

# Performance Evaluation of Diesel Engine Operated High-speed Chaff Cutter

Ramesh Beerge<sup>1\*</sup>, K. Revanth<sup>2</sup>, Prabhakar Shukla<sup>3</sup>, Vinayaka<sup>2</sup> and Basavaraj<sup>2</sup>

<sup>1</sup>Department of Agricultural Engineering, PI, FMTC, University of Agricultural Sciences, Dharwad, India.

<sup>2</sup>Farm Machinery Testing Centre, Vijayapur, UAS, Dharwad, India.

<sup>3</sup>Farm Power and Equipment, ICAR-CIAE, Bhopal, India.

## Authors' contributions

This work was carried out in collaboration among all authors. Author RB designed the study and wrote the first draft of the manuscript. Authors KR and V were conducted the test and collected the data during experiment. Author PS managed the analyses of the study and performed the statistical analysis. Author B managed the literature searches. All authors read and approved the final manuscript.

## Article Information

DOI: 10.9734/CJAST/2021/v40i1631425

### Editor(s):

(1) Dr. Giovanni Bucci, University of L'Aquila, Italy.

### Reviewers:

(1) Jéssica Alves Justo Mendes, Universidade de São Paulo - USP (University of São Paulo), Brazil.

(2) Hitesh Shakya, Anand Agricultural University, India.

Complete Peer review History: <https://www.sdiarticle4.com/review-history/65594>

**Received 17 December 2020**

**Accepted 24 February 2021**

**Published 21 July 2021**

**Original Research Article**

## ABSTRACT

Dairy farming has become one of major sources of income for farmers. To maintain a large dairy farm, fodder must be available in palatable form at every point of time in sufficient quantity. To ensure that the ready fodder is available for cattle, a high-capacity chaff cutter is necessary. A high speed and high-capacity chaff cutter procured from the local market and tested for its performance. The machine consisted of a flywheel type cutter head which was mounted on the rectangular platform. The cutter head consisted of three rectangular plain knives fixed 120° apart on a circular disc of 440 φ. The feeding assembly was mounted with three feed rollers viz., upper, low, and additional. Chute type feeding mechanism was provided. The machine was operated by a 3.73 kW diesel engine. The 'v' belt was provided for power transmission from engine to cutter head with a reduction ratio of 1:0.32. Feed rollers were driven by bevel and spur gears. Short run and long run evaluation of the machine were conducted for napier grass and dry jowar. The variation in length of cut pieces was found to be 8.39% and 5.78% for dry jowar and napier grass, respectively. Quality of

\*Corresponding author: E-mail: beergerm@uasd.in;

cut was calculated and found to be -0.80 for dry jowar and -0.53 for napier grass. The average efficiency of the machine was found to be 86.87% and 88.93% for dry jowar and napier grass, respectively. The average diesel consumption was found to be 0.69 l h<sup>-1</sup>.

*Keywords: Cutter head; diesel engine; feeding chute and feed roller.*

## 1. INTRODUCTION

India is second largest producer of milk in the world. Dairy is one of the major sources of income for the majority of Indian farmers. India's cattle population was over 303 million in 2020. While the global cattle population is over 987 million. India has the highest cattle population followed by Brazil, United States and China Anon [1]. Animal feeding is one of the important aspects in livestock management. With the decreasing trend in the total livestock population and increasing trend in the demand of milk and dairy products, quality of fodder plays a major role in achieving higher yield of lactating animals. Cutting or chaffing of fodder into optimum length improves the palatability and digestibility of feed. Chaffing of fodder, which is the primary aspect of silage preparation, reduces the wastage of fodder and improves the keeping quality. Chaffing can be achieved by manually operated chaff cutters, electric motor operated chaff cutters, diesel engine operated chaff cutter and tractor operated chaff cutters. For a large dairy farm, availability of ready fodder plays a major role in feeding of livestock. The capacity of the manual operated chaff cutter and electric motor operated chaff cutters are of comparatively less and it is difficult to prepare feed for higher cattle population from low capacity chaff cutters. Apart from the capacity issue, it has been found that manual fodder cutting machines accounted for about 37 per cent of total agriculture related injuries Mohan et al. [2] Manual chaff cutters do not offer safer feeding options and hence it is a high risk operation. Besides considering the positive implications of technology in recent times, the quality and safety of operation, which accounts for maximizing the performance parameters of agricultural machines. [3].

Karunya et al. [4] evaluated the performance of a power operated chaff cutter for chaffing paragrass. They have evaluated the machine at three different speeds with two different blades and at three levels of moisture content. They reported that the maximum efficiency obtained was 85.10 per cent with maximum capacity of 0.47 Mg h<sup>-1</sup>.

Kankal et al. [5] conducted performance evaluation of a power chaff cutter for dry sorghum and Ginni. They found that feed rate varied from 179.90 to 310.38 kg h<sup>-1</sup>. Power consumption varied between 1.03 and 1.19 kW. Output of the machine was in the range of 177.00 to 304.37 kg h<sup>-1</sup>.

Muhammad et al. [6] designed and evaluated the performance of a forage chopper for small dairy systems. The forage chopper prototype was operated by a 5.20 kW water cooled diesel engine. They reported that the machine was capable chopping 859.30 kg h<sup>-1</sup>. The average length of the chopped materials was 2.90 cm and 2.10 cm for Napier grass and maize, respectively. Keeping all these points in view, a high capacity and high speed chaff cutter was procured from the market and evaluated for its performance.

## 2. MATERIALS AND METHODS

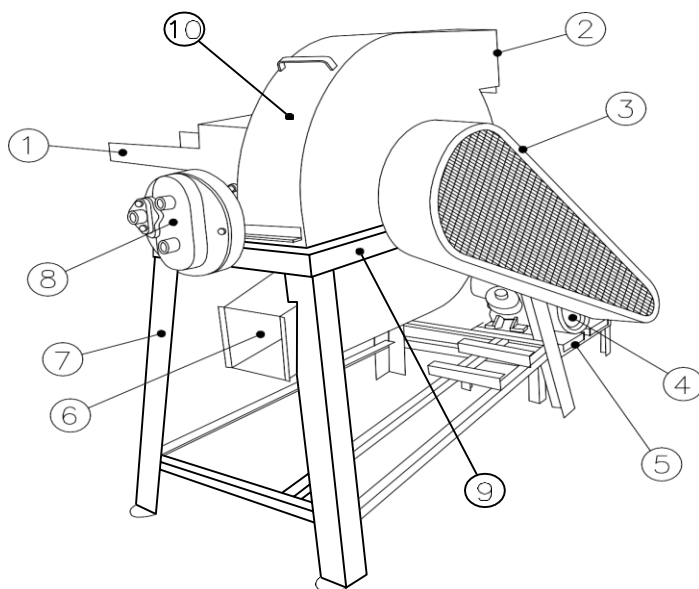
Adiesel engine operated high speed chaff cutter was procured from Techstone Industries, Kolhapur, Maharashtra. The machine was commercially developed and various working components are described as follows.

### 2.1 Description of the Machine

The isometric schematic diagram of the machine is shown in Fig. 1. The general details of the machine are given in Table 1.

#### 2.1.1 Mainframe

The main frame was fabricated in trapezoidal shape to form rectangular platform using four MS angles for size 1002 × 60 × 60 × 4 mm (2 No's) and 526 × 60 × 60 × 4 mm (2 No's) at the top and four MS angles of size 1015 × 30 × 30 × 3 mm (2 No's) and 692 × 30 × 30 × 3 mm (2 No's) at the bottom. The frame was provided with four legs which were made of MS angles of size 915 × 80 × 80 × 3 mm for which ground clearance was measured to be 895 mm.



**Fig. 1. Schematic view of chaff cutter**

1	Feeding Tray	6	Lower Blower
2	Upper Blower	7	Chaff cutter
3	Safety Guard		Stand
4	5 HP Diesel Engine	8	Transmission Box
5	Engine Stand	9	Platform
		10	Upper Blower Guard

**Table 1. General details of machine**

Sl. No.	Parameters	Details
1	Type	Diesel engine operated
2	Make	Techstone
3	Model	5 HP R/F
4	Serial number	CC-009
5	Year of manufacture	2019
6	Suitability	Both dry and wet fodder

**2.1.2 Cutter head**

Flywheel type of cutter head was provided in the machine which was mounted on the main shaft of size 413 x 32 φ mm supported by three ball bearings. The flywheel consisted of a circular solid disc of size 440 φ x 10 mm on which three straight and plain high carbon steel knives (332 x 98 x 8 mm) were mounted on the periphery with an angular distance of 120°. Each blade was supported through two MS angles of size 370 x 50 x 50 x 6 mm and 390 x 75 x 75 x 8 mm. The cutter head was also provided with shear plate with a throat area of 248.2 cm<sup>2</sup> at the rear side of feeding mechanism to act as a stationary blade. Three blower flats were

mounted on the circular disc in between the knives to throw the cut chaff away.

**2.1.3 Feeding mechanism**

Feeding mechanism was provided with three feed rollers (upper, lower and additional) which were fabricated from cast iron rounds of size 230 x 80 φ mm mounted within roller casing. The effective length was measured to be 200, 210 and 210 mm for upper, lower and additional feed rollers, respectively. Rollers were provided with triangular teeth arranged in eight rows and each row consisted of 10 teethes on upper and 11 teethes on lower and additional rollers with a teeth pitch of 21 mm. The roller shaft was

fabricated with cast iron round of size 340 × 23 φ mm. Each roller shaft was supported by two CI bushes. The space adjustment between upper and lower roller was facilitated with a tension spring.

#### 2.1.4 Feeding assembly

Feeding assembly was provided with a feeding chute fabricated from MS sheet having thickness of 1.6 mm. The length of chute was measured to be 900 mm and length of covered portion was found to be 450 mm. The chute was bolted to the front end of roller casing with a provision for adjustment of chute angle from 10° to 30° with the horizontal.

#### 2.1.5 Power source

The machine was powered with a 3.73kW diesel engine which was mounted on a separate frame fabricated from MS angles adjacent to the mainframe. The details of the power source are described in Table 2.

#### 2.1.6 Power transmission

The power was transmitted from engine to main shaft/cutter head through 'V' belt drive. The size of pulley was measured to be 102 φ mm and 330 φ mm of engine and main shaft, respectively with a reduction ratio of 1:0.32. The speed at the cutter head was measured to be 495 rpm by a non contact type digital tachometer. The main shaft was connected to upper and lower feed rollers through bevel and spur gears with the reduction ratio of 1:0.08 with the speed of 54 rpm at the roller. Additional roller was driven by a chain drive from lower roller with an equal speed ratio.

### 2.2 Safety Components and Provisions

The machine was well equipped with safety components. Primary transmission system from

diesel engine to flywheel was provided with safety mesh guard with sheet metal periphery which is supported by the main frame. The cutter head of the machine was provided with a MS sheet cover of thickness 1.60 mm, surrounded along the periphery and 100 mm on either side of the cutter head. The feed rollers were mounted within the rigid roller casing which was fabricated from cast iron and supported by the main frame of the machine. A warning roller has been provided at the front end of the feeding mechanism to avoid human accidents. The machine had the provision in feed rollers reverse the direction of their rotation with an operating lever at the gearbox.

### 2.3 Performance Evaluation of the Diesel Engine Operated High Speed Chaff Cutter

The chaff cutter was fixed firmly on a level, preferably hard surface. Clearance between rotating and fixed blade was set and other adjustments were made for proper working as per manufacturer's recommendations. The machine was evaluated in the dairy farm, College of Agriculture, Vijayapur to examine its performance characteristics under no load test, short run test and long run test as per IS: 7897 – 1975 [7], IS: 11459 – 1985 [8] and IS: 15542 – 2005 [9]. Feeding was done continuously to full width and height of throat throughout the course of test. Diesel consumption was measured in all test trials by standard refilling method. The allowances for V-belt drive losses was taken as 5 per cent as per IS: 7897-1975 [7], Kankalet al. [5].

#### 2.3.1 Laboratory tests

The hardness of the knife of the chaff cutter was determined by Brinell's hardness testing machine in the laboratory which had 10 mm diameter of indenter.

**Table 2. Details of power source**

Sl. No.	Parameters	Details
1	Make	Rocket Engineering Corporation Pvt. Ltd.
2	Model	Comet
3	Serial number	6728
4	Year of manufacture	2019
5	Rated speed	1500
6	Specific fuel consumption, g/kWh	230
7	BIS Certificate number	CM/L7062461
8	Weight, kg	85

Dry jowar stalk and Napier grass were employed for conducting the test trials and their moisture contents were determined by hot air oven method. The bulk density of both dry jowar stalk and napier grass were determined. The average length and diameter of the fodder was measured using steel tape and digital vernier calipers, respectively. The chemical composition of knife was analyzed by Non Destruction Method using SPECTRO MAX instrument in Karnataka Material Testing and Research Centre, Hubli.

### 2.3.2 No load test

Test was conducted at recommended speed in idle condition without load for one hour. The visual observations were recorded and the diesel consumption at no load condition was measured.

### 2.3.3 Short run test

Four tests were conducted for dry jowar and napier grass (two for each). The fodder which was supposed to be cut was weighed prior to the test and the amount of chaff cut obtained after test was weighed. The time required to cut the pre-weighed fodder was recorded with a digital stopwatch.

### 2.3.4 Quality of cut

Theoretical length of cut of the machine was determined by the following equation IS: 7897-1975 [7].

$$x = \frac{\pi D_f N_f}{N R}$$

Where,

- x – Theoretical length of cut, mm
- D<sub>f</sub> – Diameter of the feed roller, mm
- N<sub>f</sub> – Speed of feed roller, rpm
- N – Speed of cutter head, rpm
- R – Number of knives

A plastic pipe of length 2 m whose diameter was almost equal to the diameter of selected fodder was fed to cutter head. 25 pieces of cut plastic pipe were selected and their length was measured using digital vernier caliper. Length of cut pieces of both dry jowar and napier grass were also measured. The variation of length of cut plastic pieces with respect to theoretical length of cut was determined. The standard

deviation between theoretical length of cut and length of plastic pipe pieces was determined using the following equation IS: 7897 – 1975 [7].

$$\sigma = \frac{\sqrt{\sum_{i=1}^n (x_i - x)^2}}{n - 1}$$

Where,

- σ - Standard deviation of length of cut
- n - Number of cut pieces of plastic pipe taken,
- x – Theoretical length of cut, mm
- x<sub>i</sub> - measured length of plastic cut pieces, mm
- i – serial number of plastic cut pieces

The quality of cut was calculated using the following expression IS: 7897 – 1975 [6].

$$Q = (1 - \sigma)$$

Where,

- Q – Quality of cut
- σ - Standard deviation of length of cut.

### 2.3.5 Quantity of cut

The theoretical capacity of the machine was determined by the following relationship Karunya et al. [4].

$$C_t = 6 \times \rho \times A \times L \times N \times R \times 10^{-6}$$

Where,

- C<sub>t</sub> - theoretical capacity of the machine, kg h<sup>-1</sup>
- ρ - Density of fodder, kg m<sup>-3</sup>
- A – Throat area, cm<sup>2</sup>
- L – Length of cut, mm
- N – Number of knives on cutter head,
- R – Speed of cutter head, rpm

Actual capacity of the machine was calculated using following equation Karunya et al.[3].

$$C_a = \frac{W_f}{T}$$

Where,

- C<sub>a</sub> – actual capacity of machine, Mg h<sup>-1</sup>
- W<sub>f</sub> – weight of fodder cut, Mg
- T – time consumed for chopping fodder, h

The efficiency of the machine was calculated by following relation Karunya et al. [4].

$$\eta = \frac{C_a}{C_t} \times 100$$

Where,

- $\eta$  – efficiency of the machine, %
- $C_a$  – actual capacity of machine, kg h<sup>-1</sup>
- $C_t$  - theoretical capacity of the machine, kg h<sup>-1</sup>

### 2.3.6 Long run test

The test was carried out for six trials for both dry jowar and napier grass (3 for each) continuously for more than 5 hours in each trial. The observations were recorded in each trial.

### 2.3.7 Wear Analysis of knives

Weights of knives before the start of test and after completion of the test were recorded using digital weighing balance. The wear analysis of the chaff cutter knife was conducted on mass basis after completion of all test trials.

## 3. RESULTS AND DISCUSSION

The chaff cutter was subjected to short run test and long run tests as per IS:7897-1975 [7]. Knives of the machine were analyzed for chemical composition and hardness. Wear analysis of knives was carried out on mass basis. Results of the performance evaluation of the chaff cutter are presented as follows:

### 3.1 Laboratory Tests

Physical properties such as average length and average diameter of fodder were measured and found be 1.85 m and 1.56 cm for dry jowar stalk and 2.34 m and 2.53 cm for napier grass, respectively. Moisture content was observed to

be in the range of 20% to 25% for dry jowar stalk and 80% to 85% for napier grass, respectively. The average bulk density of dry jowar stalk and napier grass was determined to be 42.50 kg m<sup>-3</sup> and 124.82 kg m<sup>-3</sup>, respectively. Hardness of the knife was determined to be in the range of 48 to 52 HRC which is within the recommended limit of BIS standards IS: 11459–1985 [8]. The chemical composition of knife was found to be Carbon - 0.620%, Silicon–1.980%, Manganese–0.890%, Sulphur–0.031% and Phosphorous–0.032%. The carbon, manganese, sulphur and phosphorous percentages were found to be in accordance with the IS: 11459–1985 [8] whereas the silicon percentage was greater than the recommendations of BIS.

#### 3.1.1 No load test

The machine was operated for one hour in the idle condition. The diesel consumption was found to be 0.50 l h<sup>-1</sup>. The following visual observations were made during the test and were in accordance with recommendation of IS: 7897 – 1975 [6] and observations are presented in Table 3.

#### 3.1.2 Short run test

The test was conducted in four trials(two for dry jowar and two for napier grass), one hour each during which both quality of cut and quantity of cut were examined. The average diesel consumption was found to be 0.63 l h<sup>-1</sup> and 0.70 l h<sup>-1</sup> for dry jowar stalk and napier grass, respectively.

#### 3.1.3 Quality of cut

The theoretical length of cut was calculated to be 9.14 mm for the machine. The average length of chaff was found to be 8.81 mm and 9.26 mm for dry jowar stalk and napier grass, respectively as shown in the Fig. 2.

**Table 3. Visual observations of no load test**

Sl. No.	Parameters	Observations
1.	Presence of any marked oscillation during operation	Not found
2.	Presence of knocking or rattling sound	Not found
3.	Frequent slippage of belts	Not found
4.	Smooth running of shaft / shafts in their respective bearings	Satisfactory
5	Any marked wear or slackness in any component	Not found
6	Any marked rise in bearing temperature	Not found
7	Stability of chaff cutter	Satisfactory
8	Other observations	None

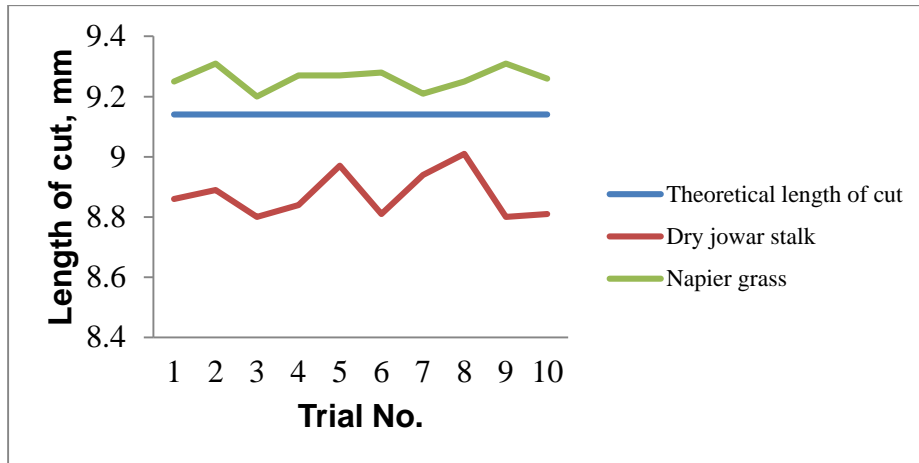


Fig. 2. Observed average length of cut for dry jowar stalk and napiergrass

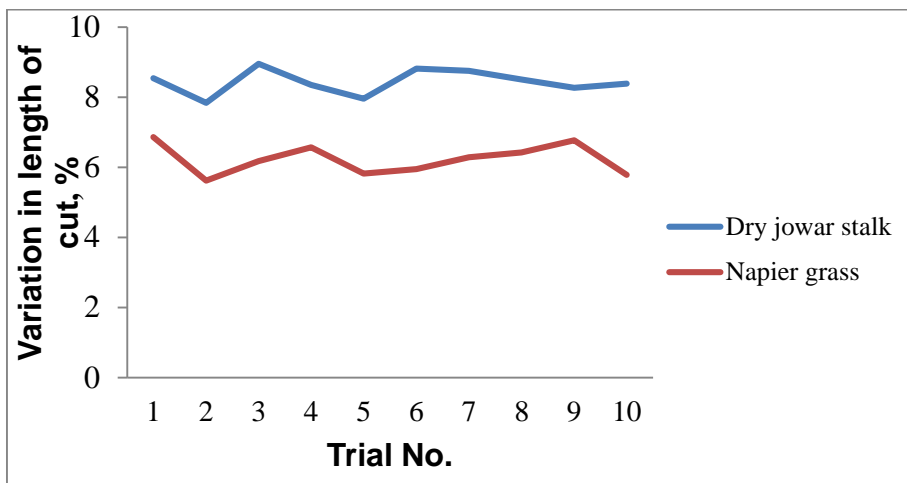


Fig. 3. Variation of length of cut from theoretical value

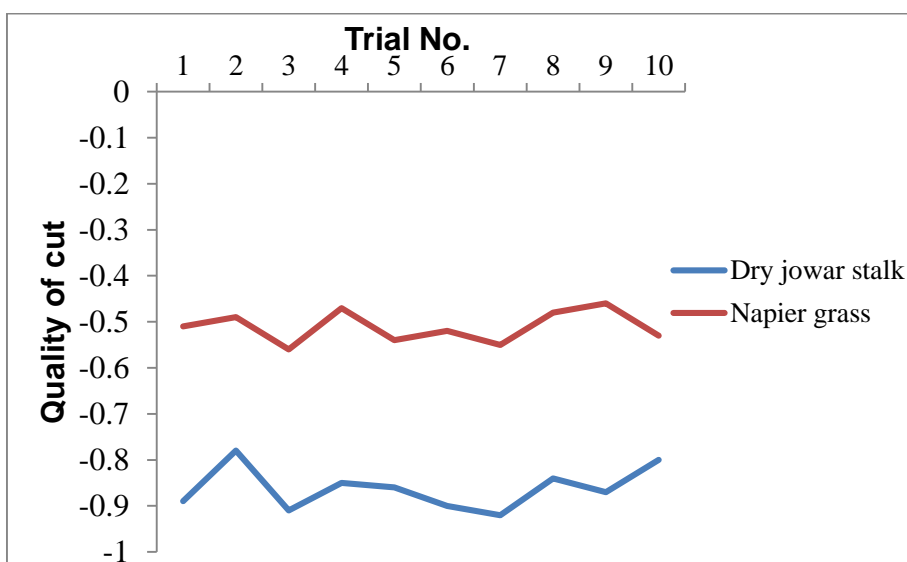


Fig. 4. Quality of cut for dry jowar stalk and napiergrass

**Table 4. Observations of long run test**

Sl. No.	Parameters	Observations	
		Dry jowar	Napier grass
1	Breakdown in cutter head	Not found	Not found
2	Breakdown in feeding mechanism	Not found	Not found
3	Breakdown in blowing mechanism	Not Applicable	Not Applicable
4	Breakdown in transmission system	Not found	Not found
5	Breakdown in body	Not found	Not found

The variation in length of cut pieces with respect to theoretical value was found to be 8.39% and 5.78% for dry jowar stalk and napier grass, respectively which was less than 10% as per the recommendations of IS: 11459 – 1985 [8]. The variation from theoretical length of cut is shown in the Fig. 3. The standard deviation of length of cut was estimated from which quality of cut was calculated and it was found to be -0.80 for dry jowar stalk and -0.53 for napier grass as shown in Fig. 4.

### 3.1.4 Quantity of cut

The theoretical capacity of machine was calculated as 859.7 kg h<sup>-1</sup> and 2524.99 kg h<sup>-1</sup> for dry jowar stalk and napier grass, respectively. Average actual capacity of the machine was recorded to be 746.85 kg h<sup>-1</sup> and 2245.54 kg h<sup>-1</sup> for dry jowar and napier grass, respectively. The average efficiency of the machine was found to be 86.87% and 88.93% for dry jowar and napier grass, respectively.

### 3.1.5 Long run test

Test was conducted for six trials (three for each fodder) for duration of 16.65 h and 16.91 h for dry jowar stalk and napier grass, respectively. The average diesel consumption was found to be 0.69 l h<sup>-1</sup>. The observations recorded are given in Table 4 which are in accordance with IS: 7897–1975 [7].

### 3.1.5 Wear analysis

The machine was operated for duration of 37.89 hours and hourly percentage wear rate of knives on mass basis was found to be 0.03 to 0.04%.

## 4. CONCLUSION

Chaffing of fodder is one of the essential operations in livestock management to obtain the cattle feed of optimum palatability. Power operated chaff cutter is one such machine which

has been proven effective in reducing the size of fodder by cutting it to desired length. The performance of procured high speed chaff cutter was evaluated for both dry and wet fodder. Physical properties such as average length and average diameter of fodder were found to be 1.85 m and 1.56 cm for dry jowar stalk and 2.34 m and 2.53 cm for napier grass, respectively. The overall performance of the machine was found to be satisfactory with an average quality of cut and average efficiency of -0.66 and 87.90%, respectively. The average efficiency of the machine was found to be 86.87% and 88.93% for dry jowar and napier grass, respectively. The average diesel consumption was found to be 0.69 l h<sup>-1</sup>. Hourly percentage wear rate of knives on mass basis was found to be 0.03 to 0.04%.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. Anonymous. Cattle population in India from 2016 to 2020; 2020. Available: [www.statista.com/statistics.1181408/](http://www.statista.com/statistics.1181408/)
2. Mohan D, Kumar A, Patel R, Varghese M. Development of safer fodder-cutter machines: A case study from North India. *Safety Science*. 2004;42:43-55.
3. Shukla P, Nandi S, Shau P, Patel A, Tripathi H. Field test analysis of straw reaper combine for optimized operating condition to improve the performance. *Current Journal of Applied Science and Technology*. 2020;39(8):77-86.
4. Karunya M, Gowthami E, Reddy KVSR, Pavani IS. Performance studies on power operated chaff cutter with Paragrass (*Brachiariamutica*). *International Journal of Agricultural Science and Research*. 2016;6(1):105-112.
5. Kankal US, Karale DS, Khambalkar VP, Thakare SH. Performance evaluation of



- power chaff cutter. Engineering and Technology in India. 2016;7(1):18-25.
6. Muhammad K, Walusimbi KH, Jimmy K, Swidiq M. Design and performance evaluation of a NARO forage chopper prototype for smallholder dairying systems. International Research Journal of Engineering and Technology. 2018;5(11):547-551.
7. IS: 7897 – 1975 (Reaffirmed in 2000), Test code for chaff cutter, Bureau of Indian Standards, New Delhi. 2000;3-19.
8. IS: 11459 – 1985 (Reaffirmed in 2000), Specification for power operated chaff cutter, Bureau of Indian Standards, New Delhi. 2000;3-11.
9. IS: 15542 – 2005, Power Operated Chaff Cutter – Safety requirements, Bureau of Indian Standards, New Delhi. 2000;1-10.

© 2021 Beerge et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

*Peer-review history:*

*The peer review history for this paper can be accessed here:*  
<https://www.sdiarticle4.com/review-history/65594>