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RESEARCH ARTICLE

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DESIGN AND DEVELOPMENT OF ENGINE OPERATED COFFEE DEHULLING MACHINE

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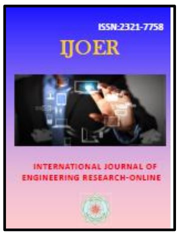

ABSTRACT

About Sixty-five percent of the country's coffee production is from Oromia region. In spite of the facts that coffee is highly economical and can boost the farmer's revenue but it is not to the potential. This may be attributed to inadequate processing technology as result of the high level of drudgery involve in the shelling of the coffee bean by manual method. Hence, Bako Agricultural Engineering Research Center (BAERC) decided to develop and evaluate engine operated that can be affordable by the farmer. The main components of the coffee dehulling include hoper, drum, concave, cleaning unit, delivery unit and frame. The experimental was conducted in a split- plot design having drum speeds in main plots, rear concave clearance in sub-plots with three replications as block. The optimum shelling efficiency of 93.80% was observed when the drum was operated at velocity of 500 rpm and 2cm rear concave clearance; whereas the minimum shelling efficiency of 86.80% was observed when the drum speed was 450 rpm & rear concave clearance was 6mm. At those combination the shelling capacity, mechanical damage and cleaning efficiency of 241.37 and 218.07kg/hr, 5.56 and 3.49% and 88.13 and 87.59% were obtained, respectively. From the results obtained, regarding to performance of the machine, it can be concluded that the machine can be used by the farmers to dehull coffee at small scale level.

Key words: Design, development, evaluation, coffee bean, dehulling

1. Introduction

Coffee crop is indigenous plant in Oromia region. It is being planted formerly at small and large scale level in the region with the farmers and planted by landlords in previous emperor. However, it is grown in nature. About Sixty-five percent of the country's coffee production is from Oromia region. Approximately, around 617,700 households are involved in coffee production (Oromia Coffee Farmers Cooperative Union, 2002). It is one of very precious items which generate income for farmers and key to country's economy.

Even though, coffee is produced by many housed holds, small scale coffee owner may face constraint in use of very sophisticated coffee processing units. Different manual operated coffee hullers from different centers were collected and tested. Due to its limitation of shelling capacity, (51.6kg/hr for Jima model at feed rate of 0.5kg/min according to GutuBirhanu and AshabirHailu, 2011), the technology was not used by farmer for mass production rather than seed shelling.

Additional, large scale coffee bean shelling is available at union but because of its cost the farmer cannot afford it and ordered to sell coffee bean to the union with less cost.

In spite of the facts that coffee is highly economical and can boost the farmer's revenue but it is not. This may be attributed to inadequate processing technology as result of the high level of drudgery involve in the shelling of the coffee bean by manual method.Hence, BAERC decided to develop and evaluate engine operated that can be affordable by the farmer.

Objectives:

To design and develop engine operated coffee shelling machine

To evaluate the performance of the machine

2. Material and Method

2.1. Experimental Site

The machine was fabricated Bako Agricultural Engineering Research Center (BAERC), which is located in WestShoaZone of Oromia National Regional State, Ethiopia. The Center lies between 90 04'45'' to 90 07'15''N latitudes and 37002' to 37007'E longitudes.

2.2. Materials of the experiments are:

- Sensitive balance.
- Tachometer (Cole-parmer 8204), ranged from 60 to 19999 rpm, resolution 1 rpm to measure the rotating speed of cylinder and blower.

2.3. Constructions of Machine Components

The construction of the machine was carried out according to specified dimensions and materials on design for component of the machine. Materials for machine components are mentioned under the design of its main components as following.

2.4. Description of the Machine Components

The main components of the coffee dehulling include hoper, drum, and concave, cleaning unit, delivery unit and frame.

Figure 1.The pictorial picture of the sheller. A – Hopper, B – Drum unit, C – Sieve, D – Delivery unit, E – Frame, F – Fan

2.5. Fabrication of the Machine Components

Frame: The frame carries the entire components of the machine. It is a trapezoidal shaped structure constructed from 40 by 40 mm square pipe based on standard minimum ratio of the frame lengths, given as L1/L2 = 0.5, (Shirgley 1980, Hannah and Stephens 1980). This was done to provide stability and make it easily transportable.

Hopper: The hopper feeds the coffee bean to be shelled into the shelling unit. The material shall be used for the construction is iron sheet metal of 1.5mm thickness. The hopper is semi circularly shaped and extended upwards, with the inlet tilted 30 degree to the horizontal to prevent splashing out of coffee bean during shelling and depends on the angle repos of unshelled coffee bean. The beans to be shelled fall into the shelling unit by gravity through the feed table and the feeding rate shall be controlled by the control gate.

Cylinder unit: The shelling cylinder carried out the function of actually breaking the bean, releasing the kernel from the coffee bean. It was closed ended rotating cylinder with round bar welded on drum and made up of two circular plates diameter of 40cm and length of 40cm, which is drilled at the center to allow 30mm diameter shaft to pass through.

Concave: The concave clearance was adjustable and round bar of 6mm diameter was welded at space of 6mm and fitted to the cylinder length. The sizes of kernel was measured using caliper to measure the minor (thickness), major (length) and intermediate (width) diameters to determine the space between the round bar of the concave.

Cleaning unit

Fan : It is centrifugal type. The fan was consists of straight blades, welded on shaft inside a casing. The fan casing shall be spirally shaped for greater blowing efficiency.

Sieves :Additionally two stage sieve was used in order to separate shelled and unshelled coffee. The sieve hole of oval shape was used by shifting two sieve drilled by 12mm based on the geometric mean diameter the kernel.

2.6. Experimental Design

The experimental was conducted in a split- plot design having drum speeds in main plots, rear concave clearance in sub-plots with three replications as block.

The details of the treatments were:

- Three levels of drum speeds V1 = 450rpm, V2= 500rpm and V3 = 550rpm (Ogunlade et al., 2014).
- Two levels of rear concave clearance C1 = 2mm and C2 = 6mm,

2.7. Statically Analysis

Data were subjected to analysis of variance using statically producer as described by Gomez and Gomez (1984). Analysis was made using Gen Stat 15th edition statistical software.

2.8. Performance of the prototype

The performance of the machine was evaluated in terms of shelling capacity (kg/h), shelling efficiency (%), cleaning efficiency (%) and percentage of damage (%) using the following equations;

Shelling capacity (kg/h) = $\frac{Q_t}{T_m}$

Mechanical damage (%) = $\frac{Q_d}{Q_{ud} + Q_d} X100$

Cleaning efficiency (%) = $\frac{W_{hw}}{W_t} \times 100$

Shelling efficiency (%) = $\frac{Q_s}{Q_t} \times 100$

Where: Qt – Mass of shelled grain at grain outlet (kg); Tm – time of shelling operation (h); Qut – quantity of an shelled (kg); Qud - quantity of undamaged grain (kg); Qd - quantity of damaged grain (kg), Whw – quantity of winnowed husk (kg); Wt – quantity of husk goes with grain and winnowed (kg); Lg – Mass of loss grain (kg).

3. Result and Discussion

Performance of the prototype machine was discussed interims of shelling capacity (SC), mechanical damage (MD), shelling efficiency (SE) and cleaning efficiency (CE) as follows and the moisture content of the used coffee bean is 11.5% which is in the recommended range of coffee bean to be threshed

3.1. Shelling capacity (Kg/hr

Source of Variation							
Interaction Effect (VXC			Main Effect				
Velocity (rpm)	Con. Clearance at rear (mm)		Velocity (rpm)	Mean	Clear.(mm)	Mean	Grand mean
	2	6					
450	225.12ᵃ	218.07ᵃ	450	221.60ᵃ	2	239.19ᵃ	
500	241.37ᵇ	237.55ᵇᵈ	500	239.46ᵇ	6	236.10ᵃ	
550	251.07ᶜ	252.69ᶜᵉ	550	251.88ᶜ			237.64
SE (M)		2.954		2.089		1.706	
LSD (5%)		8.202		5.80		4.736	
CV (%)		1.5					

The maximum shelling capacity of 251.69 kg/hr was recorded at interaction effect 550rpm and 6mm drum speed and rear concave clearance respectively. Generally, shelling capacity has direct relationship with drum speed and inversely relationship with rear concave clearance. Means followed by the same letter has no significant difference

3.2. Mechanical damage (%)

Source of Variation							
Interaction Effect (VXC)			Main Effect				
Velocity (rpm)	Con. Clearance at rear (mm)		Velocity (rpm)	Mean	Clear. (mm)	Mean	Grand mean
	2	6					
450	4.48ᵃ	3.49ᵇ	450	3.98ᵃ	2	5.11ᵃ	
500	5.56ᵃ	4.44ᵃ	500	5.00ᵇ	6	4.38ᵃ	
550	5.30ᵃᵇ	5.20 ᵃ	550	5.25ᵇᶜ			4.47
SE (M)		0.677		0.479		0.391	
LSD (5%)		1.881		1.330		1.086	
CV (%)		17.5					

Mechanical damage has direct relationship with drum speed and inversely relationship with rear concave clearance.Maximum percentage kernel mechanical damage, 5.56 %, occurred when the bean were shelled at cylinder speed of 500 rpm and rear concave clearance of 2mm, while the least % kernel mechanical damage, 3.49%, was recorded at drum speed of 450 rpm and at rear concave clearance 6mm.

3.3. Shelling efficiency (%)

Source of Variation							
Interaction Effect (VXC)			Main Effect				
Velocity (rpm)	Con. Clearance at rear (mm)		Velocity (rpm)	Mean	Clear. (mm)	Mean	Grand mean
	2	6					
450	91.68[ad]	86.80[c]	450	89.24[a]	2	92.81[a]	
500	93.80[b]	90.71[d]	500	92.25[b]	6	88.80[b]	
550	92.96[ab]	88.88[e]	550	90.92[c]			90.80
SE (M)		0.604		0.427		0.349	
LSD (5%)		1.677		1.186		0.968	
CV (%)		0.8					

ANOVA revealed that both main effects were highly significant at 1% level. The optimum shelling efficiency of 93.80% was observed when the drum was operated at velocity of 500 rpm and 2mm rear concave clearance; whereas the min. Shelling efficiency of 86.80% was observed when the drum speed was 450 rpm & rear concave clearance was 6mm

3.4. Cleaning efficiency (%)

Source of Variation							
Interaction Effect (VXC)			Main Effect				
Velocity (rpm)	Con. Clearance at rear (mm)		Velocity (rpm)	Mean	Clear. (mm)	Mean	Grand mean
	2	6					
450	88.17[ab]	87.59[b]	450	87.88[a]	2	88.20[a]	
500	88.13[ab]	88.72[a]	500	88.43[ab]	6	88.71[a]	
550	88.29[ab]	89.83[c]	550	89.06[b]			88.45
SE (M)		0.604		0.427		0.349	
LSD (5%)		0.925		0.654		0.534	
CV (%)		1.3					

The maximum cleaning efficiency of 89.83% was obtained when the drum is operated at speed of 550 rpm and rear concave clearance of 6mm. Cleaning efficiency has direct relationship with both factors

3.5. Analysis variance of (Split-Plot design) of the performance of the machine

Source of variation	df	F value			
		SC (Kg/hr)	MD (%)	SE (%)	CE (%)
Rep	2				
Velocity (V)	2	1390.45**	2.70[ns]	13.69**	2.10[ns]
Rear conc. Clearance (RCC)	1	42.82[ns]	2.43[ns]	72.63**	1.20[ns]
V X RCC	2	28.84[ns]	0.46[ns]	1.20[ns]	1.70[ns]

** Highly significant at 1% level; * significant at 5% level; ns, non-significant; df, degrees of freedom.

4. SUMMARYAND RECOMMENDATIONS

Summary

A coffee seed shelling machine was developed and evaluated, the following conclusions were drawn: The maximum shelling capacity of 251.69 kg/hr was recorded at interaction effect 550rpm and 6mm drums speed and rear concave clearance respectively.

The optimum shelling efficiency of 93.80% was observed when the drum was operated at velocity of 500 rpm and o cm rear concave clearance; whereas the minimum shelling efficiency of 86.80% was observed when the drum speed was 450 rpm & rear concave clearance was 6mm. From the results obtained, regarding to performance of the machine, it can be concluded that the machine can be used by the farmers.

Recommendation

1. If the work will be done on the cleaning unit is good to have high cleaning efficiency
2. Additionally work should be done to decrease percentage of mechanical damage.

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