# Integrating of Corm Grating and Leaf Sheath Decorticating Machine

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***Abstract*–Enset processing, in Ethiopia at present, is labour demanding and time-consuming activity which calls for technology to make it efficient and lighten the burden on women. Additionally, multipurpose enste processing machine was not developed. So, engine operated enset processing machine that can grate the corm and decorticate the leaf sheath of enset was adapted. The machine was consisting basically three parts: the hopper, the grating and decorticating drum. All these components are mounted on an angle iron frame that has trapezoidal shape. All machine parts that contact with the enset while processing is food graded materials. The machine assembly is powered engine of small horsepower of 5hp. Enset processing machine that can grate the corm and decorate leaf sheath of the enset was adapted. The machine was easy for fabrication, transport and can be affordable by farmers. It was recommended for conducting performance evaluation of the machine at the most produced enset farmers to determine the performance of the machine.**

***Keywords*– Development, grating, decorticating and Enset**

## I. INTRODUCTION

ENSET (*Enset ventricosum*) is commonly known as "false banana" and it is a traditional staple crop or co-staple food in the densely populated South and South-Western parts of Ethiopia. It serves as food security for about twelve million people in Southern region of Ethiopia (Brandt *et al.*, 1997). It is a multipurpose crop used as human food, animal feed, to shade other crops like coffee, decoration, is a drought resistant crop which makes it risk avoidance crop. It resembles the banana plant, but is somewhat larger, up to 10 m tall with a pseudo stem up to 1 m in diameter and is produced primarily for the large quantity of carbohydrate rich food found in the false stem (pseudo stem) and an underground bulb (corm).

The major foods obtained from enset are *kocho*, *bulla* and *amicho*. *Kocho* needs a lengthy period of processing and preparation, which is carried out by women. The first stage involves removing the leaf stalks and grading of the corm. *Kocho* is increasingly exported to urban markets. *Bulla* is the unfermented starch of a mature plant, which can be prepared as a pancake or porridge. *Amicho* is the core of a young plant, which is boiled and consumed as other tuber crops. Due to their low protein content these foods are eaten in combination with protein rich products like milk. The fiber is used to make sacks, bags, ropes, mats, construction material and sieves. Fresh enset leaves are used as food wrappers, serving plates and for stall feeding of cattle. There are many other uses, e.g., for medicines.

It is expected that enset can be introduced in many other regions to improve food security. However, this needs further study and work on trial demonstration farms. Further research is needed on: diseases, processing technologies, improvement of the livestock component, and production of protein-rich food crops in enset systems, marketing of *kocho*and sustainability of enset farming under increasing population pressure and marketing.

However, little effort or research is made to improve the processing aspect of the crop especially corm grating, and thus traditional processes are predominantly used by farmers. Both men and women are involved in growing and managing enset at field level in most cases, however, there are places where it is most associated with women. Women are mainly responsible for harvesting and processing enset. Enset processing requires more labour and thus it is additional burden for women beside to handling daily house routines. The burden remains as a challenge of women for a long time, and this has influence on gender relations at household level. Some enset processing technologies (e.g. scraping and squeezing tools) have been developed by Bako Agricultural Engineering Research Center, Sodo Rural Technology Promotion Research Centre and Melkassa Agriculture Research Institution.

However, the technologies that farmers used for enset corm grating and leaf sheath decorticating still in the area were traditional. The introduced technologies mainly differ from traditional methods in terms of time and labour taking, and their provided yield of quantities and qualities. The traditional harvesting and post harvesting procedures are cumber some; labour intensive, unhygienic, impose a lot of inconvenience to the working women, and associated with great yield lose. Traditionally 2-3hr per tuber require to grating.

***Statement of the problem***

Women in rural community of Ethiopia have more workload in general as compared to men. The workload is expressed in household, farm and social activities. Almost all the household activities (including childcare) are performed by women alone. Therefore, women are busy all day from very early in the morning to late in the evening. Men do not involve in household activities and in some places, in certain area women are not allowed even to share bread with their husbands in some cases, i.e., women eat what is left from their husbands. Women are also involved in farm operations mainly at planting, weeding and harvesting of different crops. Some crops are more managed by women than men. Such crops include enset, vegetables and spices. Moreover, milking and managing calves is among the daily routines of women. Processing of the staple food source enset is entirely done by women because traditionally men are not allowed to involve on such activities.

Enset processing is labour demanding and time-consuming activity which calls for technology to make it efficient and lighten the burden on women. It is unimaginable to perform social activities such as wedding, funeral and circumcisions' ceremony without active involvement of women. Due to all these workloads, women may not have enough time to have adequate care for their child and may not perform the house needs to the satisfaction of men. This at times creates conflict among spouses. In general, the existing enset processing coupled with other farm and household activities has negatively affected the relationship between men and women biasing the workload to women and affecting maternity health (Sodo Rural Technology Promotion Center report document, 2010). Thus, different development programs have introduced enset processing technologies as a solution to lessen the burden on women.

The tubers of enset cannot be stored longer after harvest before decaying, and so processing follows immediately after harvesting. Enset processing leading to size reduction includes decorticating, grating, and squeezing. A typical enset processing plant should therefore consist of units produced to achieve all the stages or steps mentioned above.

Traditional processing method have low productivities and tedious, solution to these problems the BAERC develop and evaluate the machines that can grate the corm of enset at high quality in a short period of time and reduce human drudgery. Performance of the machine was evaluated interims of Grating capacity (Kg/hr) and Grating uniformity (%) for all varieties. Grating efficiency (%) and Fuel consumption (Kg/ml) were taken for Baladati variety. Based on the results obtained, the grand mean grating capacity of 1048.3Kg/har (~1ton/hr) is recorded for the prototype. The optimum grating capacity of 1277Kg/hr was observed when the drum was operated at velocity of 2200rpm at Sharte variety; whereas the minimum grating capacity of 604.0Kg/hr was observed when the drum speed was 2000 rpm at Baladati variety. Fuel consumption of 1.32lit/hr was recorded at drum speed of 2400rpm and Baladati variety. The machine can be used by farmers for all varieties at drum speed range of 2200 – 2400rpm (Gelgelo, 2018).

Additionally, the BAERC also develop and evaluate enset decorticating machine for leaf sheet solely. The maximum decorticating capacity of 255.38 kg/hr was obtained at drum speed of 850 rpm, when the concave clearance was 1 mm, and the feeding rate was 0.074 kg/s. Nonetheless, the decorticating capacity of the prototype machine decreased with increasing concave clearance and increased with increasing feeding rate. The highest decorticating efficiency of 98.97% was obtained at drum speed of 850 rpm, concave clearance of 1 mm and feed rate of 0.074 kg/s while the lowest decorticating efficiency of 72.41% occurred at drum speed of 950 rpm, concave clearance of 6 mm and feed rate of 0.037kg/s. The mean decorticating efficiency with respect to the feeding rates of 0.037, 0.056 and 0.074 kg/s were 86.77, 89.41 and 89.91 %, respectively ( Merga, 2019).

Even though, the center develops and evaluate the machines that are effective for enset corm grating and leaf sheet decorticating solely, taking one rather than two machines to the farmers for one crop is compulsory. Therefore, this paper is initiated to integrate/adapt corm grating and leaf sheath decorticating machine for enset processing that is a cheaper and more affordable price to our farmers.

## II. MATERIAL AND METHOD

### *A) Experimental Site*

The modification of the machine was done at Bako Agricultural Engineering Research Center (BAERC), which is located in West Shoa zone of Oromia National Regional State, Western Ethiopia.

### *Materials*

- Angle iron, Stainless-steel sheet,
- Stainless steel Electrode, Wooden planks,
- Diesel engine, B-Belt, L-angle (stainless steel angle), etc.

### *B) Machine Parts and Design calculation*

#### *Frame*

The frame carries the entire components of the machine. It has a trapezoidal shape structure. The top to bottom length ratio is according to standard minimum ratio of the frame lengths was L1/L2 = 0.5, (Shirgley 1980, Hannah and Stephens 1980).

#### *Drum*

The drum has grating and decorticating part that integrated and welded on one shaft. It was a closed ended with L-angle welded on cylindrical shape for corm grating and leaf sheath decorticating separately. Both drums drilled at the center to allow shaft to pass through.

#### *Hopper*

Corm grating and leaf sheath decorticating hopper were separately produced then incorporating to make one part. Corm grating hopper has two trapezoidal structure and rectangular shape at the bottom. The volume of corm grating hopper was calculated as follow equation.

$$V = (\frac{H_t}{2}(b_{1t} + b_{2t}) + \frac{H_b}{2}(b_{1b} + b_{2b}) + (b_{2b} * h)L ------1$$

Where V = Volume of the hopper, $m^3$, L = Hoppers' length, m, $b_{1t}$ and $b_{2t}$ = bases' length of top trapezoidal, m, $b_{1b}$ and $b_{2b}$ = bases' length of top trapezoidal, m and H = Hoppers' height of top and bottom trapezoidal, m

### *C) Selection of pulley*

The selection of pulleys for leaf sheet decorticating was done based speed ratio of the larger pulley on the machine shaft to the smaller pulley on the engine is givens as (Khurmi and Gupta, 2004):

$$N_1 D_1 = N_2 D_2 ------------2$$

Where N1 = speed of engine, N2 = speed of machine driving shaft, D1 = diameter of engine pulley, and D2 = diameter of machine drive pulley.

### *D) Selection of belt*

Length of belt was calculated by Equation (Khurmi and Gupta, 2004),

$$L_p = 2C + 1.57(D_p + d_p) + \frac{(D_p - d_p)^2}{4C} ----3$$

Where: $L_p$**:** effective length of belt (mm), C: center distance (mm), $D_p$**:** pitch diameter of large pulley (mm), $d_p$**:** pitch diameter of small pulley (mm)

### *E) Selection of Shaft*

The shaft is considered for satisfactory performance is to be rigid enough while transmitting load. Determination of belt tensions ($T_t$ and $T_s$) and torsional moment (Mt) was done according to Khurmi and Gupta, 2004, from the following equation.

$$d^3 = \frac{16}{3.14 \times 40MPa}\left[(1.5\times 40)^2 + (0.23)^2\right]^{\frac{1}{2}} --4$$

$$\frac{T_t - T_c}{T_s - T_c} = e^{\mu\theta \operatorname{cosec}\frac{\beta}{2}}$$

Where Tt, Ts, Tmax, Tc, ð, a ,m, v, μ, β and θ are the tension at tight side, tension at slack side, maximum tension in belt (N), centrifugal tension of a belts (N), maximum safe normal stress (N/mm2), a is cross sectional area (mm2), mass per unit length (kg/m) of belts, speed of belt (m/s), coefficient of friction between belt and pulley, groove angle and angle of wrap respectively.

## III. RESULT AND DISCUSSION

### *A) Design Considerations*

The machine that should be efficient during use in the household as well as movable (portability) and safely or easily operate was considered.

### *Description of the machine*

The machine was consisting basically 3 parts: the hopper, the grating and decorticating drum. All these components are mounted on an angle iron frame that has trapezoidal shape. The machine assembly is powered engine of small horsepower of 5hp.

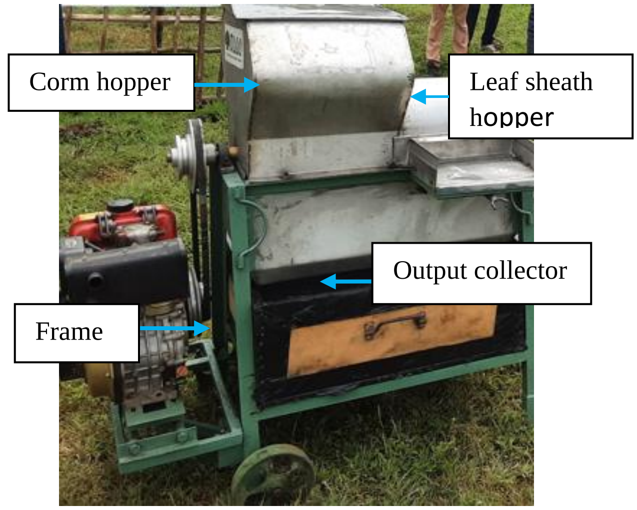


Fig. 1. Major parts of modified enset processing machine

### *B) Modified Parties of the Prototype*

#### *Frame*

The frame carries the entire components of the machine. It i s a trapezoidal shaped structure, 374 mm by 760 mm at the to p and 600 mm by 760mm at the base, constructed from 40 m m by 40 mm angle iron. The standard minimum ratio of the fr ame lengths was determined based on Shirgley 1980, Hannah and Stephens 1980 ($L_1/L_2 \geq 0.5$,). Taken is 0.49 and 0.79 for base and top respectively. Therefore, the above condition is satisfied. This was done to p rovide stability and make it easily transportable.

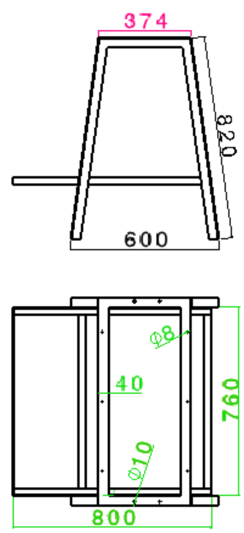


Fig. 2. Modified frame part

#### *Hopper*

The hopper is the receptacle through which corm and leaf sheath were admitted into the machine for grating and decorticating. Corm grating and leaf sheath decorticating hopper were separately produced then incorporated to make one part. Corm grating and leaf sheath decorticating was made of stainless-steel sheet of 1.5mm thickness. The corm grate hopper has two trapezoidal shapes at bottom and top. It is volume was calculated as equation 1 and obtained the following result.

$$V = (\frac{H_t}{2}(b_{1_t} + b_{2_t}) + \frac{H_b}{2}(b_{1_b} + b_{2_b}) + (b_{2_b} * h)L = 0.06m^3$$

Where V = Volume of the hopper, $m^3$, L = Hoppers' length, m, $b_{1t}$ and $b_{2t}$ = bases' length of top trapezoidal, m, $b_{1b}$ and $b_{2b}$ = bases' length of top trapezoidal, m and H = Hoppers' height of top and bottom trapezoidal, m.

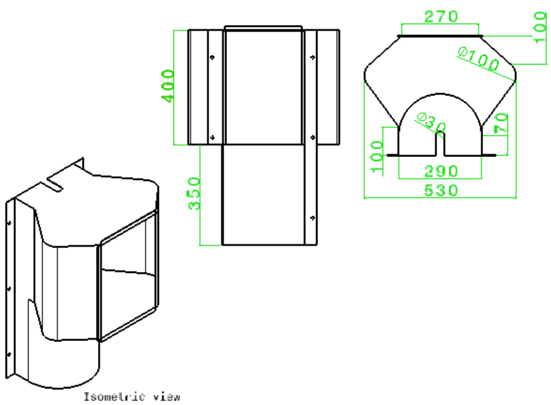


Fig. 3. Modified hopper part

*Grating and decorticating drum*

Cylindrical drum of 367mm length and 220mm diameter and 338mm length and 243mm diameter was formed by rolling 1.5mm thickness stainless steel sheet metal for corm grating and leaf sheath decorticating respectively. Drums were welded on the shaft that pass through the center and L – angle of 20x20 and 30x30 welded on it for corm grating and leaf sheath decorticating. Twenty and fifteen of them were welded on surface of corm and leaf sheath drum at equal distance spacing which served as the grating decorticating respectively.

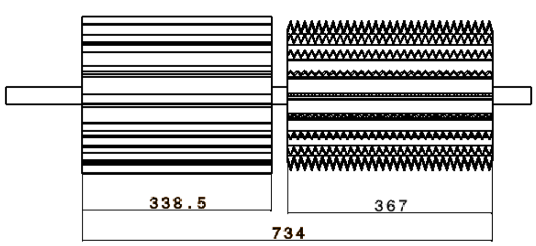


Fig. 5. Modified drum part

*Selection of pulley*

Determination of pulley was done based on equation 2 and assuming the following parameters of selected engine type (low speed 5hp engine).

Let N1 = Speed of the driver in r.p.m. = 1200rpm and D1 = 210mm; Nd = maximum speed of the driven in r.p.m. = 2100rpm

$$1200 \text{ x } 210 = 2100 \text{ x } D2$$
$$D2 = 120mm$$

Based on availability and cost aluminum pulley was selected for corm grating while vice versa for leaf sheath decorticating in order to use one belt for the operations.

*Selection of belt*

Length of belt was calculated by Equation (Khurmi and Gupta, 2004) as equation 3, assume C = 460mm based on the height of frame.

$$L_p = 2C + 1.57\left(D_p + d_p\right) + \frac{\left(D_p - d_p\right)^2}{4C}$$
$$= 2x460 + 1.57(210+120) + ((210\text{-}120)2)/4*460 = 1442.5mm$$

Where: $L_p$**:** effective length of belt (mm), C: center distance (mm), $D_p$**:** pitch diameter of large pulley (mm), $d_p$**:** pitch diameter of small pulley (mm), based on the driven and driving pulley diameter, the length correction factor for belts shorter or longer than average length determines and the closest belt length B – 51 belt type was selected.

*Selection of Shaft*

The shaft was considered for satisfactory performance is to be rigid enough while transmitting load. Determination of belt tensions ($T_t$ and $T_s$) and torsional moment (Mt) according to equation 4 was done as follows.

$$\frac{T_t - T_c}{T_s - T_c} = e^{\mu\theta \operatorname{cosec}\frac{\beta}{2}} = e^{0.3*2.95*2.92} = T_s = 32.57N$$

$$T_t = T_{max} - T_c = 4.2 - 32.88 = -28.68N$$

$$T_{max} = \partial a = 2.1 * 2 = 4.2N$$

$$T_c = mv^2 = 0.189 * 13.19^2 = 32.88N$$

From the maximum drum speed (2100rpm) and pulley (/\

$$V = \frac{\pi D_1 N}{60} = \frac{\pi x.12x2100}{60} = 13.19m/s$$

Wrap angle determination was determined) for drum pulley.

$$\theta = 180 - 2\sin^{-1}\left(\frac{D_2 - D_1}{2C}\right) = 2.95rad$$

$$M_t = (T_t - T_s)\frac{D_1}{2} = (28.68 - 32.56)0.06$$
$$= 0.23Nm$$

Where $T_t$, $T_s$, Tmax, Tc, ծ, a ,m, v, μ, β and θ are the tension at tight side, tension at slack side, maximum tension in belt (N), centrifugal tension of a belts (N), maximum safe normal stress (N/mm2), a is cross sectional area ($mm^2$), mass per unit length (kg/m) of belts, speed of belt (m/s), coefficient of friction between belt and pulley, groove angle and angle of wrap respectively.

According to standard table Khurmi and Gupta (2005) the value of ð, a, m, μ, β and θ are 2.1 N/mm$^2$, 2mm$^2$, 0.189 kg/m, 0.3, 40º and 2.95rad respectively. From above equations $T_t$, $T_s$, Tmax, Tc and Mt are 28.69N, 32.25N, 4.2N, 32.88N and 0.23 N-m respectively

The diameter of the shaft was calculated as follow. The maximum bending moment of 40Nm was obtained at point A. Assume $K_b$ = 1.5 and $K_b$ = 1 and $\tau_{max}$ = Allowable Stress; 40MPa (for steel shaft with keyway).

$$d^3 = \frac{16}{3.14 \times 40MPa}\left[(1.5\times 40)^2 + (0.23)^2\right]^{\frac{1}{2}}$$

= 19.7mm but by taking 1.5 safety factor, 30 mm diameter of shaft was selected.

### *Bearing Selection*

Bearing selection was made in accordance to American Society of Mechanical Engineers (ASME, 1995) standard as given by Hall *et al.* (1988). Therefore, UCP of 205 bearing were selected.

## IV. CONCLUSION AND RECOMMENDATIONS

### *Conclusion*

Enset processing, in Ethiopia at present, is labour demanding and time-consuming activity which calls for technology to make it efficient and lighten the burden on women. Additionally, multipurpose enste processing machine was not developed. So, engine operated enset processing machine that can grate the corm and decorticating the leaf sheath was adapted.

The machine that should be efficient during use in the household as well as movable (portability) and safely or easily operate was considered for design consideration. The machine was consisting basically three parts: the hopper, the grating and decorticating drum. All these components are mounted on an angle iron frame that has trapezoidal shape. All machine parts that contact with the enset while processing is food graded materials.

Trapezoidal shape structure frame, 374 mm by 760 mm at the top and 600 mm by 760mm at the base, constructed from 40 mm by 40 mm angle iron. The volume of corm grate was 0.6m$^3$ and constructed from 1.5mm thickness stainless steel sheet.

Cylindrical drum of 367mm length and 220mm diameter and 338mm length and 243mm diameter was formed by rolling 1.5mm thickness stainless steel sheet metal for corm grating and leaf sheath decorticating respectively. The machine assembly is powered engine of small horsepower of 5hp.

### *Recommendation*

From design consideration, functional test and size of machine, the fabrication, operation of the machine was simple and easy to transport respectively. So, it was recommended for conducting performance evaluation of the machine at the most produced enset farmer to determine the performance of the machine.

### *Acknowledgements*

I would like to thank all Bako Agricultural Engineering Research Center (BAERC) employees who supported me during the fabrication of the prototype machine. Special thanks for Gizachew Tefera and Yohanis Negera for your commitment and dedication. I would also like to thank my sponsor, Oromia Agricultural Research Institute for the provision of research fund.

## REFERENCES

ASME, 1995. Design of Transmission Shafting. American Society of Mechanical Engineering, New York, USA.

Brandt A. et al., 1997. The Tree against Hunger. Enset Based Agricultural Systems in Ethiopia. American Association for the advancement of Science with Awassa Agricultural Research Centre. Kyoto University Centre for African Area Studies and University of Florida.

Gelgelo Kibi, 2018. Development and Evaluation of Engine Driven Corm Grating Machine. International journal of multidisciplinary sciences and engineering,Vol. 9, no. 10, November 2018

Khurmi, R.S. and J.K. Gupta, 2004. Theory of Machines. New Delhi: Eurasia publishing house

Merga Workesa, 2019. Design, construction and performance evaluation of engine driven warqe/enset (enset ventricosum) decorticator