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# Design, Development of Feed Conveyor and Performance Evaluation of an Integrated Melkassa Maize Sheller

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## Abstract

The removal of stalks and husks from seeds is called threshing. It can be done convectional or mechanically. One of the mechanical types is the Melkassa Sheller. When using it, the feeding process is labor-intensive and it is not suitable for operator. To solve that, development of feed for Melkassa maize Sheller is the best solution. The developed conveyor consists of: frame, bearings, rotating belts, pulleys, a side cover and lower hopper. To know the effect of conveyor the evaluation is done by comparing manual and conveyor feed with completely randomized design. At the end, the economic cost of the analysis is done. Performance evaluation in terms of shelling capacity, efficiency, seed breakage, fuel consumption, and labor requirement. The tests were carried out on a Melkassa maize sheller, maize variety (Melkasa-II) and a moisture content of 12.3 percent. The capacity of the Sheller is 7518 kg per hour, with a fuel consumption of 2.685 litres per hour when feeding with a conveyor and 6248 kg per hour and 2.0678 litres per hour without conveyor feeding. The seed breakage during test feed with conveyor was 0.21 % and 0.22 % without conveyor feed. Using a feed conveyor can increase threshing capacity, reduce drudgery, save time and energy, and reduce risk.

**Keywords:** Feed conveyor; Shelling performance; Economics

## Introduction

Crop production in Ethiopia has a significant effect on the gross domestic product (GDP) and mostly covered by cereal crops. According to CSA,(2021), cereal crops are the principal crops which is covers around 87.42% of the total area of crop production in Ethiopia. During cereal crop production, post-harvest loss highly affects the quantity of yield. The losses occurs during the threshing, transportation and seed storing processes (Abhay, 2018) [1].

Mechanical threshing can be reduce post-harvest losses and improve grain quality. According to Ahmad et al.(2019), suggested, the primary aim of mechanical threshing is to reduce the labor required for the threshing process, reduce post-harvest losses, save energy and reduce drudgery. However, there is a challenge during shelling operations of cereal crops using the Melkassa maize Sheller. Since the feeding operation is manual. It is labor intensive; time consumes and decreases thresher capacity. During the operation the dust had blown to the operator and that exposes for accident. To solve that, using mechanical feeding or conveyor feeding can reduce the drudgery, simplify the feeding operation, and increase the thresher's performance. The aim of these studies was to solve the problem of feeding units during the threshing operation by design, development of feed conveyor and evaluate the performance with an integrated Melkassa maize Sheller [2].

## Materials and Methods

### Experimentation Site

The proposed machine parts were built at the Melkassa Agricultural Research Centre (MARC). The study carried out at Ethiopia's Oromia regional state's Melkassa Agricultural Research Centre. It is located at 8° 24' 985 N and 39° 19' 529 E, with an elevation of 1550 meters above sea level.

### Materials

During design and development of feed conveyor the main material used was Melkassa developed maize Sheller, maize crop verity Melkasa (II) for testing performance evaluation, and for construction of conveyor: RHS supporting frame, ball bearings, belts, aluminum for pulleys, mild steel, angel iron, belt conveyor, round bar used [3].

### Embodiment design of feed conveyor machine

Design feed conveyor for Melkassa maize Sheller depend on the feed rate. The design of feed rate determination using equation (1).

$$Q = q \times L \times N \tag{1}$$

Where: Q, is the Sheller feed rate (kg/s), q, denotes the permissible feed rate (kg/s. m.) and from (0.35 to 0.4), L, is the length of the drum (in meters), and N is the number of beaters (in rows). According to (Belay & Fetene, 2021), the number of rows (N) is 8, the length of the drum (L) is 0.83 m, and the speed (q) is 0.375 kg/s.

$$Q = 0.375 \text{ kg/s}, \times 0.83 \text{ m} \times 8 = 8964 \text{kg.hr}^{-1}$$

Based on the dimensions of the Melkasa maize Sheller the harvested crop's inletThe dimension of inlet maize Sheller was 0.34 m in width and 0.2 m in height. Then inlet area was determined using equation (2).

$$A = w \times h \tag{2}$$

Where: A, is the area ($m^2$) and W, is the width (m) meters and h, is the height (m)

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

### Power determination for feed conveyor

To determine the power requirement for drum Sheller and

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the conveyor is determined using equation (3). The total power requirement is the summation of drum power and conveyor required to get total power.

$$P = F \times V \tag{3}$$

Where, P, is denotes the power in watts, F is the amount of force required to move the material in (N), and V is the material's speed in (m/s). The power required for a flat belt conveyor can be calculated using equation (4) based the following data of length (m), width (m), capacity (kg/s) and height (m) using equation developed by the motion resistance is equal to the sum of weight of the conveyor and the transported mass crops (Mohammed et al.,2017).

$$W = CFL(G_g + G_b)\cos\delta + G_r + H(G_b + G_g) \tag{4}$$

Where, W is the total weight of the material plus the mass of the belt in kg, C is the secondary use of the resistance factor (1.7), F is the standard conveyor (0.02), h, is the conveyor height (1.5 m), Gg is the weight of the material per meter, and Gb is the weight of the belt per meter, and sign plus (+) upward movement and minus (-) dawn ward movement and inclination angle and the mass crop is 77.394kg [4].

$G_g$ = 77.394kg × 1.5m = 51.5 kg/m

Weight of the belt (wb), is the ρ x v and where the Rubber density of belt (ρ) is 1140kg.m-3

Width (w) the belt is equal to width of in let Sheller (w) which is 0.34 m. the thickness belt is 0.003 m and length 3m. By consider top and lower cover of belts the volume required determined using numerical formula. The volume (V) equal to area (A) multiplies the length of belt (L) which is 0.0027$m^3$. The mass of the rubber belt (kg) is equal to density of rubber multiplies the volumes which is 3.078kg and $G_b$ is total mass divided time length belt 1.026kg/m [5].

W= CFL (Gg + Gb) cos θ + H (Gb + Gg) = 49.05N

**Determination Tension of belt conveyor**

Using equations (5) the belt tension in tight side and slack side belt conveyor determined. From the literature review the recommended feed conveyor 2.5m/s (Kukhmazov & Konovalov, 2021).

$$P = (T1 - T2) \times V \sim 0.5\ HP \tag{5}$$

Where: P is the power in watt, T1, is the tight side tension in N of conveyor and T2, is the slight side tension in N of conveyor

## Selection of pulley diameter for feed conveyor

Using equation (6) the diameter of the pulley computed. According to Hussein, (2016), the recommended speed for belt conveyors is 400 rpm. The driving pulley diameter (D1) was 120 mm by direct measurements. The maximum speed was (N1) 1000 rpm and (N2, 400 rpm.

$$N1D1 = N2D2 \tag{6}$$

Where N1 is the speed of the driver, N2 is the speed of the driven, D2 is the diameter of the driven, and D1 is the diameter of the driver. If the width of the belt known then the width of the pulley (w) is assumed 25% greater than the width of the belt (Khurmi and Gupta 2005) [6].

$D2$ = 300mm

## Selection of belts

Belt selection was selected using equation (7) by considering the strength of materials. The total power required according to Robert L. Mott, (2004) the maximum tension of the belt is determined.

$$T = S \times A \tag{7}$$

Where, T, is the maximum permissible belt stress in (N) and A, is the area of the belt

According to Król, (2016) suggestion the measurement length from the inside inch of the table standard it must be adjusted from center-to-center pulley. The number of belts determined using equation (8). The total power transmitted divided by the Power transmitted by belt is the number belt requirements. The power (p) transferred by the belt is calculated by (T1-T2) x V. The speed (v) calculated radius (rpm) multiplies angular speed (ω)

$$\text{The Number of belts required} = \frac{\text{the total power transmitted } (wat)}{\text{Power transimited bt belt } (wat)} = \sim 1 \tag{8}$$

**Selection shaft for feed conveyor**

A shaft is a power transmission machine which is calculated using equation (9) and based on the code (ASME) and (Khurmi and Gupta 2005).

$$d^3 = \left\{\frac{16}{\pi\tau_{max}}\sqrt{(KbMb)^2 + (KtMt)^2}\right\} \tag{9}$$

Where D is the shaft's diameter (mm), Mt is the torsional moment (Nm), Mb is the bending moment (Nm), and max is the maximum allowable shear stress: MN.$mm^{-2}$, Kb is the combined shock and fatigue factor for bend moment and Kt is the combined shock and fatigue factor for torsional moment. Then the calculated diameter of shaft is (D) is 25mm [7].

## Bearing selection feed conveyor

The bearing selection determined using equation (10) which is based on the life in working hours are used on the load rating should be sufficient to give an appropriate mix of life and reliability (Khurmi & Gupta, 2005). Because bearings were not subjected to axial loading (Bhandar, 2010).

$$L_{10} = \frac{60 \times N_0 \times L_{10h}}{10^6} \tag{10}$$

Where: $L_{10h}$, is rated bearing life (hours) and $N_o$, is speed of rotation of output shaft

**Design of supporting Frame feed conveyor**

The framework can support the full weight of the feed conveyor equipment. Equation represents Euler's theory for crippling and buckling loads under varied end circumstances (Khurmi and Gupta 2005).

$$P_{cr} = \frac{\pi^2 EI}{(Le/R)^2} \tag{11}$$

Where E is the material's modulus of elasticity (E=210Gpa).

$P_{cr}$, is the Euler's critical load N and A is the cross-sectional area material ($mm^2$) (Figure 1).

## Performance evaluation with Melkassa Maize Sheller

Testing performance was 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.

## Moisture content during threshing and shelling operation

The moisture content was determined using equation (12) as follows.

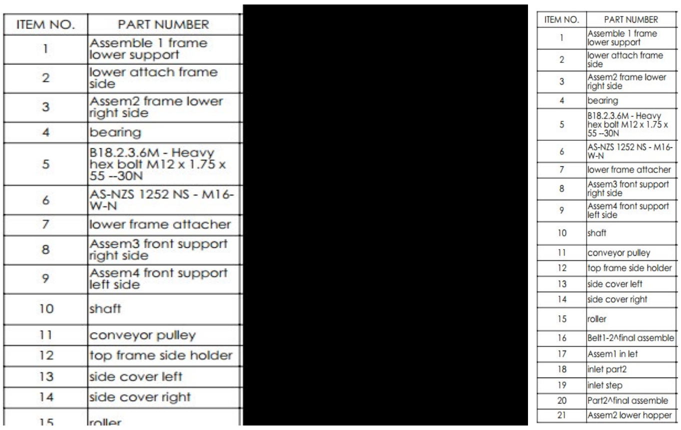


**Figure 1:** Assemble of feed conveyor machine.

$$M_c = \frac{Wi - Wd}{Wd} \times 100 \quad (12)$$

Where: $M_c$, is the moisture content (%), Wi, is the initial weight of the sample (g) and Wd, is the dried weight of the sample (g) and it obtained two samples of 100g each from the shelled grain to determine the damaged grain (Singh, and Shojaei 2014).

According to (Merga. 2016) & (Kidanemariam, 2020), the range of speed for threshing or shelling speed for cereal crops was 500 (rpm) to 1200 (rpm) that is depending on crop variety. For maize, the drum speed was 500-750 rpm. The conveyor was tested to identify the best conveyor slope and the best conveyor speed using two conveyor slopes at 20 and 30 degrees, and three conveyor speeds (300, 350, and 400) rpm with a split-plot design with three replicates were used to identify the best performance. Then to determine the effect of feed using the two treatments manual feeding (MF) and feeding with the conveyor (CF) using CRD experimental design was feeding method evaluated [8].

## Statistical analysis

Analysis of variance (ANOVA) is used to examine under different treatments (verson3.4.3, 2018).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.

# Results and Discussion

## Engineering properties of maize

The physical characteristics of the maize (Melkassa II) and the three axial dimensions (length, breadth, and thickness) shown in the table below (Table 1).

## Performance evaluation of the developed feed conveyor with an integrated Melkassa maize Sheller

The feed conveyor with integrated melkassa maize Sheller and the performance evaluation is expressed in terms of shelling efficiency (%), shelling capacity and percentage of grain damage (%), fuel consumption (FC) and economical aspects shown below (Table 2).

According to the results of analysis, the effects of feed conveyor slope and conveyor speed had a significant effect on shelling capacity ($p < 0.05$). The highest shelling capacity 7500.8 kg per hour obtained for a combination of 400 (rpm) conveyor speed and 20 degree of conveyor slope, while the minimum 6440.97 kg per hours obtained by combination of 300 (rpm) conveyor speed and 30 degree of conveyor slope (Table 3).

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

| Crop variety Melkassa-II | Mean ± SD | Minimum | Maximum | Shattering |
|---|---|---|---|---|
| Head average diameter (cm) | 24.86±1.8 | 23.5 | 29.3 | Medium |
| Intermediate diameter (cm) | 38.80±4.4 | 34.2 | 46.3 | Medium |
| Tail average diameter (cm) | 24.55±6.7 | 15.9 | 34.2 | Medium |
| Length of head (cm) | 23.27±2.1 | 23.27 | 25.3 | Medium |
| Moisture (%) | 12.65± 0.4 | 12.2 | 13.2 | Medium |

**Table 2:** ANOVA of the slope and conveyor speed effect on Sheller capacity.

| Source of variation | Df | Sum Sq | Mean sq | F –Value | Pr(>F) |
|---|---|---|---|---|---|
| Replication | 2 | 148647 | 74324 | 12.2769. | 0.0753186. |
| Conveyor angle ($^0$) | 1 | 767530 | 767530 | 126.7824 | 0.0077954 ** |
| Ea | 2 | 12108 | 6054 | | |
| Conveyor speed(rpm) | 2 | 373571 | 186785 | 8.4679 | 0.0105942 * |
| Conv. angle: Conv. Speed | 2 | 969567 | 484783 | 21.9776 | 0.0005621*** |
| Eb | 8 | 176465 | 22058 | | |
| CV, (a) = 1.144%, CV, (b) = 2.185% | | | | | |

**Table 3:** Mean of shelling capacity of conveyor slope and speed.

| Conveyor slope (degree) : conveyor speed (rpm) | Capacity ($kg.h^{-1}$) |
|---|---|
| Slope 20 : speed 400 | 7500.8 ± 1.25[a] |
| Slope 20: speed 350 | 6899.87 ± 0.38[b] |
| Slope 20: speed 300 | 6713.45 ± 1.01[bc] |
| Slope 30: speed 400 | 6621.93 ± 0.172[bc] |
| Slope 30: speed 350 | 6614.7 ± 1.12[c] |
| Slope 30: Conveyor speed 300 | 6440.9 ± 0.85[c] |
| CV (a) 1.14 %, CV (b) 2 .18 %, LSD 2.5, SEM, 1.76 | |
| Note: CV is the Coefficient of variation, LSD is the list significance difference, and SEM is the standard error of mean. | |

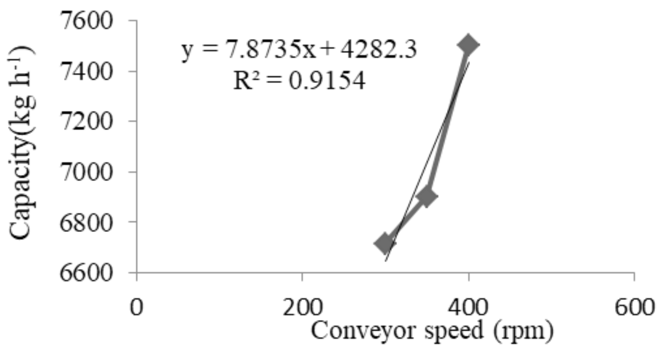


**Figure 2:** Effect of conveyor on shelling capacity at slope 20 degree.

When the conveyor slope increases, the capacity of the rake to carry harvest crop for feed is decreases and it resulting shelling capacity decreases. As the conveyor slope lowered, the rake's feeding ability improves, which increases the shelling capacity. The rake or pocket was determined to have a significant influence on the feed rate (Figure 2).

The liner regression model related feed on maize shelling capacity in ($kg\ hr^{-1}$) is 7.8735 SP + 4282.3 and where, sp, are the conveyor speed (rpm) and the conveyor speed and the shelling capacity at slope 20 degrees are of liner regression equation (Figure 3) [9].

The liner regression model at 30 degree is in terms shelling capacity ($kg.hr^{-1}$) is 1.18103sp + 5925.6, and where; *Sp*, is the conveyor speed

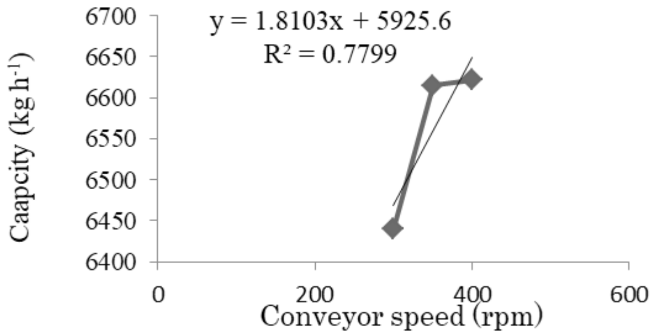


**Figure 3:** Effect of conveyor on maize Sheller at conveyor slope 30⁰.

is as the conveyor speed increases from 300 (rpm) to 350 (rpm). The Conveyor slope and conveyor speed interaction had a significant effect on shelling capacity ($p < 0.05$). This finding is in agreement with (Ahmed, 2017),who reported, as the speed of conveyor is direct effects, the capacity of shelling.

## Effect of feed method on maize sheller with an integrated feed conveyor

The ANOVA on the shelling data of the maize Sheller indicated that the feeding type had a very significant influence on the Sheller capacity ($p<0.05$), as shown in the ANOVA table below (Table 4 and Table 5).

Where CV is the Coefficient of Variation, LSD is the list significance difference; SEM is the standard error of mean. According to the above table, the highest mean shelling capacity for conveyor feeding was 7518 kg per hour, whereas for manual feeding it was 5924 kg per hour. The results indicated that the Melkasa maize Sheller needed higher feed rates to work at its peak, which is difficult to achieve with manual labor (Figure 4).

The result was similar with the results reported by (Tekeste & Degu, 2020),) also gate the shelling capacity of manual feeding was in the range of 58 quintal per hour to 70 quintal per hour depending on labor capacity to feed continuous [10].

## Effect of the feed on the shelling efficiency and seed breakage

The threshing efficiency of maize shellers for the two treatments of manual feeding and feeding with a conveyor is significant ($p < 0.05$). The shelling efficiency performed at the same moisture content (12.3%), and the result is 95.02 for manual feed and 99.86% for conveyor feed. According to the same trends (Belay & Fetene, 2021), shelling efficiency is highly affected by feeding type during testing. Based on the analysis of variance, manual feed and feed with conveyor had no significant seed breakage during maize Sheller performance evaluation ($P >0.05$). The highest seed breakage rates with conveyor feed were 0.21% and

**Table 4:** ANOVA of the feeding effect on maize sheller capacity.

| Source of variation | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Treatment | 1 | 496.44 | 496.44 | 42.27 | 0.00063** |
| Residual | 6 | 70.46 | 11.74 | | |
| Total | 7 | 566.9 | | | |

**Table 5:** Mean shelling capacity of Melkassa maize Sheller.

| Treatment | Capacity mean ± Std (kg.hr⁻¹) |
|---|---|
| Conveyor feed type | 7518 ± 1.07 ᵃ |
| Manual feed operation | 5942 ± 1.02ᵇ |
| CV (%) 5.09, LDS (5%), 5.9 | SEM, 2.4 |

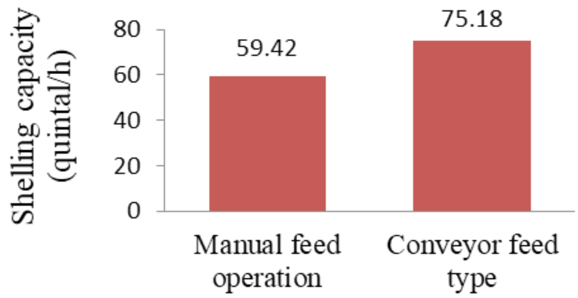


**Figure 4**: Mean shelling capacity of Melkassa maize sheller.

manual feed 0.22%, respectively, which is a statically not significant change. This trend was similar to the one obtained by (Amare and Tekeste, 2017), Mean breakage result was 0.233 ± 0.105 BH661 maize variety when using manual seed feeding [11].

## Effect of the feed conveyor on the fuel consumption

The Analyses of Variance on the fuel consumption between the two treatments feeding using manual feeding and conveyor feeding non-significant effect ($P > 0.05$). When using the feed conveyor integration, the amount of mean fuel consumption was 3.285 liters /hr, and 2.742 liters/hr was consumed during manual feeding. The maximum amount of fuel consumed by the feed conveyor by the Melkasa maize Sheller integrated was 3.021L/hr. Similar findings were made by (Tekeste & Degu, 2020), who determined that the fuel consumption for hand feeding of the BH661 and limu kinds of maize is 3.04 L $h^{-1}$ and 3.03 L $h^{-1}$, respectively.

## Economic analysis of conveyor feed with an integration Sheller

To analyze the economics of the local experience, for shelling, the fees are 50 ETB per 100 kg. The Sheller capacity for feeding with a manual is 5942 kg per hour, and feeding with a conveyor is 7518 kg per hour. The amount of mean fuel consumption when feeding with a conveyor was 3.285 liters per hour and 2.742 liters per hour consumed during manual feeding. the thresher capacity conveyor feed (TCCF) minus the Sheller capacity of manual feeding (TCMF) in kg per hour in to Birr per hour and the collect data on fuel price (FP) in Birr per liter differences in fuel consumption (DFC) between conveyor feed (FCCF) and manual feeding (FCMF) in liter per hour. Multiply fuel prices (FP) by the difference to get losses in fuel consumption (LFC) in Birr per hour. The difference between Sheller cost (DTC) and fuel cost (DFC) is the economic benefit of using the conveyor per hour. The machine cost is 13596.20 ETB (CC) during manufacture. The assumption made was based on the agricultural implement concept: the expected life of the feed conveyor (EL) is 10 years, the feeding threshing operation conveying per year is 90 days, Annual working hours (NAOHW), when the working hours are 8 in the day, salvage value (SVC): 10% capital cost, Interest rate (I) 8% per annum, Fuel cost (FC) per liter is 60 ETB [12]. The cost of conveyor feed divided into two categories: fixed cost and variable cost. The operational feed cost of the conveyor was estimated in Birr per hour [13]. The fixed cost is depreciation cost (Dp) plus interest on capital (IC) and then total fixed cost (ETB/h) is depreciation plus interest rate is 11.96 ETB per hour and the operational cost is fuel cost (ETB/h). The fuel consumption of the feed conveyor was the difference between feeding with the conveyor and feeding with a manual maize Sheller (0.55 liter per hour). To change ETB per hour is 60 ETB/l x 0.55 $L.hr^{-1}$, or 33 $ETB.hr^{-1}$. Therefore, the total cost of the machine (TC) is the sum of the fixed cost and variable cost (45 ETH/hr). When the conveyor worked for 8 hours, the total feed conveyor was 360 ETB/day. Feeding with conveyor minus feeding without conveyor is 1576 kg per hour saved. The cost difference per day is equal to 1576 kg per hour x 8 hours per day x 50 ETB per kg was get 6304 ETB per day. The net profit is 6304 ETB per day minus 360 ETB/day, for 5,944 ETB/day. If you used conveyor feed per day, the result in net profit is 5944 ETB/day. Therefore, when using a conveyor with an integrated maize Sheller, we can save money as well as energy [14,15].

## Conclusion

The feeding with conveyor had a significant impact on the dependent factor of shelling operations. Without changing the Sheller, only the addition of a feed conveyor can alter the performance of threshing or shelling. The capacity of shelling is increases as the conveyor speed increases. The feed rate increased as the slope of the feed conveyor decreased, and the shelling capacity also increased. Using of the feed conveyor results is the best option which can save energy, safe time, and reduction drudgery, during threshing operation.

## Recommendation

After these research results, the following suggestions:

- Automatic feeding mechanisms for all threshing machines, which would be improve the thresher performance and reduction of drudgery.
- To generate demand, scale up, and acceptance with attaching the thresher, a participatory field demonstration of the equipment at the farm level is required.

### Declaration of competing Interest

- The authors declare that they have no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

- The authors declare the contributions to the manuscript such as the following sections:
- Tasfaye Aseffa Abeye: Conceptualization, proposal writing, design, prototype manufacturing, performance evaluation, and the review process for both the thesis and the manuscript of this research
- Melesse Temesgen: Conceptualization, proposal writing, design, prototype manufacturing, performance evaluation, and the review process for both the thesis and the manuscript of this research (advisor).

### Ethics committee decision

This article does not require any ethical committee decision

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