https://dergipark.org.tr/en/pub/turkager 2025, 6(1): 15-31 DOI: 10.46592/turkager.1542019

TURKAGER
TURKISH JOURNAL OF AGRICULTURAL ENGINEERING RESEARCH
e-ISSN: 2717 - 8420
https://dergipark.org.tr/tr/pub/turkager

Modification and Evaluation of Motorized Enset Corm Grinding Machine

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ARTICLE INFO: Research Article
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Received: 2 September 2024 / **Accepted:** 9 December 2024 / **Published:** 30 June 2025

Cite this article: Ertebo, A.E. (2025). Modification and Evaluation of Motorized Enset Corm Grinding Machine. Turkish Journal of Agricultural Engineering Research, 6(1), 15-31. *https://doi.org/10.46592/turkager.1542019*

ABSTRACT

This study was executed to redesign and evaluate a motorized enset corm grinding machine. The collected data for tests were analyzed utilizing the Statistix 8 software. The result of the design calculation indicated that the volume of the feeding hopper, the volume of a grinding unit, the length of the belt, the speed ratio, lap angle, shaft diameter, belt tension, torque, the power needed to grind, as well as the force required to grind were obtained as 0.1114 m^3, 0.0796 m^3, 1.18 m, 1.3, 2.95 rad, 40 mm, 1958.6 N, 21.41 Nm, 7 hp, and 298.7 N, correspondingly. The results of the ANOVA tests revealed that the efficiency and percentage loss of the machine were affected by operating speed and feed rate, except for the combined effects, which were due to both factors. The findings revealed that the highest grinding capacity of 894.8 kg h^{-1} was obtained at 2200 rpm operating speed as well as 10 kg min^{-1} feed rate while the lowest grinding capacity of 785 kg h^{-1} was obtained at 2000 rpm operating speed and 15 kg min^{-1} feed rate. The test's results revealed that the maximum grinding efficiency was obtained as 97.9% at 2200 rpm operating speed and 15 kg min^{-1} feed rate, and the minimum grinding efficiency was obtained as 94.3% at 2000 rpm and 10 kg min^{-1} feed rate. The test's result implied that the minimum loss percentage was noted as 4.1% on the operating speed at 2200 rpm and feed rate at 15 kg min^{-1} when operating at 2000 rpm and feed rate at 10 kg min^{-1}, the maximum loss was noted as 7.7%. This redesigned machine was cost-effective because it was fabricated from local source materials. The test results suggested that this redesigned machine was recommendable for growers of enset for grinding the enset corm.

Keywords: *Enset corm, Grinder, Grinding capacity, Efficiency, Percentage loss.*

INTRODUCTION

Enset (*Ensete ventricosum*) is one of the most extensively utilized food in southern Ethiopia and has frequently offered Ethiopians their primary source of food security because of its importance and versatility. It is the primary food source in Ethiopia's highly populated South and Southwestern areas. In the southern region of Ethiopia, it offers a sustainable food supply to roughly twenty-four million people (Blomme *et al.*, 2023). Enset plays a significant role in ensuring access to nutritious food, throughout the year generating income, protecting assets, and maintaining the availability of food. Due to its drought resistance, its adaptable plant can be grown to reduce risk and provide food for humans and animals (Tiruneh, 2020).

Ensets are grown exclusively in Ethiopia's highlands and are not widely recognized abroad (Degefa and Dawit, 2018). The domesticated enset plant is grown solely in Ethiopia (Yemata, 2020). Enset can be kept for a lengthy duration of time, both before and after the process, but it is typically harvested twice per year. It can also be collected over numerous years and every day of the year (Egizabiher *et al.*, 2020). The predominant regions in Ethiopia that produce enset are Central, South, and Southwest Ethiopia. Ensets are grown between 1100 and 3000 m overhead sea level, a yearly rainfall of 1100 to 1500 mm, and an average temperature of 10 to 22 degrees Celsius with a relative humidity of 63 to 85% (Ajema, 2022). The typical enset production for a household is 62.5 quintals per hectare. The estimated production of ensets is approximately 0.7 million tons a year on over three million hectares of land in Ethiopia (Haile *et al.*, 2020).

The most common foodstuff products of enset crops are kocho, bulla, and amicho subsequently decortication enset yields fiber as a result of the process (Teshome, 2023). Most fermented starch, commonly referred to as kocho, is made from a mixture of ground corm and decorticated leaf sheaths and is typically consumed with protein-rich foods (Tsegaye and Gizaw, 2015). For a long duration of time, it stores well. Processing and preparation take a long time, and this work is carried out by women (Tiruneh, 2020). It is now being exported from rural to city markets more frequently. In contrast to bulla and kocho, amicho does not demand processing only a part of the inner corm is eaten (Tsegaye and Gizaw, 2015).

The grinding, squeezing, and decorticating of an enset are steps in the size-minimized process. The enset corm grinding is time-wasting and laborious, necessitating technology to manage and make it easier for women during processing (Senbeta *et al.*, 2022). Along with handling daily tasks at home, it is a further duty for women and the workload persists for a lengthy period, which influences sex interactions within a household. The conventional processing methods are complex, laborious, and unhygienic, causing great stress for working women and resulting in a significant loss of grind pulp (Borrell *et al.*, 2020). Grinding enset corms by hand takes two to three hours per the whole root (8 to 15 kg).

In order to address the problem of enset corm grinding, the existing machine had to be significantly modified. The Melkassa Agricultural Engineering research team developed the machine, which had the following shortcomings: The grinding capacity of the existing machine was too low, the efficiency and percentage loss of the machine were also low, the outlet of the grinding machine was not placed in the proper inclination, the hopper of the grinding machine did not have adequate length, the inclined part of the hopper was not positioned in the proper inclination this-forced the users to use wood to push size reduced corm and the length and diameter of the drum were too small. In comparison, the redesigned machine solved the problems related to the existing one also the grinding capacity and efficiency of this machine were high with a low percentage of loss. The modified corm grinding machine primarily differs from conventional methods in that it produces excellent quality and quantity products while requiring less time and labor. There is currently a huge demand for enset by-products as a food source, and this demand is growing significantly, which implies that machine processing is necessary.

The main purposes of grinding corm with a machine are to improve the quality of processed pulp without negotiating the pulp look and to minimize the time requirement for processing. The other purpose of motorized enset corm grinding is to minimize the number of tasks that women must perform while increasing the speed at which corms are processed. Therefore, this study aimed to redesign and evaluate the enset corm grinding machine for enset growers to replace manual grinding with the machine.

MATERIALS and METHODS

Study area

A redesign and testing corm grinding machine was executed at MARC (Figure 1), located near the town of Awash Melkassa, Adama Woreda, East Shewa Zone, Oromia Regional State, 117 km east of Addis Ababa and 17 km southeast of Adama city. It is found at the elevation of 1561 m above sea level and found between 8° 24' 0" to 8° 30' 12" N, 39° 21' 0" to 39° 35' 14" E.

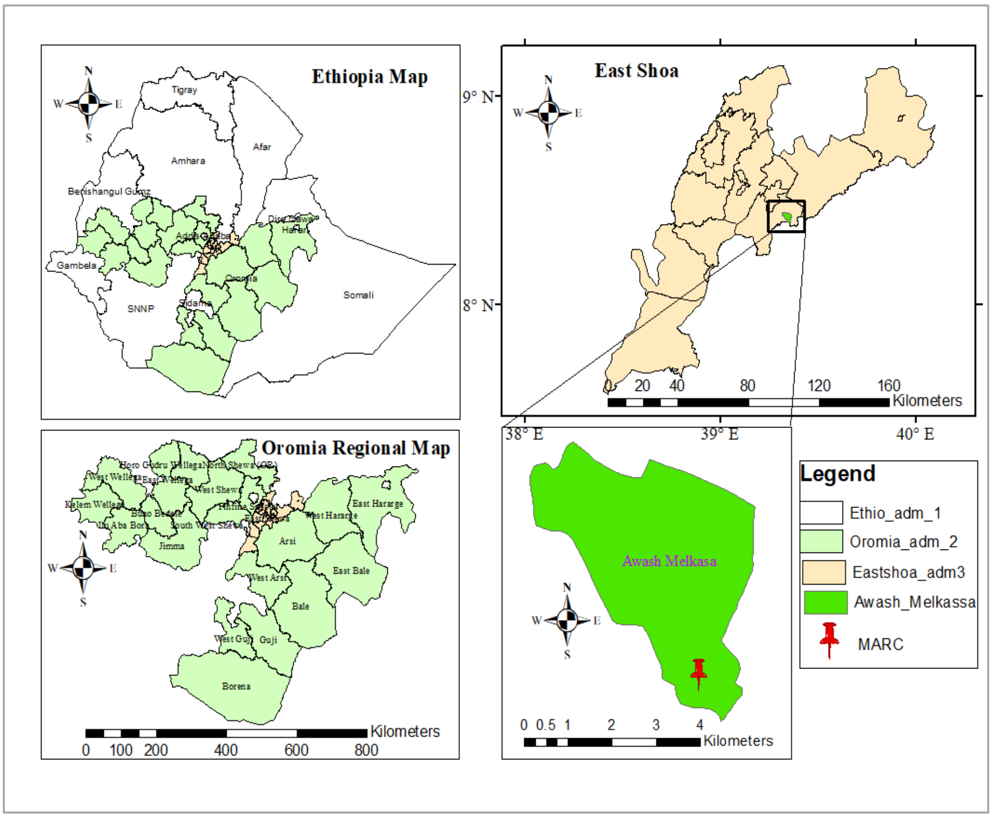

Figure 1. Study area map.

Materials

In this investigation work of simplifying enset processing, a motorized enset corm grinding machine was fabricated as a material that freely existed locally. During the modification of the existing grinding machine, the strengths of the material, as well as the mechanism were considered. The sheet metal, angle iron, shaft, pulleys, belts, bearings, bolts and nuts, and motor had been employed for the improvement of the machine. The digital caliper, tape meter, tachometer, receptacles (sacks), digital weight balance, angle of repose meter, stopwatch and other apparatus were utilized to test the machine's functionality. The test materials were acquired from Oromia, Arsi Zone, and Kulumsa Agricultural Research Centre, to conduct both initial and final assessments on the modified corm grinding machine.

Methods

Redesign considerations

Certain pertinent variables have been taken into account when redesigning the motorized enset corm grinding machine. These variables comprise the need for power, ease with which different parts can be replaced, easiness of movement, safety of part operating, and the cost of maintenance. Since the machine needs mechanical power to run, maintenance would be extremely simple. To achieve optimum function for this machine, proper considerations were made to specify and identify some problems which hindered effective performance as in the former machines, and effort was put to identify the factors and constraints as put together.

Redesign calculation

Hopper redesign

The modified enset corm grinding machine consists of a rectangular-shaped feeding hopper constructed of 2 mm thick aluminum material. The grinder hopper dimensions are 550 mm in length, 450 mm in width, and 450 mm in height. It was fastened to the cover portion and held the enset corm while being grinded. The grinder machine hopper alongside rectangular cross-section had been considered in this case, according to Khurmi and Gupta (2005), the volume of which was obtained using Equation 1 as follows:

$$V = LxWxH \tag{1}$$

Where L is the hopper's length (m), $W$is the hopper's width (m), H is the hopper's height (m), and V is the volume of the hopper (m^3).

Drum redesign

The grinding unit was constructed from a length of 650 mm, diameter of 500 mm, and thickness of 3 mm stainless steel sheet metal that was punctured to form a rough surface on which the grinding is done. The revolving grinding unit produced the constant abrasive force that the rough surface of the grinding unit applied to the enset corm. The grinding unit was powered by an engine motor that was transferred through a V-belt and moved in a circular motion. The shaft that ran through it was backed up by the bearings at each end. The grinding unit was held in place by circular discs on both ends. To guarantee optimal contact between the grinding unit and the enset corm, each grinding surface had a tooth angle of 38°. The grinding unit was cylindrical according to Khurmi and Gupta (2005), the volume of a cylinder, the circumference of the grinding unit, and the force acting on the cylinder unit were determined using Equations 2, 3 and 4 as follows:

$$V=\pi r^2 l \tag{2}$$

$$C=2\pi r \tag{3}$$

$$F=V\rho g \tag{4}$$

Where V is the volume of cylinder (m^3), C is the circumference of the grinding unit (m), F is the force in action on cylinder (N), r is the radius of cylinder (m), l is the length of drum (m), and ρ is the density of stainless steel (kg m^{-3}).

The grinding force needed by the machine for the enset corm, the power needed to grind the enset corm, and the torque needed to turn the shaft were obtained from Equations 5, 6, 7, and 8 as follows:

$$F=Mt\times g \tag{5}$$

$$P=F\times V \tag{6}$$

$$V=\frac{\pi DN}{60} \tag{7}$$

$$T=F\times r \tag{8}$$

Where Mt is the total mass (kg), P is the power needed to turn the shaft (hp), V is speed (m s^{-1}), F is force (N), D is the diameter of driver pulley (m), N is the speed of motor (rpm), T is torque (Nm), and r is the radius of driven pulley (m).

Outlet redesign

The outlet was fabricated from aluminum sheet angled at 39.7° and had a thickness of 2 mm. The outlet's inclination angle was connected, but the corm's moisture content determines its inclination of the outlet. The grinder's outlet continued at the frame, which was attached to the cover, its pathways the flow of the grind enset corm into a container as a discharge chute for grinded pulp.

Shaft redesign

The shaft's diameter under varying load conditions can be estimated using Equation 9 (Khurmi and Gupta, 2005). The ASMBE code for shafts that revolve states that when a load has been placed with only a slight amount of shock, the values of Kb = 1.2 to 2 and Kt = 1 to 1.5. Furthermore, it was noted that for the shaft with a keyway, allowable stress τ did not exceed 40 MN m^{-2} (Khurmi and Gupta, 2005).

$$d_s^3=\frac{16}{\pi\tau all}\sqrt{(KbMb)^2+(KtMt)^2} \tag{9}$$

Where d_s is the diameter of the shaft (mm), τall is allowable stress (Nm^{-2}), Mb is the bending moment (Nm), and Mt is the torsional moment (Nm).

Pulley redesign and belt selection

Pulleys are power transmission components; however, their design demands much thought. A pulley's highest pitch diameter and corresponding speeds are indicated by the horsepower rating of the drive pulley. When choosing a belt, careful consideration must be given to the types and dimensions of the standard V-belt as specified by ISO 4184. The shaft speed of the pulley and the speed of the prime mover pulley were related using Equation 10 (Khurmi and Gupta, 2005).

$$\frac{N2}{N1} = \frac{D1}{D2} \tag{10}$$

The nominal pitch length of the belt from a motor shaft to the grinding unit shaft must be determined to know the actual belt size needed to transmit power from a motor to the grinding unit. Then, nominal pitch length and center-to-center distances between pulleys can be determined using Equations 11 and 12 (Khurmi and Gupta 2005).

$$L_b = 2C_d + 1.57(D2+D1) + \frac{(D2-D1)^2}{4C} \tag{11}$$

$$C_d = \frac{(D1+D2)^2}{2} + D1 \tag{12}$$

Where L_b is length of belt (m) and C_d is distance between driving and driven pulleys (m).

According to Khurmi and Gupta (2005), the wrap angle, angle of the lap, and belt tension for an open belt can be estimated utilizing Equations 13, 14 and 15, respectively.

$$Sin\alpha = \frac{r2-r1}{c} \tag{13}$$

$$\theta = 180 \pm 2sin^{-1}\left(\frac{D2-D1}{2C}\right) \tag{14}$$

$$2.3log\left(\frac{T1}{T2}\right) = \mu\theta \tag{15}$$

Where α is the wrap angle (°), θ is the angle of lap (rad), and μ is the coefficient of friction.

Description of modified machine

The enset corm grinding machine was powered by a seven-horsepower (7hp) engine motor, which revolves at a constant operating speed. The machine mainly consists of a grinding unit, hopper, drum cover, chute, main frame, shaft, pulley, bearing, V-belt, and engine frame (Table 1). Its grinding mechanism could depend on a grinding unit when the actual grinding operation takes place. The enset corm grinder machine is easy to utilize and less complex to run due to its basic operational mechanism. This modified machine is an outstanding choice for farmers who grow enset. The grinder machine could grind at high grinding up, was fast enough, lasted longer in use with high capacity, and was accessible for farmers.

This modified machine was completely different from the existing one in different ways. The overall length of the machine as indicated (Figure 2) was 720 mm, through a width of 500 mm, besides a height of 1440 mm this indicated that the dimension was higher (Table 2) than existing one. The redesigned machine (Figure 3) was fabricated from stainless steel and aluminum but the existing one was constructed from mild steel. The reason for selecting stainless steel for the fabrication of the grinder was that it had direct contact with the foodstuff to be processed and prevent contamination. The modified machine component was larger than the existing machine (Figure 4) meaning the grinding unit diameter was 500 mm and the grinding unit length was 650 mm for the fabricated machine. For the existing machine, the grinding unit diameter was 200 mm, and the grinding unit length was 300 mm. A redesign of the feeding hopper shape ensures safe feeding and grinding.

Table 1. *Main features or components of both machines.*

No.	Redesigned and existing machine features
1	Feeding hopper
2	Grinding unit or drum
3	Drum cover
4	Chute or outlet
5	Main frame
6	Shaft
7	Pulley
8	Bearing
9	V-belt
10	Engine setting

Table 2. *Bill of materials.*

Item No.	Part number	Descriptions	Quantity
1	Frame width	(40x40x440x3) mm	2
2	Frame length	(40x40x640x3) mm	2
3	Frame height	(40x40x750x3) mm	4
4	Length support	(40x40x570x3) mm	2
5	Width support	(40x40x370x3) mm	2
6	Housing	(640x300xØ440x2) mm	1
7	Shaft	(1000xØ30) mm	1
8	Grating drum	(600xØ40x2) mm	1
9	Circular plate	(Ø40x2) mm	2
10	Discharge chute	(250x370x720x1.5) mm	1
11	Hopper	(40x50x40x1.5) mm	1
12	Bolt and nut	(M16x40) mm	24
13	Rectangular plate	(60x600x3) mm	4
14	Bearing (P206)	(Ø30*x*62x16) mm	2
15	Pulley	(Ø300xØ80x30) mm	1

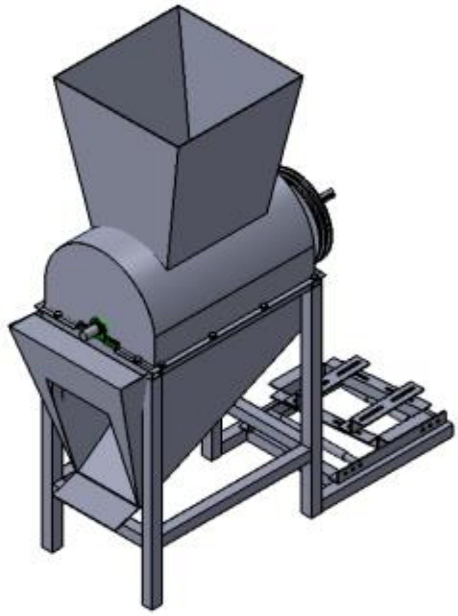

Figure 2. *3D drawing with dimensions for redesigned machine.*

Figure 3. *Redesigned machine.*

Figure 4. *Existing machine.*

Evaluation of the grinding machine

The evaluation was accomplished at an enset corm grinder at three selected operating speeds after weighing the test sample of the enset corm (Figure 6). The grinding was implemented by reducing the size of the peeled enset corm with the help of a knife. The operating speeds were selected based on studies by Kibi (2018), to evaluate the machine's effectiveness on enset corm. Three hundred kilograms (300 kg) of newly removed, clean, and without any harmful enset corm might be utilized in the studies in order to assess the grinder machine.

Evaluation of the grinder machine (Figure 5) was implemented by considering the grinding capacity, grinding efficiency, and loss. Criteria for assessment such as grinding capacity, grinding efficiency, loss, and grinding time were assessed by applying the following equations by Sogaard and Sorensen (2004).

$$\textit{Grinding capacity (kg h}^{-1}\textit{)} = \frac{Wc}{t} \tag{16}$$

$$\textit{Grinding efficiency (\%)} = \frac{Wc}{Wf} \times 100 \tag{17}$$

$$\textit{Percentage loss} = \frac{Wf-Wc}{Wf} \times 100 \tag{18}$$

Where Wc is the weight of collected mash in kilogram, Wf is the weight of corm fed in kilogram, and t is the time taken to grind in hour.

Figure 5. *Grinder during testing.*

Figure 6. *Corms for testing.*

Statistical analysis

The experiment implemented a two-factor factorial design within RCBD, and three settings speed through two feed rate levels were considered as treatment combinations. The experiment replicates three times for each treatment. Data analysis was executed using the Statistix 8 software. The significant relationship in factors was indicated using the 95% confidence interval. The comparisons between treatment means were executed by LSD at a 5% level. An analysis of variance

(ANOVA) was executed on the data utilizing a methodology suited to the experiment's design. The two-factor factorial experiment were tested using the ANOVA.

RESULTS and DISCUSSION

The various design parameters were computed, including the power required to grind the enset corm, force required to grind the enset corm, torque needed for the turning shaft and others in order to guarantee the outstanding performance of enset corm grinding machine. The criteria such as compactness, safety, ease of use, maintainability and cost-effectiveness were taken into account. So, the design calculations (Table 3) were carefully undertaken during the redesign of the enset corm grinding machine for meeting the machine's operational needs.

Table 3. *Results for design analysis.*

No.	Design criteria	Computed values	Units
1	Volume of the feeding hopper	0.1114	m^3
2	Volume of the grinding unit	0.0796	m^3
3	Circumference of grinding unit	1.267	m
4	Length of belt	1.18	m
5	Belt speed	7.7	m sec^{-1}
6	Speed ratio	1:3	
7	Belt tension	1958.6	N
8	Lap angle	2.95	rad
9	Distance between pulley	0.14	m
10	Shaft diameter	40	mm
11	Torque	21.41	Nm
12	Grinding power	7	hp
13	Grinding force	298.7	N

The grinder's machine evaluation was executed at three distinct operating speed settings (2000, 2100, and 2200 rpm) as well as the two distinct feeding rate settings (10, and 15 kg min^{-1}) at the moisture content of 56.8% (wet basis) for enset corm about grinding capacity, grinding efficiency, as well as loss. When finished enset corm grinding by the machine, weight measurements were undertaken for the grinding mash, fine mash, course mash, and grinding time. It was observed throughout the evaluation that the machine was producing the greatest amount of output while grinding the enset corm into the mash. The evaluation results revealed that the grinding machine performed incredibly well when it became grinding enset corm. The benefit-cost ratio was calculated to be 1:1.4, indicating that the utilization of the enset corm grinder for grinding corm is an economically feasible choice for enset producers.

Grinding capacity

The ANOVA for a two-factor factorial experiment was executed to test the effects on grinding capacity. The analysis of variance for effects of speed, feed rate as well as interactions for grinder machine grinding capacity was displayed in Table 4. By the findings, an analysis of the variance test illustrated that effects speed, feed rate, as well as interactions had been significant at five percent levels (5%) as shown (Table 4). The findings revealed that feed rate, operating speed, and the combined effects due to both factors affected grinder output.

***Table 4**. An analysis variance of grinding capacity.*

Source	DF	SS	MS	Fo	P	Notice
Replication	2	6.8	3.4			
Operat. speed	2	27485.9	13,742.95	312.48	0.000	Sig.
Feed rate	1	460.3	460.3	10.466	0.008	Sig.
N×Fr	2	599.7	299.85	6.817	0.013	Sig.
Error	10	439.8	43.98			
Total	17	28967.9				

Sig. = significant, Ns = non-significant, $P < 0.05$, significant at 5 % level, $P>0.05$, non-significant at 5% level.

The grinding machine's mean grinding capacity varied from 785 to 894.8 kg h^{-1}, as can be seen in Figure 7. With an increase in speed from 2000 to 2200 rpm, the grinding capacity increased from 785 to 894.8 kg h^{-1}. The capacity of the grinder began to rise with an increase in speed but was reduced by the feed rate. This result showed that the operating speed had a direct relation to the grinding capacity as well as adversely related to the feed rate (Kibi, 2018).

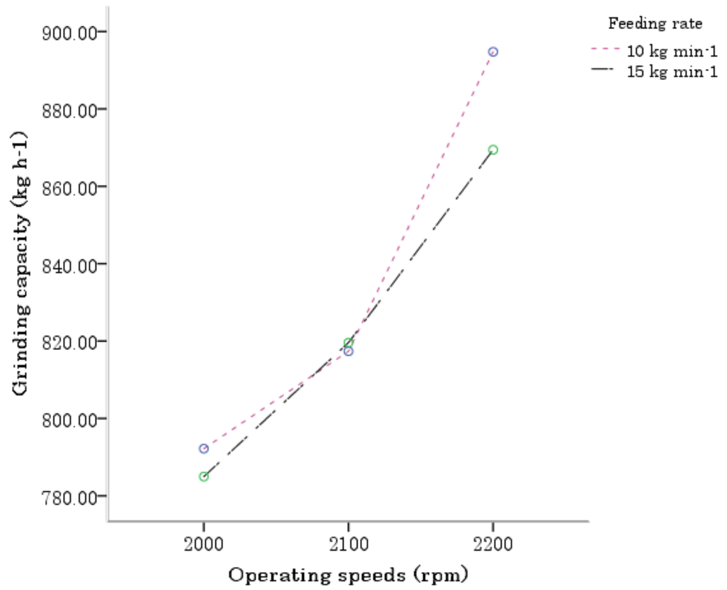

***Figure 7**. Effects of speed as well as feed rate on grinding capacity.*

The findings revealed that the maximum grinding capacity of 894.8 kg h^{-1} was obtained at 2200 rpm operating speed and 10 kg min^{-1} feed rate, while the lowest grinding capacity of 785 kg h^{-1} was obtained at 2000 rpm operating speed and 15 kg min^{-1} feed rate. However, the capacity of the existing machine was obtained as 114.94 kg h^{-1}. This result indicated that in comparison to the modified one, the existing machine's capacity had been extremely low.

Grinding efficiency

The ANOVA for a two-factor factorial experiment was executed to test the effects on grinding efficiency. The analysis of variance for effects of speed, feed rate, as well as interactions on grinder grinding efficiency as can be seen in Table 5. The ANOVA indicated that, at 5% levels, the effects of operating speed and feed rate were significant since p values were below 0.05 ($P < 0.05$). However, their combined impact was non-significant depending on the result obtained (Table 5). From the ANOVA investigation result, machine grinding efficiency was impacted by feed rate and operating speed, not including the combined effects due to both factors.

Table 5*. An analysis of variance for grinding efficiency.*

Source	DF	SS	MS	Fo	P	Notice
Replication	2	0.0379	0.01895			
Operat. speed	2	42.8926	21.4463	22.993	0.000	Sig.
Feed rate	1	5.4722	5.4722	5.866	0.044	Sig.
N×Fr	2	4.8999	2.44995	2.627	0.144	Ns
Error	10	9.3274	0.93274			
Total	17	51.3963				

Sig. = significant, Ns = non-significant, $P < 0.05$, significant at 5 % level, $P>0.05$, non-significant at 5% level.

Concerning the results, it implied that the mean grinding efficiency varied from 94.3% to 97.9%, as seen in Figure 8. The grinding efficiency ascended from 94.3% to 97.9% as the speeds increased from 2000 to 2200 rpm. As operating speed and feed rate increased, its grinding efficiency also increased. This suggests that the operating speed and feed rate of the material being tested ought to directly influence grinding efficiency.

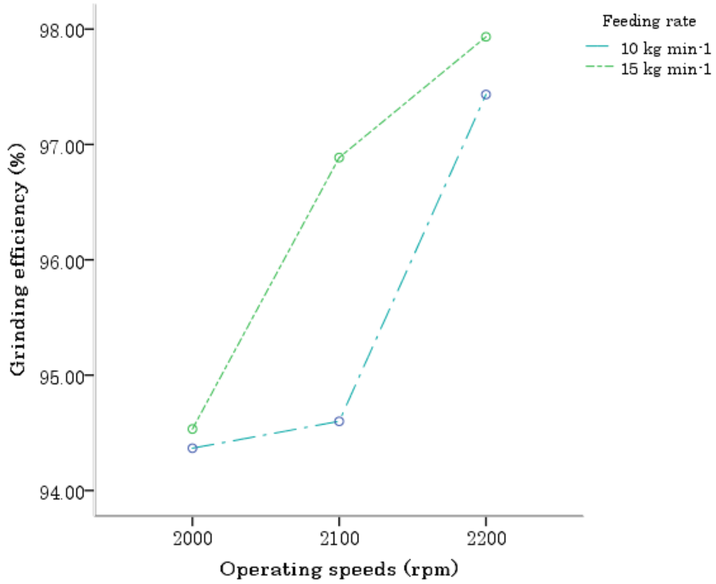

Figure 8*. Effects of operating speed and feed rate on grinding efficiency.*

The test's results revealed that the maximum grinding efficiency was obtained as 97.9% at 2200 rpm operating speed and 15 kg min^{-1} feed rate, and the minimum grinding efficiency was obtained as 94.3% at 2000 rpm and 10 kg min^{-1} feed rate. The similar trend was reported by Kibi (2018).

Percentage of loss

The ANOVA for a two-factor factorial experiment was executed to test the effects of the loss. The analysis variance effects of speed, feed rate, and interactions on grinder loss can be seen in Table 6. The result of the analysis of variance revealed that, at 5% levels, the effect speed as well as feed rate was significant since p values were below 0.05. However, their combined effect was non-significant depending on the results presented (Table 6). From the results of ANOVA, the machine percentage of loss was affected by feed rate and operating speed except for the combined effects due to both factors.

***Table 6**. An analysis of variance for a percentage of loss.*

Source	DF	SS	MS	Fo	P	Notice
Replication	2	0.0415	0.02075			
Operat. speed	2	42.7548	21.3774	22.99	0.000	Sig.
Feed rate	1	5.5613	5.5613	5.982	0.042	Sig.
N×Fr	2	4.9295	2.46475	2.651	0.142	Ns
Error	10	9.2958	0.92958			
Total	17	52.3385				

Sig. = significant, Ns = non-significant, P < 0.05, significant at 5 % level, P>0.05, non-significant at 5% level.

In accordance with the test findings, the grinder machine's mean percentage of loss varied between 4.1% and 7.7%, as shown in Figure 9. With a rise in speed from 2000 to 2200 rpm, the loss was reduced from 7.7% to 4.1%. The machine's percentage of loss was found to decrease in tandem with a higher feed rate and operating speed. It suggests that there was an adverse association of the percentage of loss with the test material's feed rate and operating speed of the machine.

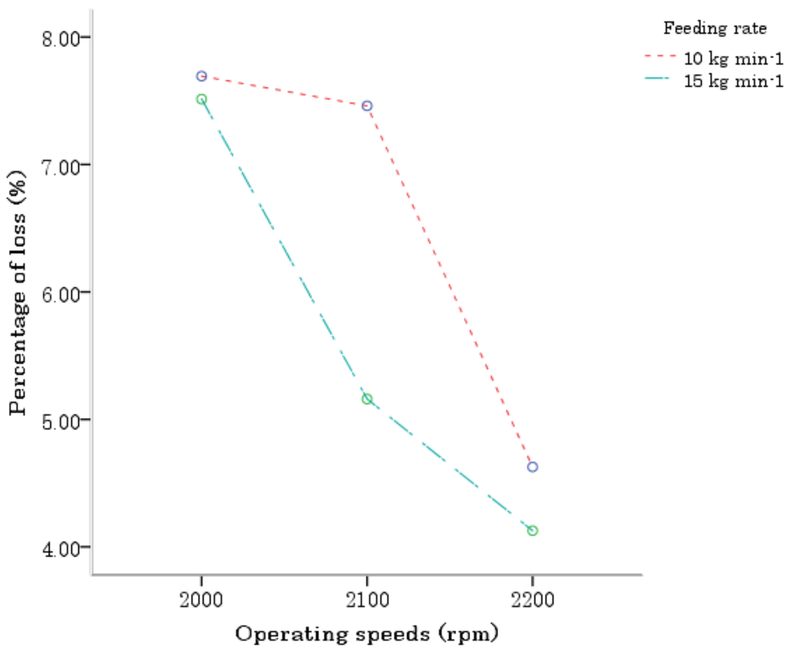

***Figure 9**. Effects of operating speed and feed rate on loss.*

According to test results, the minimum percentage of loss was noted as 4.1% at speed of 2200 rpm and feed rate 15 kg min^{-1}, when operating at 2000 rpm and feed rate of 10 kg min^{-1}, while the highest loss was noted as 7.7%. Considering that the 2200 rpm operating speed had a small percentage of loss when compared to both other speeds.

Grinding time

The ANOVA for a two-factor factorial experiment was executed to test the effects on grinding time. The ANOVA for the effects of speed, feed rate, and interactions on grinder grinding time can be seen in Table 7. The result implied that, at 5% levels of significance, the operating speed and feed rate were significant since p values were smaller than 0.05 ($P < 0.05$). However, their combined effects were not significant based on the results obtained (Table 7). From the results of ANOVA, the machine grinding time was influenced by the feed rate and operating speed, not including the combined effects.

***Table 7**. An analysis of variance for grinding time.*

Source	DF	SS	MS	Fo	P	Notice
Replication	2	0.53	0.265			
Operat. speed	2	1791.9	895.95	112.556	0.000	Sig.
Feed rate	1	12361	12361	1,552.8	0.000	Sig.
N×Fr	2	37.4	18.7	2.34924	0.200	Ns
Error	10	79.6	7.96			
Total	17	14047.5				

Sig. = significant, Ns = non-significant, $P < 0.05$, significant at 5 % level, $P>0.05$, non-significant at 5% level.

From the test results, the grinder machine's mean grinding time varied between 186 and 260 seconds at a 2200 rpm operating speed with a feed of 10 kg min^{-1} and at a 2000 rpm operating speed with a feed of 15 kg min^{-1} (Figure 10). Generally, the result shows that there had been a tendency for the machine's grinding time to reduce as it raised the operating speed and lowered the feed rate.

As a result, the grinding time was inversely related to the operating speed but closely related to the feed rate of the enset corm, which was for the reason greater operating speed were executed faster than lower operating speed.

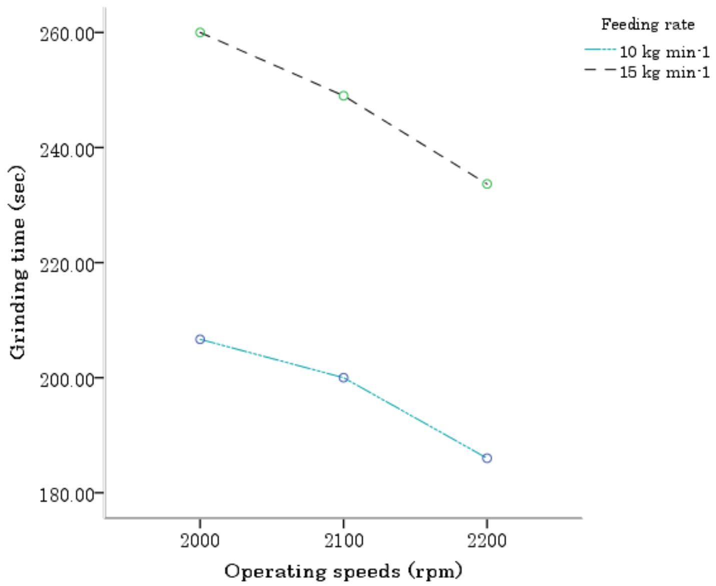

Figure 10. *Effects of operating speed and feed rate on grinding time.*

The lowest grinding time (186 seconds) was achieved with a speed of 2200 rpm and a feed rate of 10 kg min^{-1}, while the highest grinding time (260 seconds) was achieved with a speed of 2000 rpm and a feed rate of 15 kg min^{-1}, contingent on the test results. The grinding time decreased from 260 to 186 seconds at a speed increase of 2000 to 2200 rpm.

Mean separations of treatment means

As given below in Table 8, the LSD all pairwise comparison tests for grinding capacity, grinding efficiency, percentage of loss, and grinding time were carried out for each treatment. In order to identify significant differences between treatment means, this analysis was then exposed to the least significant difference in all pairwise comparison tests for variables for the levels of operating speed and the levels of feed rate. The results of all pairwise comparison tests with the LSD (Table 8) revealed that the treatment means wasn't different at the 5% level. Still, in the case of grinding time, all six means differed from one another at the 5% level.

Table 8. Comparisons between treatment means.

No.	Treatment combination	Operating Speeds (rpm)	Feeding rate (kg min^{-1})	Grinding capacity (kg h^{-1})	Grinding efficiency (%)	Percentage of loss (%)	Grinding time (sec)
1	N1F1	2000	10	792.19^{c}	94.37^{a}	7.693^{b}	206.67^{d}
2	N1F2	2000	15	784.97^{c}	94.53^{a}	7.513^{b}	260^{a}
3	N2F1	2100	10	817.37^{d}	94.6^{a}	7.46^{b}	200^{e}
4	N2F2	2100	15	819.6^{d}	96.89^{b}	5.16^{a}	249^{b}
5	N3F1	2200	10	894.77^{b}	97.43^{b}	4.6267^{a}	186^{f}
6	N3F2	2200	15	869.43^{a}	97.93^{b}	4.1267^{a}	233.6^{c}
7	Grand mean			829.7	96.1	6.09	222.56
8	CV			0.79	0.94	14.85	1.18

N = Speed, F = Feeding rate and CV = Coefficient of variation

CONCLUSION

The grinder's machine evaluation was executed at three distinct operating speed settings (2000, 2100, and 2200 rpm) as well as the two distinct feed rate settings (10 and 15 kg min^{-1}). An investigation has been done on the grinder about grinding capacity, grinding efficiency, percentage of loss, and grinding time. The benefit-cost ratio was calculated to be 1:1.4, indicating that the utilization of the enset corm grinder for grinding corm is an economically feasible choice for enset producers. The results of design calculations implied that the volume of the feeding hopper, volume of the grinding unit, length of the belt, speed ratio, lap angle, shaft diameter, belt tension, torque, the power required to grind, and force required to grind were obtained as 0.1114 m^3, 0.0796 m^3, 1.18 m, 1.3, 2.95 rad, 40 mm, 1958.6 N, 21.41 Nm, 7 hp, and 298.7 N, correspondingly. The results of the assessment revealed that when the speed was raised from 2000 to 2200 rpm, the grinding capacity of the machine raised from 785 to 894.8 kg h^{-1}, whereas the grinding efficiency raised 94.3% toward 97.9%, and loss dropped to 4.1% from 7.7%. The results of all pairwise comparison tests with the LSD indicated that the treatment means weren't different at the 5% level, but in the case of grinding time, means were differing from one another.

DECLARATION OF COMPETING INTEREST

The author declares he have no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The author declared that the following contributions is correct.

Amanuel Erchafo ERTEBO: The author would like to declare that he solely developed all the sections in this manuscript including Investigation, Methodology, Conceptualization, Formal analysis, Data curation, Validation, Writing - original draft, Review, and Editing, Visualization.

ETHICS COMMITTEE DECISION

This article does not require any Ethical Committee Decision.

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