficient, and low labor intensive with high capacity shelling performance. The materials used to build the machine are inexpensive and locally available. The maximum shelling capacity was recorded at a feed rate of 750 kg/hr and a drum speed of 6608.90, while the minimum shelling resulted at 5000 kg/hr and a drum speed of 600 rpm. The highest shelling efficiency was 99.9 percent, and the maize Sheller evaluation parameter was shelling capacity, efficiency, seed breakage, and fuel consumption with moisture content and crop variety, and the specifications were low breakage with 1.06 percent, and it is driven by an engine with 8 hp. The maximum fuel consumption during performance valuation was 2.347214 l per hour. The machine can significantly reduce the energy, drudgery and good quality and quantity performance for shelling maize operation at a low cost, as well as the time required for shelling operations on large and small farms. There is no doubt that the machine will alleviate the long-term problem of maize shelling, particularly among rural farmers.

5. Recommendation

As we said above, the maize sheller technology has the benefits of a reduction of labor and a reduction of tedious work. While in testing in different places, some farmers and investors have tractor for different agricultural operations, and they want to change from engine-driven to PTO-driven to reduce the cost of the engine. So availing of the two types of shellers (existing shellers to use for PTO-driven and engine-driven) is more profitable for the country because of the mechanization level of the country, which has some farmers and investors in tractor. The farmers also want a mechanism of easy transportation from one site to the other. And some grains out at the cob outlet that can be reduced.

Abbreviations

ANOVA	Analysis of Variances
HP	Hourse Power
MARC	Melkassa Agricultural Research Centre
PTO	Power Take off
SNNP	South Nation and Nationality Peoples

Author Contributions

Tesfaye Aseffa Abeye: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft

Amhedie Uomer Amhed: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft

Dereje Alemu Anewuteh: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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