Effect of Different Cutters, Feed Rates and Speed on Performance of Chopping of Green Sorghum

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Abstract

This study was divided into three phases. In the first phase the feasibility of available water hyacinth chopper cum crusher was tested for the chopping of sorghum and modified. In the second phase the different cylindrical cutters were selected and fabricated. During the last phase, their performance was evaluated for per cent volume reduction and power requirement for chopping of Sorghum. On the basis of preliminary trials of water hyacinth chopper cum crusher for chopping of Sorghum drawings of a modified Sorghum chopper was prepared in AutoCAD. The system was fabricated at CTAE, MPUAT Udaipur, workshop and a testing plan was developed for its performance evaluation. The performance of the developed system was evaluated on the basis of its ability to per cent volume reduction and cutting power required for chopping of sorghum crop. Four levels of independent variables namely feed rate (1250, 1500, 1750 and 2000 kg/h), cutter speed (13.4, 14.4, 15.4 and 16.4 m/s), and three cutters (cylindrical cutter, spiral cutter and forage cutter) were selected and tested. It was found that with the increase in feed rate and speeds of cutter the per cent volume reduction increased. The results shows that the modified machine can reduce the per cent volume of sorghum up to 76 per cent at the feed rate of 2000 kg/h and cutter speed of 16.4 m/s when forage cutter is in use whereas; cylindrical and spiral cutter gives 68 and 61 per cent at the same cutter speed and feed rate. The minimum cutting power requirement was found when spiral cutter is operated at minimum speed of 13.4 m/s and feed rate 1250 kg/h where as the maximum power is consumed by the cylindrical cutter with all levels of feed rates and cutter speeds. t last it can be concluded that the modified chopper gives best results with forage cutter at the feed rate of 2000 kg/h and cutter speed of 16.4 m/s.

Keywords

Volume reduction power requirement, cutters, feed rate and speed.

1. Introduction.

There is a great importance on the harvesting and storage of chopped forage for future use in lesser time. With a field chopper and its complementary equipment, the hay making or silage making operation can be completely mechanized. It chops the forage crop and allows transporting it in a wagon in bulk amount. Chopped forage is not free flow like hay cubes but is readily adaptable to mechanized feeding. The versatility of a field forage chopper often permits its use for several different products, thereby increasing the annual use and decreasing the cost per mega gram. Animals equipped by nature to grind and chew most fodder crops, but still they are fed chopped fodder to save storage space, aid in curing and make it more palatable.

Cutting with single element is pure impact cutting and depends mainly on the knife speed, cutting edge sharpness and crop inertia. Stalk resistance to bending is insufficient by itself to provide the force necessary for the cutting process depends on the stalk inertia to give the required opposing force. The energy required for the cutting unit of stalk cutter may be categorized as: frication in the moving parts of the machine and air friction; kinetic energy required to accelerate the chopped material; energy required to overcome friction of the chopped material against the stationary parts of the machine; and energy required to cut the stalk (Dernedde and Peters, 1971; O'Dogherty et al., 1995; Kronbergs, 2000; Chattopadhyay and Pandey, 2004). Blevins and Hansen (1956); Richey (1958); Liljedahl et al. (1961); McRandal and McNulty (1978) also considered energy expended in stubble deflection. In the case of a slasher or harvester, the

relationship between peripheral speed of the rotating blade and the translatory speed of the machine (speed index) is also an important factor (Kepner et al., 1978).

Forage choppers used for cutting fodder crops are of cylindrical, flywheel and flail type depending on cutting mechanism used on it. The chief objective of the proposed work is to develop a machine in order to reduce the bulk of the forage crop so that it can be transported and stored safely with minimum storage space and cost. The chopped material can also be feed easily to the cattle. Review suggested that the cylindrical chopper requires less energy as compared to flail and flywheel type choppers.

2. Materials and Methods

2.1 Sorghum chopper

It consists of hopper, Cylindrical cutter with blades, spiral cutter, forage cutter, power transmission system, and MS angle frame with supports. The hopper was made of 2mm thick MS sheet.

2.1.1 Cylindrical Cutter

The cutting cylinder of length 425 mm was made from 250 mm diameter pipe of 5 mm thickness. Blades were made up of 25 mm x 5 mm MS flat with cutting edge sharpened at bevel angle of 240. The length of the blade was kept equal to the length of the cylinder. Keeping in view the ease of resharpening of blades and their replacement they were clamped on the cylinder periphery at a distance of 12 mm using nuts and bolts.

2.1.2 Forage Cutter

A forage cutter having a shaft of 30 mm diameter and 740 mm length was fabricated by using MS rod on which the knives mounted in the cylinder housing. The cylindrical housing was made from 6 MS plates of 250 mm diameter. The plates were fixed on the shafts with the help of bushings and nuts of 5 mm diameter acting as key in the shaft. The plates were such that they had a cut section of 900 with the maximum length of 500 mm arrayed in polar rrangement of 450 at the outer periphery. Each side of the cut sections was used as a base for fitting of the knives in cylindrical fashion. Holes of 10 mm diameter were made between two cuts and 10 mm inside from the outer periphery so that it will accommodate a cylindrical bolt of 8 mm diameter for clamping of knife on the cut section in the plate with a nut of 5 mm diameter.

2.1.3 Spiral Cutter

Spiral cutter was also reported to be used behind the combine for chopping the straw (Pearson, 1987). The length and diameter of this cylindrical cutter were kept same as the existing cutter i.e. 425 mm and 250 mm respectively so that it could be fitted in the available chopper cum crusher. Three circular MS plates of 250 mm diameter and 5 mm thickness were welded directly on the shaft and kept 128 mm apart from each other. Radial slots were made on the plates of length 10 mm and 3 mm wide in the polar arrangement of 300 before welding of the plates on the shaft they were so arranged that the middle plate was rotated half a distance between two slots. Blades were made up of a 425 mm long MS flat of size 62.5 x 5 mm and the cutting edge sharpened at the angle of 900. A three phase, 1 hp electric motor of 960 rpm, was used to power the various components of the machine. A speed reduction unit (eddy current coupling) was connected to the motor and was controlled from the control panel. V-belts were used to supply the power to cutter cylinder, pressing cylinder and conveyor belt of the machine.

2.2 Experimental set up

The developed Sorghum chopper is operated by variable speed motor. The energymeter was connected to motor and speed was varied by regulator. A reversible switch is also provided to rotate the cutting cylinder in opposite direction if required. Three cutters i. e. cylindrical, spiral and forage cutter are tested. The volume of material chopped and after chopping were determine. The feed rate was varied manually. The power required to operate the chopper and speed of cylinder was measured. The belt conveyor is placed below the cylinder and conveys the chopped material. The cylinder and conveyor is operated by 3hp electric motor with help of belt pulley. The speed of cylinder can be varied by variable speed motor or by changing pulley. The wheels are provided to chopper for easy transport.

2.3 Determination of various Parameters

The samples of Sorghum crop was fed to the chopper and collected at the end of the conveyor belt after chopping. The chopped material will again be filled in the container for its volume measurement. The power required to run the machine at no load and at different loads will be recorded with the help of digital power meter.

2.3.1 Feed rate:

It is the amount of material fed per hour to the chopper. It was varied by varying the speed of the feeder conveyor.

2.3.2 Cylinder speed:

The speed of the cutter cylinder was varied by using eddy current coupling, which is connected to the variable speed

motor. The speed selected between 13.4 m/s to 16.4 m/s. Reason behind to select this speed was at the speed less than 13.4 m/s the chopping is not done well,and the speed more than 16.4 m/s clogging in the hopper, that's why speed between 13.4 to 16.4 m/s is selected.

$$V_{ks}=\frac{\pi \times DN}{60}$$

Where,

VKS= Cutter speed, m/s;

π = 3.14;

D = Diameter of cutting cylinder, m and

N= Speed of cutter cylinder, rpm

Table 3.1: List of Material and specification used for Sorghum chopper

Sr. No	Iteam	Material	Specification
1	Frame	MS channel	100x50x5
2	Hopper	MS Sheet 3 mm	(620x450x426)
3	Cutting cylinder	MS pipe	9mm thick 272 mm Ø
4	Rollers for conveyors	MS pipe 308 mm Ø	6mm thick 308 mm Ø
5	Blades	Leaf spring steel	425x24x10
6	Support plate	MS plate	5mm thick
7	Shafts	E.N. round bar	50 mm Ø
8	Motor platform:	MS angle	35x35x5
9	Bearings blocks		MPG 40, MSTG 40
10	Pulleys	Triple B-groove Single B-groove	100mm,100mm 200mm,500mm
11	Belts	V-Belts	B-100, B-102
12	Conveyor belts	Rubber sheet	6 mm thick x 360 mm
13	Comb for belt	MS	400 mm
14	Side plate for wheels	MS plate	10 mm
15	Transport wheels	Rubber tyred Solid wheels	200 mm Ø
16	Rings and clamp rings for blades on cutting cylinder	MS flat	25x10 mm
17	Shear plate	Leaf spring steel	70x10 mm
18	Electric motor	Variable speed motor	3 Ø 3hp, 960 rpm

Measurement of volume reduction

To measure the volume of Sorghum crop a container of GI sheet was made. The samples of known volume of forage crop was fed to the chopper and collected at the end of the conveyor belt after chopping. The chopped material was filled in the GI sheet container and its volume was determined. Per cent volume reduction is the ratio of change in volume to the initial volume of the sample. It can be expressed as Percent Volume reduction=$\frac{V1-V2}{V2}\ X\ 100$,

Where,

V1= initial volume of the sample, m^3

^{V2} = final volume of the sample, m^3

Measurement of power

An electronic digital power meter was used to determine the power required to run the system without load and to chop the Sorghum. It was connected between the motor and the motor starter. The power consumed was recorded directly from the digital display of the meter in kW.

Principle of Operation

The chopper works on the principle of a shearing action between stalk and shear plate. The Sorghum stalks was fed from hoper and chopped by cylinder due to shearing action. The collector at bottom of cylinder directs the chopped material to the conveyor. The cylinder cutter can be replaced by another type of cutters if required. The conveyor conveys the chopped material to one side and collected in the container. The length of chop can be varied by changing feed rate, speed of cylinder or type of cutter as per requirement.

3. Results and Discussion

3.1 Effect of feed rate on volume reduction

The initial volume of the sample of Sorghum was determined and fed to the machine at different feed rates of 1250, 1500, 1750 and 2000 kg/h. After chopping at different feed rates the volume of each sample was determined and recorded. The results (table 1) show that as the increase in feed rate increases the volume reduction for all the blade systems. The maximum reduction in volume was 75.98 per cent obtained with forage cutter at feed rate 2.0t/h and at 16.40 m/s cutter speed.

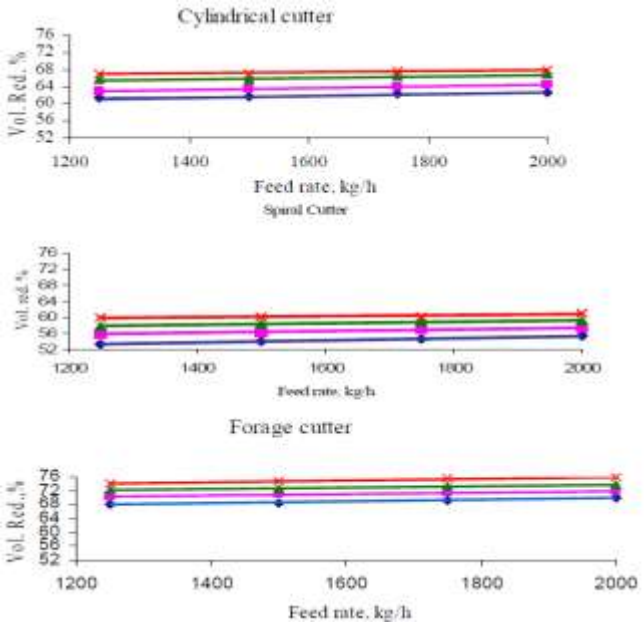

Fig 3.1 Effect of feed on rate per cent volume reduction of Sorghum at different cutter speed (m/s) and all types of cutters

13.4 14.4 15.4 16.4

Table 3.2 Effect of Performance Parameter on Volume Reduction of Sorghum chopper

Speed m/s	Feed Rate kg/h	Voume reduction %		
		Cylindrical cutter	**Spiral cutter**	**Forage cutter**
13.40	1250	61.20	53.24	68.02
	1500	61.64	53.96	68.57
	17500	62.15	54.57	69.18
	2000	62.60	55.32	69.88
14.40	1250	63.04	55.89	70.24
	1500	63.55	56.25	70.98
	17500	63.95	56.93	71.45
	2000	64.45	57.37	71.92
15.40	1250	65.58	57.37	72.09
	1500	65.84	58.34	72.78
	17500	66.23	58.89	73.33
	2000	66.87	59.15	73.88
16.40	1250	66.99	59.91	74.12
	1500	67.03	60.06	74.79
	17500	67.66	60.11	75.45
	2000	67.99	60.97	75.98

Table 3.3Effect of Performance Parameter on Power Requirement of Sorghum chopper

Speed m/s	Feed Rate kg/h	**Power Requirement, kW**		
		Cylindrical cutter	**Spiral cutter**	**Forage cutter**
13.40	1250	3.1	2.7	2.9
	1500	3.4	3.0	3.2
	17500	3.8	3.2	3.5
	2000	4.3	3.5	3.8
14.40	1250	3.3	3.1	3.1
	1500	3.7	3.4	3.7
	17500	4.2	3.7	3.7
	2000	4.7	4.0	4.1
15.40	1250	3.6	3.3	3.4
	1500	3.9	3.8	3.8
	17500	4.4	4.1	4.1
	2000	4.9	4.5	4.3
16.40	1250	4.0	3.5	3.7
	1500	4.3	4.1	4.1
	17500	4.7	4.4	4.4
	2000	5.1	4.9	4.7

3.2 Effect of feed rate on power requirement

The power requirement for chopping was calculated by subtracting no load power from total power. The maximum total power requirement at highest possible speeds of cutting cylinder and conveyors (required for highest feed rate of 2000 Kg/h) was 5.1 kW. The power requirement (total and cutting) change with change in cutter for all combinations of other independent parameters. The cutting and total power requirement increased with increase in feed rate significantly.

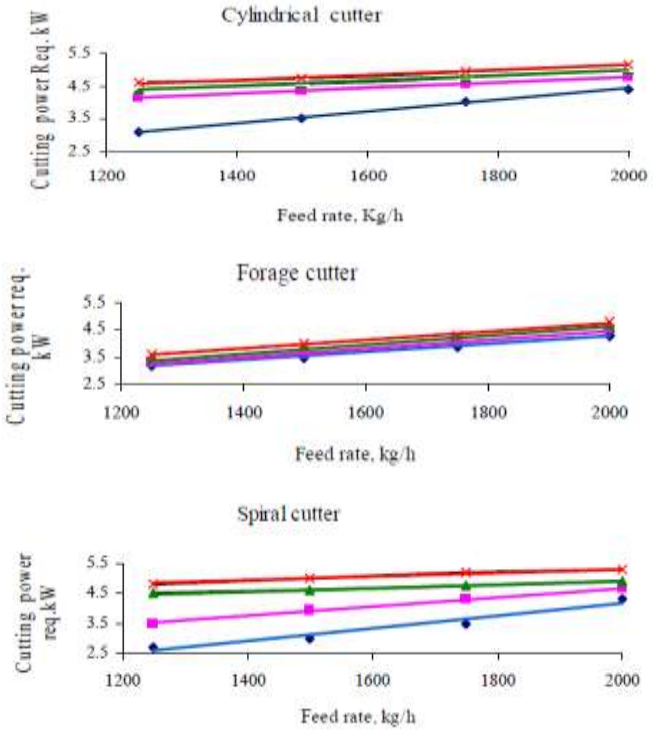

Fig. 3.2 Effect of feed rate on cutting power requirement of Sorghum at different speeds(m/s) 13.4 14.4 15.4 16.4 and cutters.

3.3 Effect of speed on volume reduction

The volume reduction increased with increase in the cutter speeds for all levels of the feed rate. This may be because at higher speeds of the motion of the knife of cutter relative to the material was higher causing maximum crushing of the fed sample (Persson, 1987). The results show that the maximum and minimum volume reductions were observed at maximum and minimum speeds of 16.4 m/s and 13.4 m/s respectively. The maximum volume reduction of 75.98 per cent was observed for forage cutter type cutter. Maximum volume reductions were observed for the blade systems consisting shear plate as a counter cutting edge while cutting.

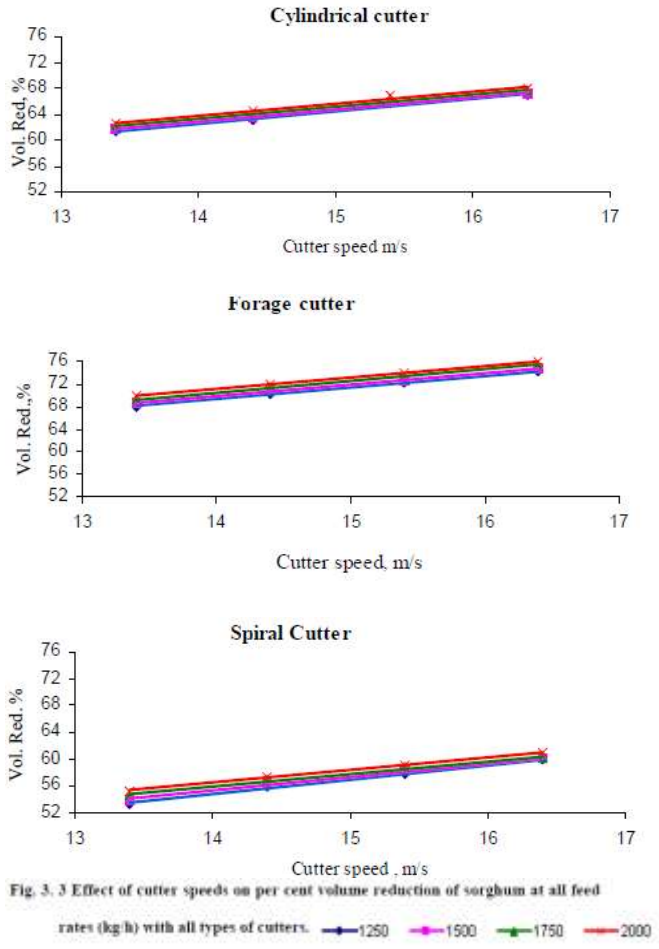

Fig. 3. 3 Effect of cutter speeds on per cent volume reduction of sorghum at all feed rates (kg/h) with all types of cutters.

Conclusions:

1. The per cent volume reduction increased with increase in cutter speed and feed rate.

2. Maximum per cent reduction was 76 per cent with forage cutter at cutter speed of 16.40 m/s. and feed rate of 2000 kg/h whereas, cylindrical and spiral cutter gave 68 and 61 per cent at the same cutter speed and feed rate.

3. The average no load power required to run the machine was 1.1 kW.

4. The cutting power requirement increased with increase in cutter speed and feed rate.

5. Spiral cutter consumed less power (3kW), where as the maximum power was consumed by cylindrical cutter (5.1kW) with all levels of feed rates and cutter speeds.

6. The cost of spiral cutter is less as compare to forage cutter and cylindrical cutter.

7. The forage cutter cost is just higher than the spiral cutter but less than the cylindrical cutter

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