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Design and construction of a conveyor system for an engine-driven maize sheller and performance evaluation

Tasfaye Aseffa Abeye^{a*} 

^aDepartment of Agricultural Engineering Research, Ethiopian Institution Agricultural Centre, Adama University, Adama, Ethiopia

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Shelling is the process of separating maize kernels from the cob, and it can be performed manually or mechanically. The Melkassa-developed maize sheller is one of the mechanical types. It has a high shelling performance, and it needs a high feed rate. Manual feeding of biomass was involved with high drudgery and consumption of time and energy. The objective of this study was the development of a conveyor feed for a sheller to mitigate human drudgery and improve the shelling performance. After development evaluation was conducted on Melkassa II and after measuring engineering properties of mean head, intermediate, and tail diameters of 32 cm, 48 cm, and 25 cm were recorded, respectively. The study evaluated three levels of feed rates of 7000, 8000, and 9000 kg/h and speeds of 550, 650, and 750 rpm at 13 percent moisture content. As the results, the conveyor feeding had significantly affect shelling capacity ($p < 0.05$). The maximum shelling capacity is 7504.8 (kg/h) at amount of biomass 9,000 (kg/h) and sheller speed of 750 rpm, and the minimum was recorded at 7000 (kg/h) feed rate with 550 drum speed 6140.9kg/h respectively. At feed rate of 7000 kg/h and speed 750 rpm the maximum seed breakage was 0.0174 percent and the minimum 0.0114 percent at speed 550 rpm and feed rate 9000 kg. As the suggestion adoption of a conveyor for the sheller improves shelling performance, ensures uniform feeding, minimizes drudgery, ensures a safe shelling operation, and enhances maize productivity.

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1. Introduction

Maize (*zea mays*) is a cereal grain that was first domesticated approximately 10,000 years ago by indigenous people in southern Mexico. Although corn is the most common term in north America, it is called as maize which is preferred term in scientific, international, and agricultural contexts. Its large ears with rows of kernels and tall stalks makes it an extremely adaptable crop (Abate et al., 2015). In Ethiopia, maize has become a primary source of food crops, even for the poorest families (Gadisa et al., 2025). Harvesting, transporting, shelling, drying, husk removal, storing,

and milling are the primary postharvest activities in maize production. Each of these processes is essential to guarantee that the final product improve in terms of quality, quantity and safeties (Dula, 2019). Shelling maize is one of the most important processing procedures used to improve its quality and quantities (Igbino J.O et al., 2019).

The main challenges during maize production faced on the farmer and producers was shelling operation. The traditional methods are tedious, time-consuming, and labour-intensive. This traditional shelling operation leads to significant post-harvest losses due to spillage, contamination, inefficiency,

* Corresponding author: tesfayeaseffa20@gmail.com or asst4907@gmail.com

low quality, and quantity losses the other hand, it challenges the social lives of women, children, and labour (Abeye et al., 2024).

To maximize profit from maize production, rural farmers should use appropriate and affordable technologies tailored to their needs. Mechanized technologies like shellers, trailers, and metal silos mitigate postharvest losses and improve qualities and increase farmers' profits from maize production. For the solu-

tion, Melkassa Agricultural Research Center (MARC) developed engine-driven mechanical sheller. The Melkassa developed maize sheller was manufactured from locally available materials. The machine has good shelling capacity, efficiency, and less than two percent seed breakage. Besides, the sheller needs a higher feed rate due to having a higher sheller capacity (Ahmed et al., 2017).



Fig 1. Pictures taken during the maize sheller display and feedback collection (source: author's own photographs)

Fig. 1 shows the operation of the maize sheller during a participatory evaluation. The machine demonstrates excellent performance, maintaining seed breakage well within accepted standards. The shelling capacity exceeded 4,000 kg/h with less than 2% seed breakage.

However, the primary challenge faced by farmers was the manual feeding system, which proved to be both time-consuming and labour-intensive. Modern improved maize sheller have integration of mechanical conveyor feeding systems. These systems significantly enhance shelling performance and reduce drudgery (Gebeyehu, 2023). The objectives of this study were to design, develop, and test a conveyor feeding system integrated with an engine-driven Melkassa maize sheller. The goal was to increase productivity, reduce human drudgery, and enhance the safety of maize shelling operations for end users.

2. Material and methods

Descriptions of Research was conducted in Melkassa Agricultural Research Center (MARC), located in the Oromia region of Ethiopia

2.1. Materials

The primary equipment used in this study was the Melkassa-developed maize sheller. As shown in Fig 2. of the sheller model - this specific model was selected due to its high performance, which includes a shelling capacity exceeding 4,000 kg/hr and acceptable seed breakage levels.



Description of material construct of conveyor feeds

1. Inlet: The feeding unit that directs maize into the shelling chamber.
2. Main Frame: The structural support of the sheller
3. Seed Outlet: The discharge point for shelled grains.
4. Auger: The conveyor mechanism for moving shelled maize.
5. Fan: The cleaning unit that separates husk from grain.
6. Shaft: The rotating part that drives shelling units.
7. Cob Outlet: The discharge point for separated cobs and straw.
8. Drum Cover: Protective cover for the shelling drum.
9. Hand Ring: The carrying handle for easy transport.

Fig 2. Melkassa developed maize sheller (source: Abeye, et al, 2024)

The conveyor feed was constructed using durable materials and precise fabrication methods. Both the left and right covers were made from 2 mm thick sheet metal with a length of 2000 mm, while the shaft was fabricated from 25 cm mild steel for power transmission. An aluminium pulley with a diameter of 230 mm was installed, connected by a V-belt to transmit power from the drum to the conveyor, and a flat belt was used for biomass conveying. The frame was built from RHS sections of 40 mm × 2 mm, with side

supports formed from angle iron measuring 30 mm × 30 mm × 2 mm, secured using bolts and nuts of varying diameters. Roller pipes of 80 mm diameter and 2 mm thickness were employed to facilitate smooth conveying. The manufacturing process utilized workshop machines including cutters, benders, drills, lathes, and welding equipment. For performance evaluation, testing tools and apparatus included a tachometer, digital weight balance, biomass cylinder, moisture meter, and stopwatch.

2.2. Methods

In this study, the general design approach was adopted by separated into three main phases: design, fabrication, and evaluation. Each phase was completed using a systematic process based on engineering principles and methods, as shown in the flow chart i

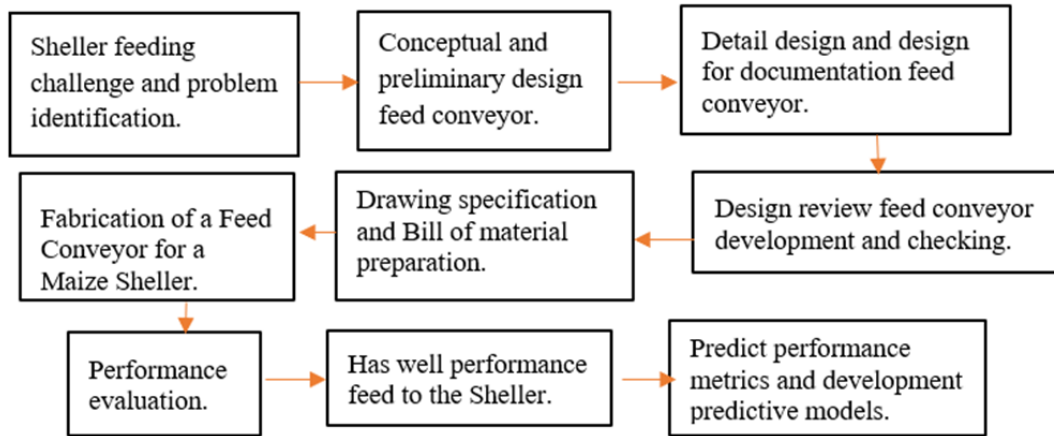


Fig 3. Schematic representation of the research methods

2.3. Numerical calculation conveyor design for maize sheller

The shelling capacity is determined by the feed rate requirements of the sheller. Feed rate had a direct relationship to shelling performance, and as the feed rate increasing, the shelling performance increased (Ali et al., 2024). During the shelling operation, the feed rate, drum length, and number bitter relation determined using equation 1 (Sharma, 2010).

$$Fr = k \cdot Dl \cdot Nb \quad (1)$$

where

Fr is the Feed rate (kg/h),

Dl is drum length (m),

Nb is the Number of beaters (dimensionless),

K is the Proportionality constant determined experimental.

According to Belay and Fetene (2021), the drum's length (l) is 0.83 m, its speed (q) is 0.375 kg/s, and its number of rows (N) is 8.

$$Q = 0.375 \text{ kg/s} \times 0.83 \text{ m} \times 8 = 2.49 \text{ kg/s}$$

According the Melkassa, the developed maize sheller, the area of inlet feeding system, where as having the width (m), and h is the height (m), was determined in equation 2.

$$A = w \cdot h \quad (2)$$

where

A is the area (m²),

W is the width (m),

h is the height (m).

$$A = 0.068 \text{ m}^2$$

2.4. Determination of conveyor power requirement

The power required for the conveyor drive was determined using equation 3, where Power Watts (W) and V is the linear speed of the conveyor belt in (m/s), and F is the total force required to move the material, measured in Newton (N) (Mott, 2004).

$$P = V \cdot F \quad (3)$$

The force needed to move harvested maize material is the total of the inertia and gravitational forces

where

V is the speed (m/s),

F is the force needed to move the material (N),

P is the power (in W).

Fig. 4 shows the diagram illustrates the forces acting on a mass of maize (m) as it is moved up an inclined plane at an angle (θ). To move the material upward, the conveyor must overcome two primary resistive forces where Gravitational Force ($mg\sin\theta$) - this is the component of the crop's weight acting against the direction of travel.

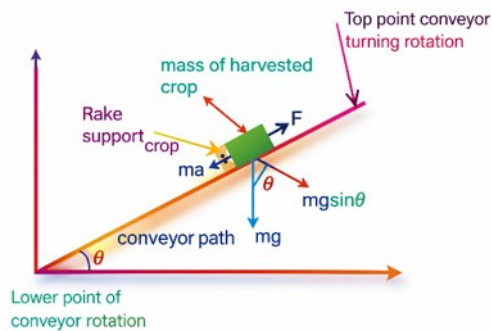


Fig. 4. Free body diagram of imaginary line conveyor system paths for sheller

$$F = mg \sin \theta + ma \quad (4)$$

The inertia force can be disregarded because it only applies to the first batch of product in the first bucket within the conveyor that the operator throws with a rake.

$$F = mg \sin \theta \quad (5)$$

According to Atere et al. (2016), the bulk density of maize at 12% moisture was 758.80 kg/m^3 , and the conveyor length is 1.5 m, and the loaded conveyor length has a 0.068 m^2 belt cross-section and a 758.8 kg/m^3 material density for maize.

$$M = \rho \times V \quad (6)$$

where

M is the mass(kg),

ρ is the density (kg/m^3),

V is the volume (m^3).

$$\text{Mass} = 1.5\text{m} \times 0.068\text{m}^2 \times 758.8\text{kg/m}^3 = 77.397 \text{ kg}$$

Then, to determine the power for the conveyor and Motion resistance is the weight of the conveyor

plus the mass of the transported is used (Miloradović et al., 2021).

$$W = CFL (Gg + Gb) \cos \delta + G \text{ roller if exist} + H (Gb + Gg) \quad (7)$$

where

W is the total weight of the material plus the mass of the belt in kg,

C is the secondary use of resistance factor (1.7),

F is the standard conveyor (0.02),

h is the conveyor height (in m),

Gg is the weight of the material per meter,

Gb is the weight of the belt per meter.

The minus sign denotes inclination angle and downhill movement, while the plus sign (+) denotes upward movement.

$$Gg = \text{Mass of crop per unit length of conveyor} = 77.397 \text{ kg} / 1.5 \text{ m} = 116.09 \text{ kg/m}$$

Weight of the belt (w_b) = $\rho \times v$, where the belt density (ρ) is 1140 kg/m^3 , the width is 0.34 m, the thickness is 0.003 m, and the length is 3 m, considering the top and lower covers of the belts.

$$V = A \times L = 0.34 \text{ m} \times 0.003 \text{ m} \times 3 \text{ m} = 0.00306 \text{ m}^3$$

$$\text{Mass of the rubber belt} = 1140 \text{ kg/m}^3 \times 0.00306\text{m}^3 = 3.4884 \text{ kg}$$

$$Gb = \text{Mass of the rubber belt (kg) / length of belt (m)} = 3.4884 \text{ kg} / 3 \text{ m} = 1.1628 \text{ kg/m}$$

$$W = CFL (Gg + Gb) \cos \theta + H (Gb + Gg)$$

$$W = 0.051 \text{ m} (116.09 \text{ kg/m} + 1.1628 \text{ kg/m}) \cos 30 + 1 \text{ m} (116.09 \text{ kg/m} + 1.1628 \text{ kg/m})$$

$$W = 5.18\text{kg} + 117.3\text{kg} = 122.48\text{kg} \text{ and } W(\text{weight}) = mg = 122.48\text{kg} \times 9.81\text{m/se}^2 = 1201.54 \text{ N}$$

From the literature review, the recommended feed conveyor is 2.5 m/s (Matsagar et al., 2022).

$$\text{Power (P)} = F \times V = 1201.54 \text{ N} \times 2.5 \text{ m/s} = 3000.38 \text{ W}$$

2.5. Conveyor belt selection

The selected conveyor belt could be made of textile, steel strip, or woven steel wire mesh. Using the formula below, determine the tension in tight and slack side belt conveyors (Mott, 2004).

$$P = (T_1 - T_2) \times V \quad (8)$$

where

P is the power (watt),

T₁ is the tight side tension (N) of the conveyor,

T₂ is the slack side of the conveyor,

V is the belt speed in 1.5m/s.

3000.38 N. m/s = (T₁ - T₂) x 1.5m/s and when both side divided by 1.5m/s

The result was T₁ - T₂ = 2000.25 N

The Euler's equation for belt friction describes how tension changes along a rope, belt, or cable that wraps around a drum, pulley, or post when friction is present (Mott, 1985).

$$T_1/T_2 = e^{\theta\mu} \quad (9)$$

where

T₁ is the tight side tension belt,

T₂ is the slack side tension,

θ is the coefficient of friction between the rope/belt and the surface,

θ, is the angle of contact (wrap angle) in radian

e, constant (~2.718), base of natural logarithms.

The friction (rad) is 0.25, and the angle of slope is a 30 degree change in radians, T₁ = 1.042T₂ in the above equation.

(1.042 T₂) - T₂ = 2000.25 and Factor out T₂ and T₂ (1.042 - 1) = 2000.25

$$0.042 T_2 = 2000.25$$

Solve for T₂ (Slack Side Tension) and divide both sides by 0.042 and T₂ = 2000.25/0.042 = 47,625 N and Solve for T₁ (Tight Side Tension). T₁ = 1.042 x 47,625 = 49,625.25 N and T₂ = 47625 N and T₁ = 49625.25N. From the material and when the power (P) is 3000.38 W and V is 2.5 m/s manufacture properties data of the canvas belt conveyor, which has a tensile strength of 4.14x10⁷ to 6.9x10⁷ Pascal, our design was making it safe.

2.6. Pulley selection

Using an equation, the pulley's diameter was determined (Mott, 2004):

$$N_1 D_1 = N_2 D_2 \quad (10)$$

The driven diameter divided by the driver diameter equals the driver's speed divided by the driven

speed from sheller data direct measurements. The driving pulley diameter (D₁) was 120 mm; the maximum speed was (N₁) 1000 rpm and (N₂) 500 rpm.

$$D_2 = \frac{1000\text{rpm} * 120\text{mm}}{500\text{rpm}} = 240 \text{ mm}$$

2.7. Belt selection for power transmission

The length of belt appropriate to drive the system was calculated using the equation given below. C is 50 cm, D₁ is 12 cm, and D₂ is 30 cm for the cross-belt length of the belt (direction change needed) (Mott, 1985).

$$L = 2C + \frac{\pi}{2}(D_1 + D_2) + \frac{(D_1 + D_2)^2}{4C} \quad (11)$$

$$L = 174.82\text{cm or } 68.8 \text{ inch}$$

According to Mott (2004) a centre-to-centre distance should be 49 cm to get a 67-inch belt standard, and belt length: 67 inches; centre to centre is 49 cm.

2.8. Selection shaft for feed conveyor

Using the formula provided by the ASME code (ASME), the diameter of a solid shaft with little to no axial loading was calculated (Mott, 2004).

$$d^3 = \frac{16}{\pi\tau_{max}} \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad (12)$$

The shaft's diameter (D) is represented by M_t, the torsional moment by N_m, the bending moment by M_b, and the allowable shear stress by τ_{max}, the factors K_b and K_t are applied to the bend and torsional moments, respectively, in MN/mm² and K_b = 1.2 to 2.0 and K_t = 1.0 to 1.50 are the values that ASME recommends using.

$$M_t = \frac{3000.38\text{W} \times 60}{2 \times \pi \times 400\text{rpm}} = 71.7\text{Nm}$$

The following formula was used to calculate the shaft's maximum resulting bending moment:

$$M_b = \sqrt{(M_v)^2 + (M_h)^2} \quad (13)$$

In this case, Mb, represents the shaft's greatest resultant bending moment, MV represents its vertical bending moment, MH represents its horizontal bending moment, and T1 = 121.5N and T2 = 71N.

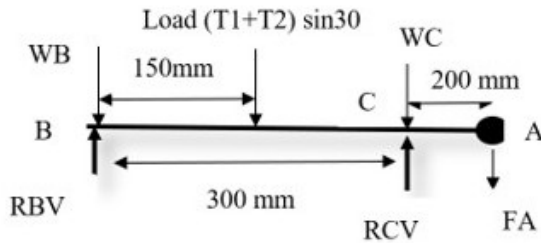


Fig. 5. Distribution of vertical loads on the shaft where the vertical load reactions at bearings B and C are denoted by RB and RCV, which are vertical supportive, whereas WB, WC, A, and conveyor load (T1 + T2) sin+ T2) sin 30 are downward load reactions, respectively

WB and WC represent the two halves of the total weight applied at point B (T1+T2) and bearing C (T1+T2), respectively. The vertical belt force at point A is denoted by FA. F2 is 28.5 N, and F1 is 71.2 N. The tension side of the V-belt is (T1) = 121.5 N, and the slack side is (T2) = 71 N. The conveyor belt's tension side (F1) is 71.2 N, and its slack side (F2) is 28.5 N. The conveyor belt was connected at 30°.

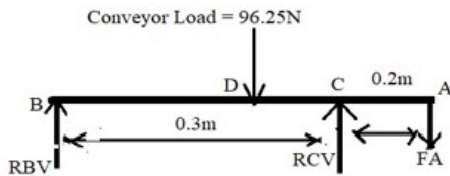


Fig. 6. Vertical load on bearing support free body diagram

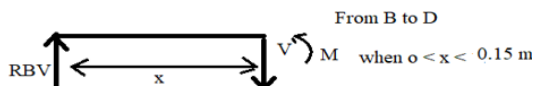
$$\sum \text{moment at B} = 0 = 192.5\text{N} \times \sin 30 \times 0.15 \text{ m} + 99.7\text{N} \times 0.5 \text{ m} = \text{RCV} \times 0.3 \text{ m}$$

$$\text{RCV} = 214.5\text{N}$$

$$\sum \text{Vertical Load (VL)} = 0 = \text{RBV} + \text{RCV} = \text{F1} + \text{F2} + (\text{T1} + \text{T1}) \sin 30^\circ$$

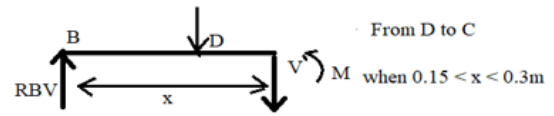
$$\text{RBV} + 214.5\text{N} = 99.7\text{N} + 192.5\text{N} \sin 30^\circ = \text{RBV} = -18.55\text{N} \text{ (- means down ward loads)}$$

Shear force at each segment point should be calculated as follows in order to create a shear force diagram.



$$\sum \text{Vertical force} = 0, V = \text{RBV} = -18.55\text{N} \text{ and } \sum \text{moment B} = 0 \text{ and from B to C}$$

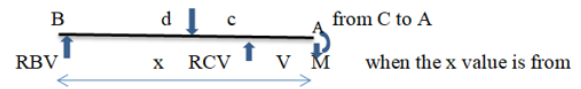
$$M = V \times x \text{ and } V = -18.55\text{N}, \text{ when } x = 0 \text{ M} = 0, x = 0.15 \text{ M} = -2.78\text{Nm}$$



$$\sum \text{Vertical force} = 0 = \text{RBV} - (\text{T1} + \text{T2}) \sin 30 - V = -18.55\text{N} - 192.5\text{N} \sin 30 - V = 0$$

$$V = -114.8\text{N} \text{ (down ward)}$$

$$M = 192.5\text{N} \sin 30 \times 0.15\text{m} - 114.8\text{N} \times x \text{ and } x = 0.15\text{m}, M = -2.78\text{Nm}, x = 0.3\text{m}, M = -20 \text{ Nm}$$



$$0.3 < x < 0.5\text{m} \text{ and } \sum \text{vertical force} = 0$$

$$\text{RBV} - (\text{T1} + \text{T2}) \sin 30 + \text{RCV} - V = -18.55\text{N} - 192.5 \sin 30 + 214.5\text{N} - V = 0$$

$$V = 99.7\text{N} \text{ (upward)}$$

$$\sum \text{moment at B} = 0 = -M = (\text{T1} + \text{T2}) \sin 30 \times 0.15 - \text{RCV} \times 0.3 + V \times X$$

When x = 0.3m, M = 20Nm, x = 0.5m, M = 0Nm for B to D shear force = -2.78N and For D to C shear force = -114.8N upward for C to A shear force = 99.7 upward and when A shear force equals 0 N. Consequently, at B and A, the shaft's maximum vertical bending moment (BM) was BM. = 0 Nm and BM at D = -2.78Nm BM at C = -20 Nm (clockwise) when, 0.15m < x < 0.3m and 20 Nm. When, 0.3 < x < 0.5 m and BM at A = 0 Nm.

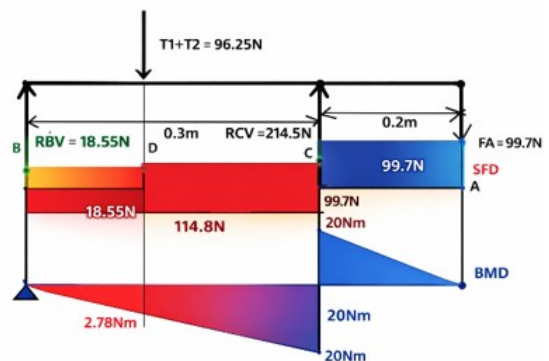


Fig. 7. Diagrams of vertical bending moments and shear forces

Below is a depiction of the response force distribution on the horizontal plane.

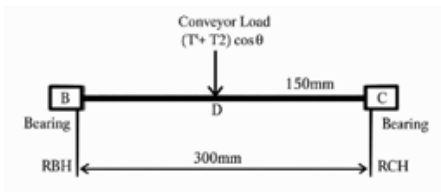


Fig. 8. Reaction force distribution on the horizontal plane
 The force need to convey the maize biomass to shelling where calculated was $192.5\text{N} \times \cos 30^\circ = 166.7\text{N}$ was the resolving forces horizontally. $RB_H + RCH = (T_1 + T_2) \cos 30^\circ$ and then $RB_H + RCH = 166.7\text{N}$

$$\sum \text{Moment at B} = 0 = 166.7\text{N} \times 0.15\text{m} = RCH \times 0.3\text{m}$$

and $RCH = 83.35\text{N}$ and $RB_H = 83.35\text{N}$

$$\text{Moment at B and C} = 0 = \text{Moment at } 83.35\text{ N} \times 0.15\text{m} = 12.5\text{Nm}$$

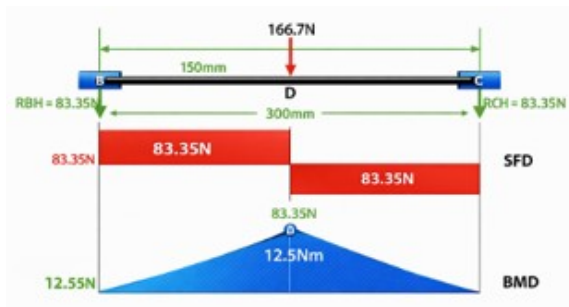


Fig. 9. Diagrams of horizontal bending moments and shear forces

The bending moment diagram is called BMD, while the shear force diagram is called SFD.

$$M_b = \sqrt{(M_{hv})^2 + (M_v)^2} = \sqrt{(20\text{Nm})^2 + (12.5\text{Nm})^2} = 23.58\text{N.m}$$

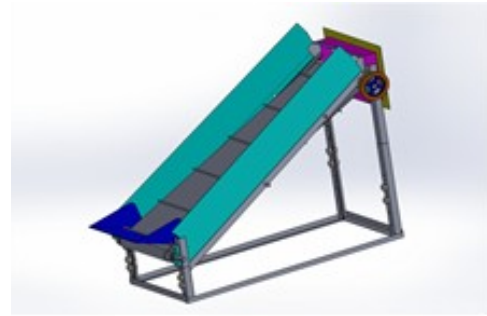
The shaft design primarily employs the maximum shear stress hypothesis. The definition states that a machine member cannot fail until reach maximum shear stress.

$$d^3 = \left\{ \frac{16}{\pi \tau_{\max}} \sqrt{(K_b M_b)^2 + (K_t T)^2} \right\} \quad (14)$$

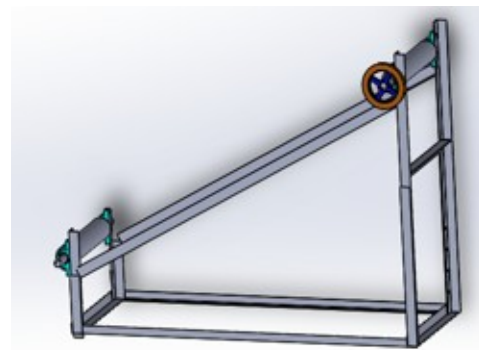
$D = 0.024879\text{m} \approx 24.87\text{mm}$, and consequently, the feed conveyor's typical size was a 25mm shaft diameter.

2.9. Bearing selection

The dynamic load factor (Lf) is due to the vibrations of the chain drive is 1.5 (Khurmi and Gupta, 2005) and from Appendix table 40 and the value (C1 & C2) taken. $C1 = 214.5\text{N} \times (192)^{1/3} \times 1.5 = 1856.2\text{N}$, and $C2 = 83.25\text{N} \times (192)^{1/3} \times 1.5 = 720.5\text{N}$. The bearing selection was bearings for a 25mm shaft diameter specified as bearing no. 6205 (four-bolt flange bearing) and the outside diameter (D), 62 mm, and the width (w), 17 mm, were chosen.



(a)



(b)



(c)



(d)



(e)

Fig. 10 a) 3D Model: The fully assembled 3D design of the conveyor system for the maize sheller; b) construction: the fabrication of the main frame and base support assembly; c) machining: the precision turning and finishing work on the conveyor shaft; d) final prototype: the complete assembly and manufacturing of the conveyor system prototype (source: author's own photographs)

2.9.1. Working principle of the conveyor Feed integrated sheller

The conveyor system is attached directly to the inlet of the Melkassa Maize sheller. It receives power from the main shelling drum via a pulley and V-belt drive system. This setup transports the biomass from the lower loading position to the upper inlet of the shelling unit. The feeding rate is governed by the rakes mounted on

the conveyor belt. The power is transmitted from the drum pulley to the conveyor connected through a V-belt, and to ensure a consistent flow feed rate, maize continues. By adjusting the rake configuration or belt speed, the operator can precisely control the feed rate into the machine.

2.9.2. Performance evaluation of the conveyor with integrated Melkassa Maize sheller

Using the Melkassa-II maize variety and factorial experimental design, the interaction was analysed and evaluated. The evaluation treatment was drum speeds (550, 650, and 750 rpm), and three feed rates (7,000, 8,000, and 9,000 kg/hr) were evaluated. The moisture content evaluated using equation below.

$$Mc = \frac{ww-wd}{ww} \times 100 \quad (15)$$

where

Mc is the moisture content wet basis percentage;

g, and Wd, the dried biomass from the sample;

Ww, the initial weight of the sample

2.9.3 Statistical analysis

The investigation effects of the various treatments as competition of ANOVA results conducted R software using. The F-test was utilized to establish the degree of significance (p) for the associations between variables. For treatments showing significant differences at the 5% level ($P < 0.05$), the Least Significant Difference (LSD) used analysis and compare treatment means.

3. Results and discussion

Before conducted the performance evaluation the engineering Properties of Melkassa II, Maize variety was recorded. The evaluation was conducted after measuring biomass moisture content.

Table 1. Physical properties of Melkassa –II maize varieties before shelling

Melkassa-II	Mean ± SD	Minimum	Maximum	Sensitive to Shattering
Head average diameter (cm)	24.86 ± 1.88	23.5	29.3	Medium
Intermediate (Av) Diameter (cm)	38.80 ± 4.41	34.2	46.3	Medium
Tail average diameter (cm)	24.55 ± 6.75	15.9	34.2	Medium

Melkassa-II	Mean ± SD	Minimum	Maximum	Sensitive to Shattering
Length of head (cm)	23.27 ± 2.12	23.27	25.30	Medium
Moisture (%)	12.65 ± 0.42	12.2	13.2	Medium

After the engineering properties are evaluated from the biomass, then the performance of the conveyor feed is evaluated. The influence of conveyor feed on shelling performance was determined in terms of shelling efficiency, seed breakage, grain dam-

age and fuel consumption with considering safety, ergonomics, and drudgery. Based on the analysis results, conveyor speed and drum speed ANOVA results were presented in the table below:

Table 2. ANOVA of the conveyor used feed rate and drum speed effect on sheller capacity

Source of variation	Df	Sum Sq	Mean sq	F -Value	Pr(>F)
Replication	2	148647	74324	12.2769	0.05318
Feed rate (kg/hr)	1	767530	767530	126.7824	0.0077954 **
Ea	2	12108	6054		
Drum speed(rpm)	2	373571	186785	8.4679	0.0105942 *
Feed rate: drum speed	2	969567	484783	21.9776	0.0005621***
Eb	8	176465	22058		

According to the results of the performance evaluation results, the feed rate and the drum speed had a significant influence on the shelling performance, with P-values below 0.05. The interaction between the conveyor belt system and the drum speed also had a significant influence on the performance of the maize

shelling machine. The highest shelling capacity obtained at a feed rate of 9000 kg/h and a drum speed of 750 rpm, and the lowest at a feed rate of 7000 kg/h and a drum speed of 550 rpm; the figures were 7504.8 kg/h and 6140.9 kg/h respectively.

Table 3. Average shelling capacity results at different feed rate and at different drum speeds

Feed rates(kg/hr) x sheller speed (rpm)	Capacity (kg /hr)
9000 x 750	7504.8 ± 1.25 ^a
9000 x 650	6894.77 ± 0.38 ^b
8000 x 750	6743.45 ± 1.01 ^{bc}
9000 x 550	6621.93 ± 0.172 ^{bc}
7000 x 750	6614.7 ± 1.12 ^{cd}
8000 x 650	6440.9 ± 0.85 ^{cd}
8000 x 550	6321.93 ± 0.12 ^{de}
7000 x 650	6214.7 ± 1.2 ^{de}
7000 x 550	6140.9 ± 0.15 ^{ef}

The capacity of the sheller when using conveyor type had higher performance and used to control feed rate. As feed decreases, the biomass feed decrease as a result the shelling capacity decreases.

As illustrated in figure 11, this implies that the impact of feed rate on shelling drum and shelling speed is directly related to shelling performance. The shelling capacity increases as the feed rate increases and drum speed increase.

As shown in figure 11, the shelling capacity is initially increased by increasing either the feed rate or the drum speed. When the feed rate and shelling speed are decreased, the shelling quantity is also decreased. These recommendations align with the findings of (Tekeste & Degu, 2020), reported that the shelling capacity the machine performance increase as feed rate and drum speed increase. But continues type more prefer for improve shelling performance.

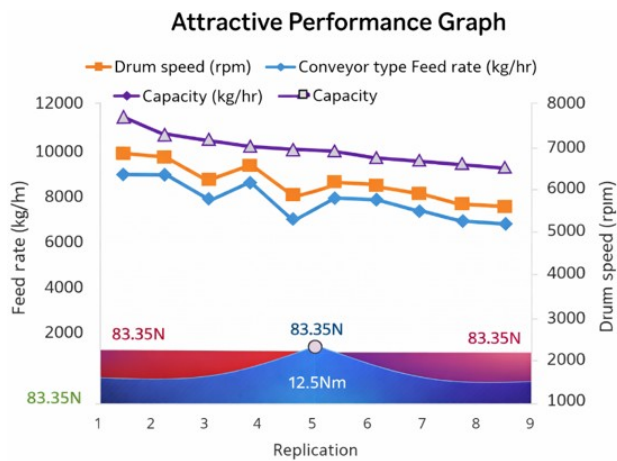


Fig. 11. Effect of feed rate and sheller speed on shelling capacity

Table 4. Mean of seed breakage and shelling efficiency performance results

Conveyor feed (kg/hr)	Shelling speed (rpm)	Seed brakeage (%)	Shelling efficiency (%)
9000	750	0.0174 ± 0.24 ^a	99.89 ± 0.17 ^a
9000	650	0.0167 ± 0.011 ^b	99.71 ± 0.08 ^b
9000	550	0.0154 ± 0.021 ^{bc}	99.65 ± 0.27 ^{bc}
8000	750	0.016 ± 0.12 ^{bc}	99.92 ± 0.12 ^{bc}
8000	650	0.015 ± 0.013 ^{cd}	99.64 ± 0.18 ^{cd}
8000	550	0.0149 ± 0.012 ^{cd}	99.52 ± 0.15 ^{cd}
7000	750	0.0167 ± 0.012 ^{de}	99.87 ± 0.02 ^{de}
7000	650	0.0163 ± 0.011 ^{de}	99.18 ± 0.23 ^{de}
7000	550	0.0148 ± 0.013 ^{ef}	98.68 ± 0.13 ^{ef}

According to the results maximum shelling efficiency was 99.89 present and the minimum was 98.68 present achieved at feed rate 9000 kg/hr and 750 rpm and feed rate 7000 kg/hr and 550 rpm respectively. From the result the feed rate and drum speed had direct related to seed breakage and shelling efficiency. The trend was similar to the result of Tekeste and Degu (2020) results of engine driven maize sheller on BH661 maize variety whereas mean seed breakage was 0.233 ± 0.105 . Hence, using conveyor system can mitigate seed breakage and improve shelling efficiency. Amount of fuel used was between 2.8 and 3.2 litres per hour and statistically there no significant changes between the treatment. The lowest feed rate and lower drum speed consumes lower and the amount feed were higher and the drum speed is higher resulted higher fuel consumption.

3.1 Impact of conveyor feeds and drum speed on seed breakage and shelling efficiency

As the results show, the effects of conveyor feed on seed breakage and shelling efficiency had insignificant ($p < 0.05$). The Melkassa II variety, which had a moisture content of 12.3%, was used for the evaluation. The maximum and minimum were achieved when biomass feed was of 9000 kg/hr and shelling speed was of 750 rpm at 0.0174 percent, and the minimum seed breakage was 0.0114 percent at shelling speed of 550 rpm and amount of feed 7000 kg/hr.



Fig. 12. Picture taken during the performance evaluation on field (source: author's own photographs)

4. Discussion and conclusions

The performance of shelling and threshing operations was significantly influenced by the use of a feed conveyor. Adding a feed conveyor altered the performance of shelling. As conveyor speed increased, shelling capacity also increased. Using a conveyor, the maximum shelling capacity is 7504.8 kg/hr at amount of biomass 9,000 kg/hr and sheller speed of 750 rpm. Shelling capacity showed a directly proportional relationship with both feed rate and drum speed. The ma-

chine performance of shelling efficiency evaluated at a drum speed feed rate at 9000 kg/hr and a sheller speed of 750 rpm was effectively evaluated on the Melkassa-II maize variety at 12.3% moisture content. The seed breakage and shelling efficiency across all treatments were statistically insignificant. effective solution for local farmers, as the suggestion of using the conveyor or automatic feeding using the conveyor system can improve shelling or threshing performance and reduce human drudgery. Also, it helps machine durability.

4.1 Conclusions

The feeding system with the conveyor had a significant impact on the shelling performance. Without changing the sheller design, only the addition of a feed conveyor can alter the performance and stabilize the safety operation. From the ANOVA, conveyor feed and sheller speed had a significant effect on the performance. But statistically, in the case of results, shelling efficiency, and seed breakage, there is no significant difference between the treatments. In general, the capacity of shelling increases as the conveyor speed increases. The drum increased as the shelling performance increased, and seed breakage also increased. Using the feed conveyor results in the best option ergonomically and economically, which can save energy, save time, and reduce drudgery during threshing operations.

4.2 Recommendations

After these research results, the following suggestions are made:

- Automatic feeding mechanisms for all shelling and threshing machines would be improving the performance and reduction of drudgery.
- Adopt conveyor systems to meet rising demand while ensuring safe, ergonomic operation and handling.

Ethical approval certificate

There is no ethical committee decision needed for this article

Author contribution statement

Tasfaye Aseffa: conception and design. Material preparation, data collection and analysis were performed by R studio, the first draft of the manuscript was written and approved the final manuscript.

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Conflict of interest

No conflict of interest.

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