Development And Performance Evaluation Of Hand Operated Dry Coffee Dehulling Machine For Smallholders Farmers

[1]**Tamiru Dibaba,**
Oromia, Agricultural Research Institute, Jimma
Agricultural Engineering Research Center
P.O. Box 386, Jimma, Ethiopia.
tamdibaba@gmail.com

[2]**Rabira Wirtu,**
[3]**Takleweld Dabi**
Oromia, Agricultural Research Institute, Jimma
Agricultural Engineering Research Center
P.O. Box 386, Jimma, Ethiopia.

***Abstract*—Coffee is the most important cash crop for our country which ranked as the fifth trade commodity after wheat, cotton, maize and rice. Therefore, the mechanism of coffee processing is direct related to the quality of coffee. hence, to increase the quality of coffee and decreasing the labour required to process the coffee as well as to minimize the postharvest losses, Jimma Agricultural Research Center developed the manual operated coffee dehuller. During testing of this machine, the experiment was conducted in a factorial design. The maximum shelling capacity of the machine was 88.10kg/hr was obtained at 10mm clearance between two drums while the maximum shelling efficiency and minimum mechanical damage was 96.277% and 1.16% observed respectively. Finally, from these results, we recommended that the machine is best for farmers who produce small coffee and use for local market.**

Keywords—development performance dehuller coffee

1. INTRODUCTION

Agriculture is the most important economic sector of the country. According to the data from the Central Statistical Agency (CSA, 2008/2009) it contributes 45% of the GDP, 85% of the foreign earnings and employs around 83% of the total population of the country.

Coffee ranks as one of the world's most valuable and widely traded commodity crops and is an important export product of several countries. Coffee ranks as one of the world's most valuable and widely traded commodity crops and is an important export product of several countries. Worldwide there are about 20 million coffee farming families and around 100 million people depend on coffee for their livelihoods. Arabica Coffee is believed to originate in humid high rain forests of south and south western Ethiopia. Coffee ranked as the fifth most important trade commodity after wheat, cotton, maize, and rice. Ethiopia is a major source of genetic resources for origin and diversity of Coffee arabica. Ethiopia is well known not only for being the home of Arabica coffee, but also for its very fine quality coffee acclaimed for its aroma and flavor characteristics. The coffee that is distinguished for such unique characteristics include Sidamo, Yirgachafe, Harar, Gimbi, Jimma and Limmu coffee types [1]. Jimma Zone is one of coffee growing zones in the Oromia Regional State, which has a total area of 1,093,268 hectares of land [5]. Currently, the total area of land covered by coffee in the zone is about 105,140 hectares, which includes small-scale farmers' holdings as well as both state and private owned plantations. Out of the 40–55 thousand tons of coffee annually produced in the Zone [5], about 28-35thousand tons is sent to the central market, while the remaining is locally consumed. Nowadays, Jimma Zone covers a total of 21% of the export share of the country and 43% of the export share of the Oromia Region, of which Gomma Woreda takes the largest share of the region [5] as cited in [1]. Even though coffee has long history of production and favorable climatic conditions in Ethiopia, coffee quality is declining from time to time due to several improper pre and post harvest management practices. These are mainly associated with poor agronomic practices like lack of stumping, pruning and weeding [11]. Other factors like climate, genetic makeup of plants and institutional effects can also affect coffee production, productivity and finally coffee quality. According to the International Organization for Standardization (ISO), quality is a set of inherent characteristics of product, system or process which fulfils the requirement of customers and/or interested parties. These inherent characteristics are collectively called attributes. Coffee quality is attributable to its botanical variety, weather and topographical conditions, handling and care during growing, harvesting, storage, preparation for export and transport. Increasing production and supply of good quality coffee is important for coffee exporting countries. Therefore, providing good quality coffee ensures sustained competiveness on the world market.

Traditional dehulling of cereal grains is a time consuming, labour intensive, but important task performed by women in rural areas in developing countries. Dehulling separates the outer envelope, which contains both non-nutritional and organoleptically unacceptable factors, from the edible portion of the grain. Traditional dehulling, which is done by women, involves pounding the dry grain in a mortar with a pestle. There is need to reduce post-harvest losses, labour cost and high energy input and generally encourage coffee production in quality and quantity to meet international and market requirement, this calls for application of mechanical methods to coffee production. there were different manual operated dehullers are there in Ethiopia such as Bako made manual coffee dehuller,Harar made coffee dehuller and Jimma made coffee dehullers. but all the existing dehullers were not effective according to [4]. The performance parameters of each huller were considered based on quality of coffee delivered at the end of operation. Then shelling efficiency, shelling capacity and percentage breakage of Bako, Jimma and Harar model manual operated coffer hullers were computed with employed formulae by varying feed rates. In scientific test, for coffee moisture b/n 10-15%, percentage breakage should never exceed 3% if it happens the problem exists with coffee processing units. In all test, Bako and Harar model manual operated coffee hullers are not suggested for shelling dry coffee. Whereas for the case of Jimma model, at feed rate of 0.5kg/min its efficiency seems higher but still breakage percentage is more or less equal to 3% which is not recommended. Therefore, feed rate of 0.8 kg/min is suggested for good output since it's breakage percentage is far below recommended one and capacity is highest. In whole testing process, Jimma model manual operated coffee huller becomes outstanding performer in each step. Despite this, the huller has several drawbacks: the concave part is not adjustable so that some of the coffee bean escapes without being shelled during operation, it has no force or speed multiplier that enhances general operation, the size of drum and concave are so small.

Objectives

- To develop and evaluate the dry coffee dehuller for small scale house hold

2. MATERIALS AND METHODS

Study area

The prototype was produced in Jimma Agricultural research center and primary testing of the machine was done at the center. Finally the testing of machine was done at Mana woreda of Jimma zone

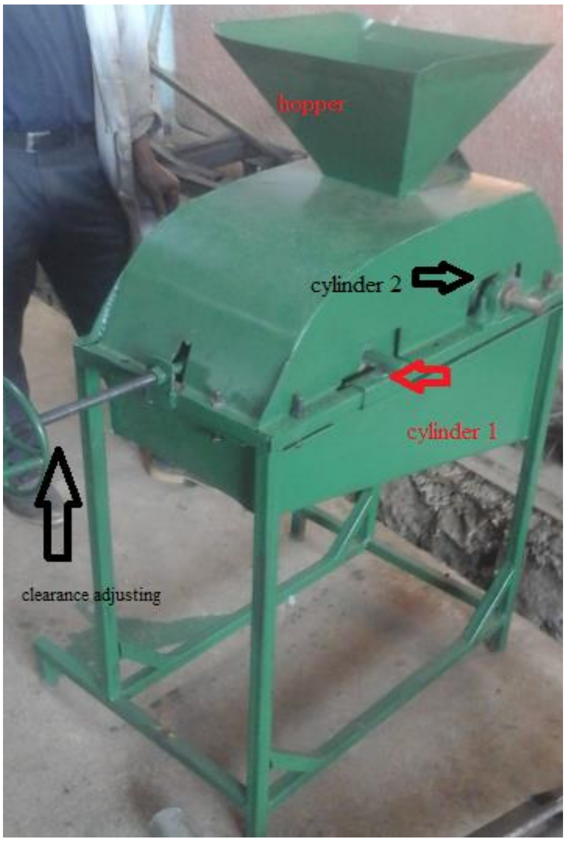
Material Selection:

the materials would be critically considered based on strength, availability, durability and corrosiveness to prevent machine damage, ease construction work and maintenance and prevent rusting or corrosion of the machine parts hence, mild steel angle iron -would be used for the frame and drum made of sheet metal and round bar for the threshing chamber.

Design Consideration

A number of points would be considered during the design. Such points include the cost of construction, power requirement of the machine and labour requirement in operating the machine. Also considered in the design would be the ease of replacement of component parts in case of damage or failure. The design considerations included use of gravity and minimum friction to reduce power requirement, economy and ergonomics, machine efficiency and product quality, simple operational and maintenance requirements to meet the need of local farmers and small scale industrialist, portability and detachability for easy transportation and low grain damage. In addition to this the capacity, angle of repose of parchment coffee and space are important factors considered.

Description of the machine



POWER REQUIRED TO DEHULL THE COFFEE SEED

Centripetal force which results from the rotation of the drum/cylinder breaks the hull and separates it from the bean. this force was determined according to [3] as follows:

$$Ph = T\omega$$

T = torque of the shaft
ω = angular speed of the shaft

Seed physical properties

To determine the physical properties of coffee, randomly selection of the beans were taken and the measurement was done using a digital calliper of sensitivity of 0.01mm. therefore, from the length (L), width (W) and thickness (T) of the beans measured, the following parameters were determined using equation given by [2].

- **Arithmetic diameter**

$$Da = \frac{L + W + T}{3}$$

- **geometric diameter**

$$Dg = \sqrt[3]{LWT}$$

- **sphericity**

$$S = \frac{\sqrt[3]{LWT}}{L}$$

Angle of repose

The angle of repose (θ) was determined by using an empty cylindrical of 50 mm diameter and 75 mm height. The cylinder was placed at the centre of galvanized iron plate, filled with coffee seeds and raised gradually until it forms a cone of seeds. The height of the cone was measured and the filling angle of repose was calculated by the following relationship [9].

$$\theta = \tan^{-1}(2H/D)$$

- Where H and D represents height and diameter of cone respectively

Static coefficient of friction

The static coefficient friction (μ) for the beans was measured against the surface of galvanized iron sheet by using a cylinder of diameter 50 mm and 75 mm depth filled with coffee beans. While the cylinder resting on the surface, it was raised gradually until the filled cylinder just started to slide down [10]. The static coefficient of friction was then calculated from the following relationship.

$$\mu = \tan(\sigma)$$

- Where μ is the coefficient of friction and α is the angle of tilt in degrees

Performance Evaluation of the Machine

The test carried out on the machine includes:

Moisture Content: The moisture content would be determined using conventional oven drying method with the aid of an electric weighing balance, oven dryer, can and coffee seeds. The seeds would be dried in an electric thermostat heated dry box a temperature of 103°C for 24 hours and computed on wet basis using the following Equation:

$$Mcwb = \frac{Wwp - Wdp}{Wwp}$$

Where: $Mcwb$ was the Moisture content in wet basis, Wwp was the Weight of wet product (g) and Wdp was the Weight of dry product (g).

ii. **Threshing Efficiency**: computed using the equation given by:

$$Te = 100 - \frac{Uthr}{Thr} * 100$$

Where: T was the Threshing efficiency (%), Uthr- was the Quantity of unthreshed coffee seeds and Thr- was the Quantity of threshed grain in sample

iii. **Capacity of the Machine**: The capacity of the machine was calculated by using the formulae:

$$capacity of\ the machine = \frac{mass\ of\ the\ output}{duration of\ operation}$$

Data collection

- machine parameter
  - threshing efficiency
  - percentage of breakage
  - threshing capacity
  - feeding rate
- crop parameter
  - arithmetic diameter
  - geometric diameter
  - sphericity
  - angle of repose
  - static coefficient of friction

Data analysis

A factorial design (feeding rate, clearance between drum and replication) experimental setup was used. The treatments under study are the feeding rate and clearance between two drum. To test the thresher, two clearance was selecting and the three feeding rate was applied at three replications and the statistic 8 software would be used to analysis the result.

RESULTS AND DISCUSSION

Power required for hulling

Centripetal force which results from the rotation of the drum/cylinder breaks the hull and separates it from the bean. This force was determined according [8] as follows:

$$F = m\omega^2 r$$

$$\omega = \frac{2\pi N}{60}$$

According to [3]:

$$P = T\omega$$

$$T = Fr$$

$$F = m\omega^2 r$$

Where,

F force produced by cylinder (N)

m mass of cylinder (kg)

w angular velocity of cylinder (rad/sec)

using the above equation, we could calculated the power required to hulling the coffee:

$$F = 24 * (\frac{2\pi * 77.3}{60})^2 * 0.125$$

$$= 196.37N$$

$$T = Fr$$

$$= 196.37 * 0.125$$

$$= 24.5Nm$$

$$P_h = T\omega$$

$$= 24.5 * \frac{2\pi * 77.3}{60}$$

$$= 0.198KW$$

The total power required to run this machine considering 10% loses was:

$$P_t = P_h + 0.1P_{sh}$$

$$= 0.198 + 0.0198$$

$$= 0.218KW$$

Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 6 Issue 1, January - 2019

Seed physical properties

To determine the physical properties of coffee, randomly selection of the beans were taken and the measurement was done using a vernier calliper of sensitivity of 0.01mm. Therefore, from the length (L), width (W) and thickness (T) of the beans measured, the following parameters were determined using equation given by [2] shown above and summarized in the table below.

Table 1. Physical properties of coffee bean

parameters	**Arithmetic mean (mm)**	**Geometric mean (mm)**	**Sphericity**	**Repose angle (^{0})**	**Static coefficient of friction**	**Moisture content (%)**
Values	10.79	10.64	0.81	25.22	0.32	10.64

PERFORMANCE OF THE MACHINE

Working principle of the machine

Before starting to shell the coffee, the clearance between two drums should be adjust to minimize the breakage of the beans and the unshelled seeds. After adjusting the clearance, the coffee seed is loaded directly into the hopper. Parchment coffee flowed under gravity to the dehulling unit where impact force of the rotating drum split/remove the beans from the parchment through the combination of stripping, rubbing and impact action. Shelled beans, unshelled coffee, chaffs/parchment and foreign materials are fall in one direction on one plate.

The shelling capacity of the machine

At a moisture content of 10.62%, the maximum shelling capacity of the machine was **88.1kg/hr** obtained at combined effect of 1.5kg/min feeding rate and 10mm drum clearance respectively as shown in the table 2. There were significantly different among the combined effect of feeding rate and 10mm drum clearance. But for 8.5mm drum clearance, there were no significantly different among them. the shelling capacity was better than others when compared to all those studied by [4] such as Jimma model, Bako model and Harar model having 51.6kg/hr, 33.6kg/hr and 30kg/hr respectively.

Table 2. Effect of feeding rate and drum clearance on shelling capacity

Combined effect (F*C)					**Main effect**	
Feeding rate (kg/min)	Clearance b/n two drum(mm) 8.5	10	Feeding rate(kg/hr)	Mean	Clearance (mm)	Mean
1.4	81.477^a	85.04^a	87.41	83.26^a	8.5	80.517^a
1.5	79.383^a	88.10^{ab}	89.42	83.742^a	10	85.75^b
1.6	80.69^a	84.103^b	93.02	82.397^a		
Grand mean						85.75
CV (%)						1.98
P- value						0.018

the mean followed by same letter in the column has no significantly different

Similarly, according to [7] the human mechanical efficiency, through-put capacity and grain handing capacity are 45%, 26.67kg/hr and 21.1kg/hr at a biomaterial test weight of 20kg with actual shelled weight of 15.8kg at a shelling time 45 minutes.

Shelling efficiency

At a moisture content of 10.62%, the coffee seeds were perfectly shelled at combined effect of 1.6kg/min feeding rate and 10mm drum clearance **96.277%** efficiency. The shelling efficiency of the machine was depends on the clearance between two drums and also the rubbing mechanism attached below the drums and the mass of the coffee induced into the shelling drum. as shown in the table 2, there were no significantly different among person running the machine on shelling efficiency. this indicate that the shelling efficiency is not based on the person who running the machine except the adjustment of the machine. This machine had good shelling efficiency when compared to all those studied by [4] such as Jimma model, Bako model and Harar model having 80%, 66% and 70% respectively.

Table 3. Effect of feeding rate and drum clearance on shelling efficiency

Combined effect (F*C)			**Main effect**			
Feeding rate (kg/hr)	Clearance b/n two drum(mm) 8.5	10	Feeding rate(kg/hr)	Mean	Clearance (mm)	Mean
1.4	88.647^{a}	95.123^{a}	87.41	91.135^{a}	8.5	88.288^{a}
1.5	89.317^{a}	94.463^{a}	89.42	90.82^{b}	10	95.719^{b}
1.6	88.193^{a}	96.277^{a}	93.02	94.055^{b}		
Grand mean						92.003
CV (%)						2.32
P- value						0.0371

Five concaves with different bar spacing, rod spacing and bar height were used to thresh hand harvested corn, using constant cylinder speed and constant cylinder-concave clearance. Increased concave open area resulted in increased concave separation efficiency, shelling efficiency and decreased kernel damaged. Amount of non grain materials passing through the concave increased with increasing concave open area [6].

Mechanical damage

At a moisture content of 10.62%, the minimum broken percentage was 1.16% obtained at combined effect of1.4kg/min feeding rate and 10mm drum clearance. this percentage of broken was occurred due to the adjustment of clearance between two drums and non uniformity of coffee dimensions. [6] Studied that, increased concave open area resulted in a decreased kernel damaged.

This percentage of breakage was low related to the others machines studied by [4] such as Bako model and Harar model which had 4% and 5% respectively except Jimma model which had 0.2%.In scientific test, for coffee moisture b/n 10-15%, percentage breakage should never exceed 3%.

Table 4. Effect of feeding rate and drum clearance on mechanical damage

Combined effect (F*C)			**Main effect**			
Feeding rate (kg/hr)	Clearance b/n two drum(mm) 8.5	10	Feeding rate(kg/hr)	Mean	Clearance (mm)	Mean
1.4	3.3733^{a}	1.16^{a}	87.41	2.2667^{a}	8.5	3.2689^{a}
1.5	2.9933^{a}	1.1767^{a}	89.42	2.085^{a}	10	1.2442^{b}
1.6	3.44^{a}	1.39^{a}	93.02	2.415^{a}		
Grand mean						2.2556
CV (%)						13.80
P- value						0.2199

CONCLUSION AND RECOMMENDATION

Conclusion

A coffee seed shelling machine was developed and evaluated. the following conclusion were drawn:

- the average shelling efficiency of the machine is 96.28% at a moisture content of 10.62% wet basis
- the maximum shelling capacity of the was about 88.1kg/hr

- the minimum un-shelling efficiency of the machine was 3.72% at a moisture of 10.62%
- the minimum percentage of breakage was 1.16%

Recommendation

- The developed coffee dehulling machine had good shelling capacity, shelling efficiency and small percentage of breakage which means that it was accepted
- This result was obtained where the clearance between two drums is adjusting on best position before starting to hulling the coffee and grading of coffee seeds done
- Finally, it was recommended that due to its good performance gained, this coffee dehuller was appropriate for small scale coffee producers.

REFERENCE

[1] Anwar Abasanbi (2010). Evaluation of coffee quality and its problem in Oromia regional state. MSc thesis, submitted to post graduate school of Jimma University College of Agriculture and Veterinary Medicine.
[2] A. Baryeh, Edwar (2002). Physical properties of millet Journal of Food Engineering
[3] G.Gbabo, I.M. Gana and M. S.Amoto. "design fabrication and testing of a millet thresher". net journal of agricultural science. Vol.1(14),100-106. avaliable at www.netjournals.org/pdf/NJAS/2013/4/13-033.PDF,2013.

[4] Gutu B. and Ashebir H., 2011. comparative performance evaluation of different manual operated coffee hullers.
[5] JZARDO (2008). Jimma Zone Agricultural and Rural development office. Annual report for year 2007/08,Jimma, Ethiopia.

[6] Norris, E. R. And G. L. Wall (1986). Effect of concave design factors on cylinder-concave performance in corn.Canadian journal of Bioengineering.

[7] Nwakaire et al.(2011). Design, construction and performance analysis of a maize thresher. NIGERIAN JOURNAL OF TECHNOLOGY

[8] T.A.Adekanye, A.B. Osakpamwan and I.E.Osaivbie."evaluation of a soyabean threshing machine for smallscale farmers". Agric.Eng. Int:CIGR Journal. Vol.18(2).426-434. available at http:/www.landmarkuniversity.academia.edu/TIMOTHYADEKANYE,2016.

[9] Ozguven F. and Kubilay V., 2004. Some physical, mechanical and aerodynamic properties of pine (Pinus pinea) nuts. J. Food Eng., 68, 191-196

[10] Seyed M. A. Razavi and Elnaz Milani (2006). Some physical properties of the watermelon seeds African Journal of Agricultural Research Vol. 1 (3), pp. 065-069, October, 2006 Available online at http://www.academicjournals.org/AJAR ISSN 1991 - 637X © 2006 Academic Journals

[11] Tena Gobena (2011). Coffee production system as tool for rehabilitation of degraded land in case of Haru. MSc Thesis submitted to post graduate of Jimma University College of Agriculture and Veterinary Medicine.pp.67-74.