Development of Chopper for Crop Residue and Hay

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Abstract

Engine driven chopper has been developed for chopping of crop residue and hay. The machine was designed with the following main components: feed hopper, rotating drum with swinging knives, casing with fixed knives welded on it, a screen, and stands. The machine was then tested in the center to evaluate its performance. The test was conducted using three levels of drum speeds; 960, 1200 and 1400 rpm and three feed rates; 420, 540, and 660 kg hr $^{-1}$. Maize stalk (at 6% M.C) and grass (at 78% M.C) were used as feed material. The test result showed that optimum drum speed and feed rate values for both maize stalk and grass were 1200 rpm 540 kg hr^{-1}, respectively. The average size reduction percentage using these optimum combinations was 92.0 and 79.5% for maize stalk and grass, respectively. The machine performed well with output rate ranging from 420 to 660 kg/hr and specific energy requirement of 11 to 20 KJ kg^{-1} output.

Key words: chopper fabrication, concave screen, drums speed

Introduction

Ethiopia stands first in livestock population in Africa. According to Alemayehu Mengistu (2002), livestock production contributes up to 80% of farmers' income and about 20% of the countries agricultural GDP. However, ever increasing human population accompanied with decline in land productivity resulted in an increased utilization of arable land for crop production. This, in turn, diminished available grazing land bringing about animal feed scarcity, the major problem threatening the countries huge cattle resource.

It is needless to say that, as grazing is the common practice in the country, traditionally livestock is dependent on natural pasture and crop residue for their daily feed requirement. However, grazing situation is exacerbated by the high density of cattle, with stocking rates about four times the recommended at global level. (Starkey *et.al* 1992). This decline in available livestock feed forced livestock owners to make use of crop residue mainly from cereals, especially in the latter part of the dry season. As residue is characterized by low nutrient content and poor digestibility and palatability, livestock tend to lose their weight, ending up with reduction in their market value, draft power, disease resistance, and amount of milk they produce.

In recent years, due to the opening of new commercial channels to external market as well as an increase in local consumption, many farmers are getting involved in cattle fattening activities and are getting good economic benefit from it. This shows that this activity deserves more attention so as to get better returns from the sector. One of the options to overcome a feed shortage, especially during long dry seasons when feed is in short supply, is to preserve excess fodder grown in rainy season in the form of silage. However, silage making has not been widely practiced in the country owing to lack of proper equipments for its preparation. Traditionally chopping is done manually using hand tools designed for other purposes. This makes the practice more burdensome and labor intensive for the farmers. Consequentially chopping will be incomplete making compacting the material difficult demanding even more labor and time.

Chopping of feed materials is known to have great advantage in silage making. In addition to assisting compaction while silage is prepared, it increases the surface area to volume ratio of fodder which, by making free of the cell juice and expelling the air, facilitates the fermentation process. Therefore, to make silage making attractive for farmers and enable them the benefit from it, chopping should be made in more user friendly ways, demanding less labor and time while the product maintains its quality. But availability of attractive chopping device has been the limiting factor for Ethiopian farmers to make silage and to chop farm residues , hence the objectives of this study was to develop and evaluate engine driven chopper which assists farmers in making more feed available for their livestock.

Materials and Methods

Design considerations

The main design aspects considered during chopper development were cost and complexity of fabrication, energy requirement, ergonomic factors, maintainability, material strength, kinematics, and style. Considering the above design aspects tangential feed type chopper (hummer mill) without blowing fan and conveyor was selected for this project. The machine utilizes the principals of hammer mill by which size reduction is accomplished by the cutting effects of rotating knives against small stationary knife plates welded in the casing. Since the knives are swinging, less danger will be occurred if hard inert material gets in to the chopper by accident. Feed enters into the chamber from top of the hopper and, chopped in to pieces by the rotating knives, will be discharged from the bottom of the machine. The knives cut the stover and other residue until it become small enough to pass through the bottom screen (Figure 1).

Figure 1. Developed motor driven chopper

Fineness of chopping is controlled by the screen size. It is obvious that the smaller the screen size the more work will be required to reduce the particles to the desired size. But during chopping grass wire mesh screen is removed. Generally the technology is simple in construction and easy to manipulate and requires little cost for the replacement of parts.

Chopper fabrication

The main body of the machine was constructed using parts that are found in the market. The drum was made from standard 3"G.I.pipe, rotating knives from 3mm steel sheet, fixed knife plates from 40X3 flat iron and the concave and screen from 6mm diameter deformed iron. The knives are punched on both sides and bolted with the drum using M10 bolts and nuts (Figure 2).

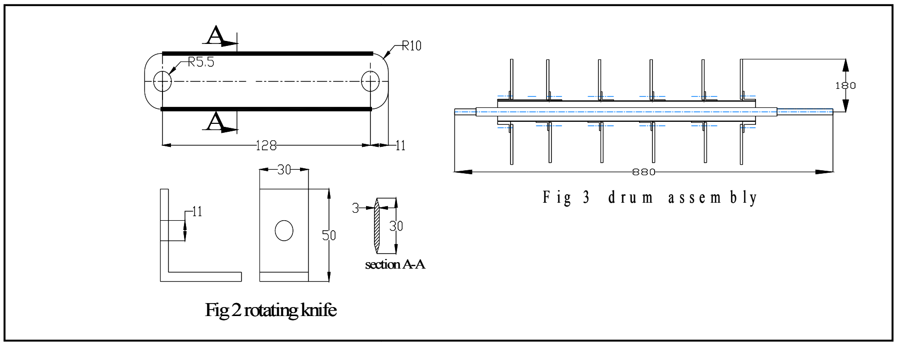

Figure 2. Assembly and details of drum component

The concave screen (Figure 3) was made from small bars welded on concave plates. The screen opening size is governed by the extent of the required size reduction and hence can easily be changed if required. Housing is made from 2 mm steel sheet. Machine design principles were used to determine the size of each component. Petrol engine 5HP rated power and 4000 rpm rated speed have been used for prime mover. Double grooved V belt and pulleys (ϕ90 and ϕ250mm) were used for power transmission.

Figure 3. concave screen

Testing and evaluation

Initially the machine was run with no load for about 6 hrs and its fuel consumption was measured. The material was then admitted uniformly to the machine and fuel consumption under load was measured using graduate cylinder and heat energy consumed for chopping unite kg of stover and grass was calculated by the outlined formula in FAO (1994).

$M = \rho * V$
$Q = M * C$
$E = Q/FR$

Where

M= mass of fuel per unit time (kg/hr)
V= fuel consumed for chopping (l/hr)
ρ= density(kg/m^3)
C= calorific value in(KJ/kg)
E = energy consumed (KJ/kg)
FR= feed rate (kg/hr)
Q= Heat transfer rate (KJ/hr

Material was fed at a constant rate manually when the machine is running. Length of the feed material was measured before and after chopping. The mass in kilogram and the time required for chopping the respective input was measured. Moisture content of the material (stover and grass) was determined using oven dry method and keeping the samples at $105c^{o}$ for 48 hours. Preliminary testing was conducted to select working ranges for feed rate and rpm for the test. Engine rpm was measured using digital tachometers while the following formulas were used to calculate capacity in dry bases, percentage size reduction (%), and moisture content (%).

$$\text{Capacity in dry bases (kg/hr)} = \frac{\text{capacity in wet bases (kg/hr) X (100\%-moisture content (\%))}}{100\%}$$

$$\text{Percentage size reduction (\%)} = \frac{Lb - La}{Lb} \times 100$$

Where

Lb =average length of the material before chopping
La= Average length of the material after chopping

$$\text{Moisture content (wet bases)(\%)} = \frac{Wb - Wd}{Wb} \times 100$$

Where

Wb =weight of material before drying (wet weight)
Wd =weight of material after drying

The following constants were used in determining the specific energy consumption of the machine (www.Kayelaby.Npl.Co.Uk/Chemistry/3-11/3-11-4.html)

- Density of petrol = 710 Kg/m^3
- Calorific value of Petrol = 45MJ/kg

Result and Discussion

Determination of optimum drum's speed and feed rate

The test was conducted to determine the optimum combination of drum speed (rpm) and feed rate and the results are summarized in Table 1. Average length of the fodder before chopping was 0.48m and 0.75m for maize stalk and grass, respectively.

Table 1. Test result on maize stock (6% MC) and grass (78%MC) using three shaft speeds and three feed rates

Trt. No	Shaft speed (rpm)	Type of fodder chopped							
		Maize stock				Grass			
		Feed rate (kg/hr)		Average length after chopping (m)	Average Size Reduction (%)	Feed rate (kg/hr)		Average length after chopping (m)	Average Size reductio n (%)
		moisture content 6%(wet bases)	moisture (dry bases)			Moisture content (wet bases) (78%)	Moisture content (dry bases)		
1	960	420	399.80	0.077	84.00	420.00	92.40	0.16	78.00
2	960	540	506.30	0.057	88.10	540.00	118.80	0.15	79.10
3	960	660	618.90	0.059	87.70	660.00	145.20	0.15	79.30
4	1200	420	399.80	0.086	82.00	420.00	92.40	0.15	80.00
5	1200	540	506.30	0.038	92.10	540.00	118.80	0.15	79.50
6	1200	660	618.90	0.050	89.60	660.00	145.20	0.15	79.80
7	1400	420	399.80	0.031	93.60	420.00	92.40	0.13	82.50
8	1400	540	506.30	0.048	90.10	540.00	118.80	0.12	83.00
9	1400	660	618.90	0.052	89.10	660.00	145.20	0.14	81.80

The result shows that as the feed rate increases, percentage size reduction increases at lower shaft speed and decreases at higher shaft speed. It was also observed that as the feed rate exceeds 660kg/hr unchopped stover passes through the sieve and the engine stops due to overloading. In addition, when the knife speed becomes 1400 rpm, very high vibration and back flow of the input materials to the hopper was observed. When the chopper works at knife speed of 1200 rpm and feed rate of 540 kg/hr, it was observed that no unchopped material passes through the sieve and the chopper was working without excessive noise.

Specific Energy requirement for chopping

The test was conducted to determine the energy requirement for chopping and the results are summarized in Table 2. By subtracting the fuel consumption with out load from fuel consumption with load the average fuel consumption for chopping 5.5 kg of maize stalk and grass is 0.117 ml/sec and 0.1 ml/sec, respectively. Using calorific value of fuel used and the fuel consumption rate average energy (specific energy) consumed for chopping a kilogram of stover and grass was found to be 20.38 KJ/kg and 11.59 KJ/kg, respectively.

Table 2. Amount of fuel consumed to run the chopper with load and without load.

Trt No	**Feed (kg)**	**Materials chopped**							
		Maize stock				Grass			
		Fuel consumed (ml) in 30 sec		Fuel consumption (ml/sec)		Fuel consumed (ml) in 20 sec		Fuel consumption (ml/sec)	
		Without load	With load	Without load	With load	Without load	With load	Without load	With load
1	5.50	12.50	16.5	0.416	0.55	7.10	9.20	0.36	0.46
2	5.50	12.00	15.8	0.4	0.53	7.10	9.10	0.36	0.46
3	5.50	13.00	15.7	0.3	0.52	6.80	8.70	0.34	0.44
Mean	5.50	12.50	16.00	0.416	0.53	7.00	9.00	0.35	0.45

Conclusion and Recommendation

The experiment has shown that developed chopper can successfully chop maize stalk and grass to the required level. It is also noted that optimum results could be obtained using540 kg/hr as a feed rate and 1200 rpm drum speed for chopping. However, more efforts should be made to evaluate the machine with farmers' participation for wide technology adoption.

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