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A LOW COST STRAW AND FORAGE CHOPPER[1]

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ABSTRACT

A flywheel-type, inclined axis chopper for small-area rice and livestock farmers, has been developed at IRRI Agricultural Engineering. The prototype is belt-driven by a 2.6 kW engine and uses four angled blades rotating below a fixed counteredge. Manual feeding is facilitated by a convenient spout presenting the crop to the inclined blade housing and also suction created by the rotating blades. The distance between the rotating blades and the bottom of the housing determines the length of chop, set here for 25 cm. The unit would cost $200 without the engine.

Tests with napier grass, corn stalks, and rice straw showed satisfactory performance within the acceptable clearance, speed and moisture content ranges of the material presented. Highest capacities were 1186, 1148 and 744 kg/hr for napier grass, corn stalks and rice straw, respectively. Corn stalks required the highest power demand at 2.3 kW. These results showed that a 2.6 kW motor, or a 4 kW engine would be adequate as power source. The chopper performance was comparable to higher cost commercial choppers in terms of capacity and specific energy.

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INTRODUCTION

The forage chopper is a regularly used piece of equipment on livestock farms. Feeding ruminants with chopped forage is more economical than free self-grazing, since grass can grow faster for the next cutting and animals are more easily managed. This is especially true for small livestock farmers or those who practice integrated crop-livestock farming. Choppers can also be used for comminuting farm residues for mulch, green manure, or into raw material for paper making.

Imported choppers of medium to high capacity, for example 1 to 5 tonne/hr are usually equipped with speed change gears and feeding units for adjustable chop length. These are appropriate for larger livestock farms. Locally designed choppers in the Philippines are either manually cranked or power driven. They may be unsafe, inconvenient to use, or excesssively priced.

The objectives of this study were: (1) to develop a low cost (about $200 without primemover), medium capacity (0.5 to 1 tonne/hr), versatile, accurate-cutting, safe and ergonomically designed chopper for small livestock farmers or small contractors; and (2) to evaluate the principle of the machine in terms of capacity, power requirements, specific energy and chopping performance with rice straw, napier grass and corn stalks.

CHOPPER DESIGN AND OPERATION

For simplicity and ease of fabrication, adjustment and repair, a flywheel type chopping principle was selected (*Fig. 1*). To keep costs down, a feeding device was not included. For convenient and effective feeding, the chopper blade housing was inclined 45^{o}, and the suction created by blade rotation was designed to assist feeding. The blades were made from leaf spring available from second hand auto shops, and were thus made of more reliable steel than some locally available steel bars. The four rotating blades were angled 10^{o} upwards with respect to the counter-edge, for effective and low-power cutting. The angled blades also serve as fans for effective throw of chopped materials. Both rotating blades and counter-edge are reversible. The floor of the housing restricts feeding length to 25 cm, theoretically, thus allowing accurate cutting with stiff-stemmed materials.

The whole unit, less the engine weighs 40 kg, thus making it easily transportable. The unit was designed to be powered by an off-the-shelf engine of 2.6 kW (3.5 hp). Chopper is driven via a quarter turn V-belt. The objective of developing a $200 chopper (without the primemover) was reached. The chopper is identified by its acronym FLIPPER, for Flywheel-type, Inclined, Precision Chopper.

MATERIALS AND METHODS

Materials

The chopper was tested with napier grass, corn stalks and rice straw. Napier grass is a high moisture, stiff grass having cross-section of 10 to 20 mm at the stems and leaf thickness of 0.5 to 1 mm. Initial tests showed that feed rate of 400 gm/sec gave a reasonable capacity and power requirement without overloading the motor. Two moisture levels (70.9 and 80.9% wb) and clearances (1.5 and 2 mm) were used.

Tests used freshly harvested corn stalks, after removal of fresh green corn, with moisture content 62.7% wb. Initial trials showed that only two stalks could be fed at a time, at 2 mm clearance.

Fresh rice straw at two moisture levels were used (47.86 and 65.9% wb). Preliminary tests showed these should be bundled to compensate for low stiffness, for effective chopping. Bundles of 150 to 200 grams gave reasonable capacities and power requirement. Bundles of 150 gram were used. Previous tests with rice straw showed the ideal clearance is 0.1 mm (Pasikatan & Quick, 1992) but manufacturing tolerance prevented this from being achieved. A more practicable clearance of 0.5 mm was used.

Test Set-up and Instrumentation

Power requirement was measured through an AC power meter and a 1.75 kW calibrated electric motor. The analog output of the power meter is recorded by a POLYCORDER - a portable data logger. Speed was varied through four sizes of driving pulley. Clearance between the blades was measured by a feeler gage and set by inserting or removing steel plates on the counteredge mounting. Capacity was measured by weighing the chopped material output over time. Size analysis of chopped material was carried out through the frequency distribution of 100 randomly selected straw pieces, for each replication (Persson 1987, Tremblay, et al., 1991).

Test Procedure

The blades were sharpened before each series of runs. Blade clearance and speed were carefully checked. Feed rate was set by bundling the materials to a set weight and feeding them in nearly continuous manner. A collecting container was placed on the chopper discharge. The polycorder was switched on at the start of each run. Feeding time was 30 seconds, after which materials were collected, sacked, labelled and weighed.

The experimental design was completely randomized with treatments consisting of four speeds: 900, 1050, 1200 and 1500 rpm, three materials with a set clearance and feed rate for each.

RESULTS AND DISCUSSION

The average power, capacity, specific energy and percent chopped materials of 25 and 50 mm length or less, at four speeds and for different materials are shown in Table 1.

Tests with Napier grass

At 1.5 and 2 mm clearance, power and capacity increased with speed. At 2 mm clearance, the highest capacity was 1113.8 kg/hr at 1500 rpm. This did not vary significantly from the capacity at 1200 rpm. However power at 1200 rpm was 16% less. Hence at 2 mm clearance, the best speed setting was 1200 rpm. In terms of length of chop, speed had no significant effect (*Fig. 2*).

At 1.5 mm clearance the highest capacity was 1186 kg/hr at 1500 rpm, 12% higher than at 1200 rpm. Power at 1200 and 1500 rpm were not significantly different, hence the best setting for 1.5 mm clearance was 1500 rpm. There was an average 74% increase in power required at 1.5 mm relative to 2 mm clearance, but there was no improvement in terms of quality of chop. Hence for napier grass 2 mm clearance is the better setting.

Tests with corn stalks

Tests were carried out at 2 mm clearance with corn stalks at three speeds: 900, 1050 and 1200 rpm. The capacity at 1200 and 1050 rpm did not vary significantly. However, power at 1050 rpm was 28% less. Hence the best speed setting for corn at 2 mm clearance was 1050 rpm. Chopping corn required almost 4 times as much power compared to napier at the same clearance because of larger stalk cross-section and higher stiffness. *Figure 3* indicates that although power can be reduced by using a larger clearance, the quality of cut would be sacrificed. The driving motor could only cope with 2 stalks at a time with these settings. The highest power measured was 2.302 kW (3.07 hp) at this feed rate.

Tests with rice straw

Chopping rice straw at 65.9% moisture yielded significantly higher capacity than at 47.8% moisture. There was no significant difference in power required to chop rice straw at these moisture levels. This could be attributed to moisture variations for a sample of rice straw. It was advisable to chop rice straw as fresh as possible for highest capacity and minimum power.

At 65.9% moisture, the highest capacity obtained was 744 kg/hr at 1050 rpm. This was 44% higher than at 1200 rpm. The power required at these two speed settings was not significantly different, therefore the speed of 1500 for rice straw was recommended. This was also supported by the results of rice straw at 47.8% moisture.

Due to its low stiffness and the 0.5 mm clearance used, rice straw yielded the lowest percentage of chopped materials of 25 and 50 mm length or less (*Fig. 3*). With a second pass, the frequency of chopped materials of 25 and 50 mm length or less, increased significantly by 59% and 23%, respectively (*Fig .4*).

Comparison with commercial choppers

Performance parameters of commercial choppers based on manufacturers' brochures are shown in Table 2. Their capacities range from 400 to 5000 kg/hr at operating speeds of 650 to 970 rpm. Their specific energy range from 0.491 to 1.875 kW-hr/tonne.

At these operating speeds, the capacity of the FLIPPER was 900, 890, and 432 kg/hr for napier, corn and rice straw, respectively. The corresponding specific energy for each material was 0.414, 1.770 and 2.417 kW-hr/tonne, respectively. These values show that the FLIPPER was comparable to the commercial machines, but it can be made for 20 to 33% the cost in its class.

CONCLUSIONS

1. The chopper performance with three materials: napier grass, corn stalks and rice straw was satisfactory, provided the materials were fresh, or had high moisture and the right clearance and speed for each were used.

2. Capacity was directly influenced by blade speed. Highest capacities were obtained at 1500 rpm.

3. The effect of speed or power requirement varied with crop material. For stiff, high-moisture materials like napier and corn, power increased with speed. For low stiffness materials like low-moisture rice straw, power was not significantly influenced by speed.

4. Power requirement increased with decreasing clearance. The smallest practicable clearance is important for effective cutting of stemmy and leafy materials.

5. For napier grass, the best setting was 2 mm clearance at 1200 rpm. At this setting capacity was 1012.8 kg/hr and specific energy was 0.513 kw-hr/tonne.

6. For corn stalks, limited tests indicate the best setting was 1050 rpm at 2 mm clearance. This setting gave 1062 kg/hr capacity and specific energy of 1.697 kW-hr/tonne.

7. For rice straw at 65.9% moisture, the best setting was 1500 rpm and clearance of 0.5 mm or less, if possible. Capacities of 744 kg/hr and specific energy of 1.475 kW-hr/tonne were obtained. Subjecting rice straw to a second pass increased the frequency of 25 and 50 mm chopped length or less, to 59 and 23%, respectively.

8. For the materials used, the highest power requirement was with corn, at 2.302 kW (3.07 hp). This power can be provided by a 2.6 kW motor or a 4 kW engine.

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Table 1. Average power requirement, capacity, specific energy and percent chopped materials of 25 and 50 mm length or less, at four speeds.

	SPEED (rpm)	POWER (kW)	CAPACITY (kg/hr)	SPECIFIC ENERGY (kW-hr/tonne)	MATERIALS WITH LENGTH ≤25 mm (%)	≤ 50 MM (%)
(1)	Napier grass, 70.9% MCwb, 2 mm clearance					
	900	0.357[a]	865[a]	0.414[a]	20	84
	1050	0.448[b]	922.5[ab]	0.483[ab]	29	91
	1200	0.517[c]	1012.8[bc]	0.513[b]	24	87
	1500	0.613[d]	1113.8[c]	0.552[b]	30	94
	F test	*	*	*		
	(CV)	(9.26)	(8.25)	(11.17)		
(2)	Napier grass, 80.9% MCwb, 1.5 mm clearance					
	900	0.740[a]	900[a]	0.820[a]	29	85
	1050	0.789[ab]	930[ab]	0.848[a]	26	87
	1200	0.827[abc]	1060[c]	0.781[a]	27	83
	1500	0.937[c]	1186[d]	0.790[a]	29	84
	F test	*	*	ns		
	(CV)	(7.68)	(4.54)	(7.81)		

(3)	Corn stalks, 62.7% MCwb, 2 mm clearance					
	900	1.574[a]	890[a]	1.770[a]	31	87
	1050	1.799[a]	1062[b]	1.697[a]	35	89
	1200	2.302[b]	1148[b]	2.016[a]	23	93
	F test	ns	*	ns		
	(CV)	(13.16)	(6.134)	(14.63)		
(4)	Rice straw, 47.8% MC wb, 0.5 mm clearance					
	900	0.996[a]	394[a]	2.535[a]	29	64
	1050	1.023[ab]	466[b]	2.196[ab]	25	59
	1200	1.055[ab]	498[bc]	2.124[ab]	28	61
	1500	1.131[b]	584[d]	1.946[b]	17	62
	F test	ns	*	ns		
	(CV)	(6.02)	(5.95)	(10.16)		
(5)	Rice straw, 65.9% MCwb, 0.5 mm clearance					
	900	1.043[ab]	432[a]	2.417[a]	28	65
	1050	0.930[b]	488[ab]	1.910[a]	27	60
	1200	1.171[ab]	518[abc]	2.263[ab]	22	62
	1500	1.026[ab]	744[d]	1.475[b]	26	62
	F test	*	*	*		
	(CV)	(7.43)	(15.22)	(14.38)		

For each material and MC, in a column means followed by a common letter are not significantly different at the 5% level by LSD.

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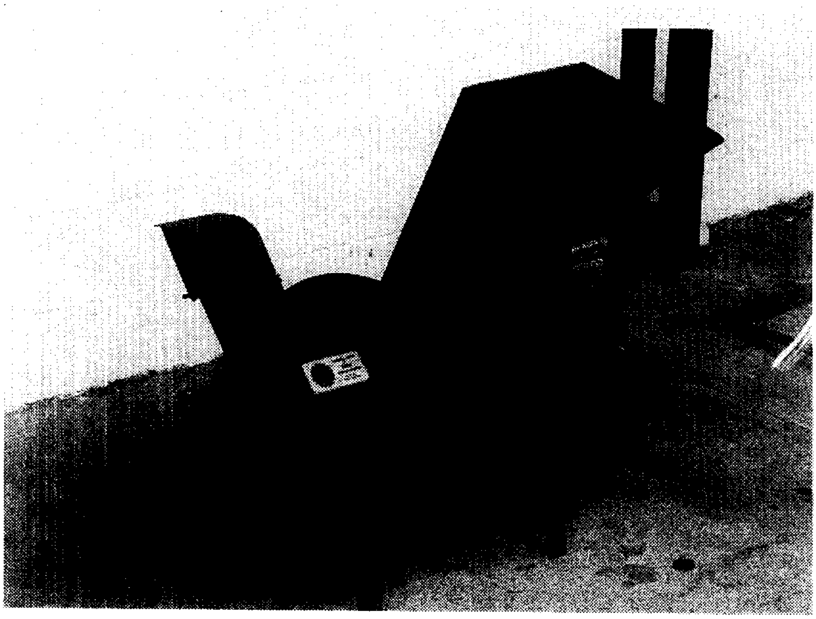

Fig. 1a. The flywheel-type, inclined axis, straw and forage chopper.

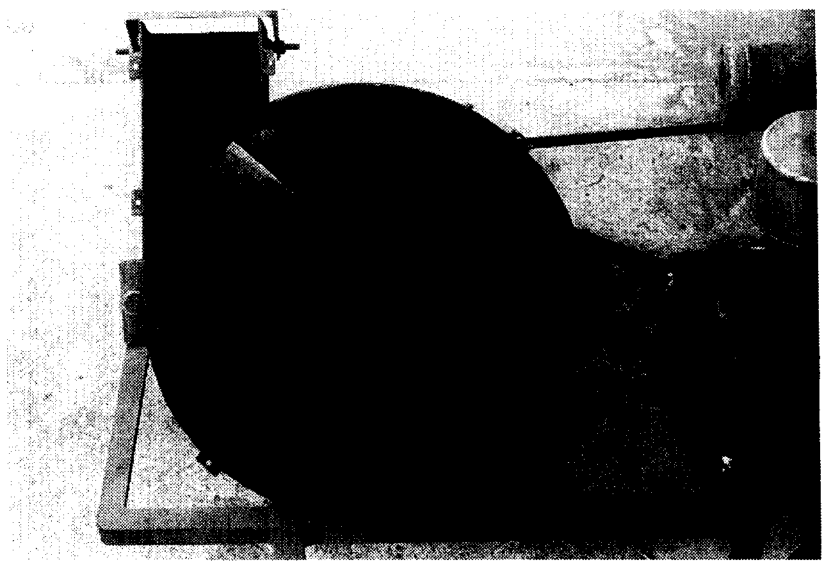

Fig. 1b. The chopper blades: four rotating blades angled 10° upwards with respect to the counteredge. The distance from the cutting plane to the bottom of the housing is 25 cm, the theoretical length of chop.

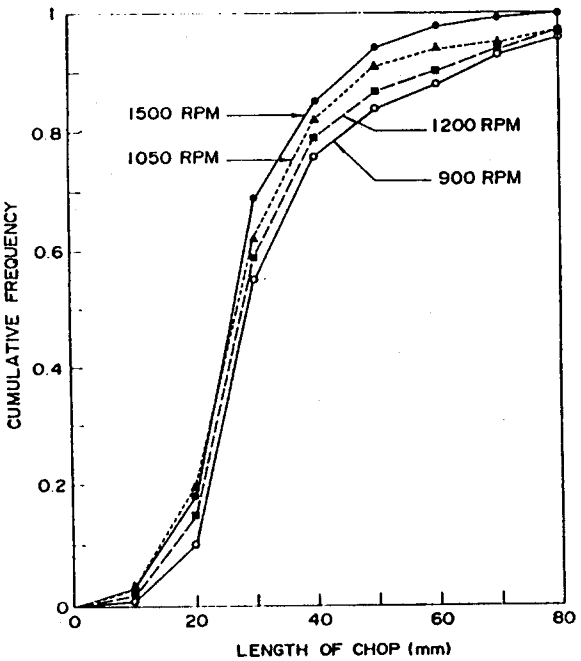

Fig 2. Frequency distribution for each length of chop for napier grass (2mm clearance) at four varying speeds.

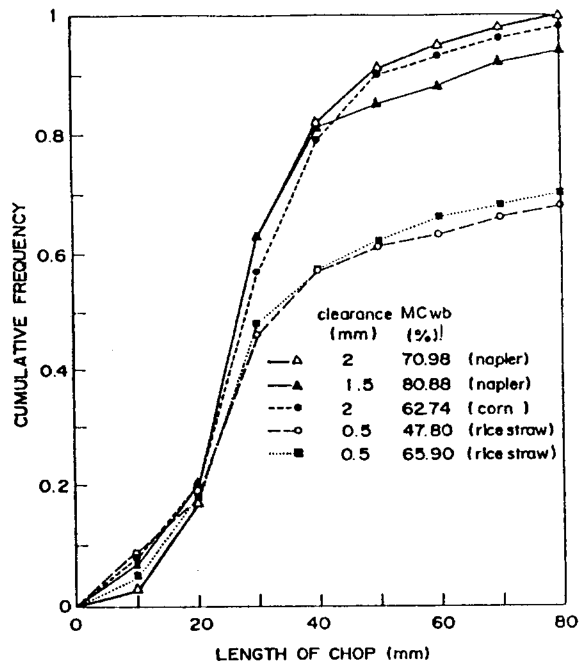

Fig. 3. Frequency distribution for each length of chop for different materials at 1500 rpm.

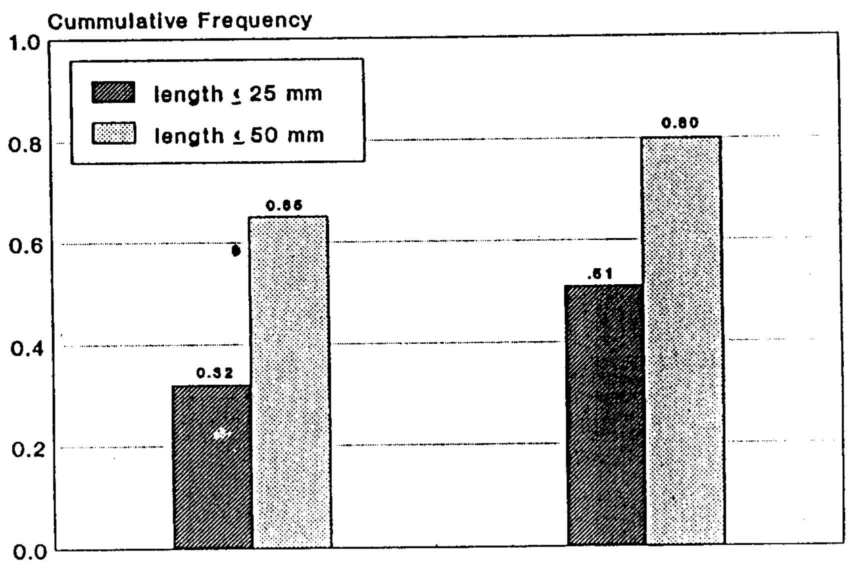

Figure 4. Frequency of chopped straw for first pass and second pass (MC = 3.7%, Clearance = 0.5 mm)

Table 2. Specification and performance parameters of commercial choppers.

Chopper Brands	PC-603[a]	PC-700[b]	YDC-[c] 125	SS-77[d]	Iseki CH101MB	Iseki CS131	Chiyada	Mitsubishi F-15
No. of Rot Blades	2	2	-	-	-	-	-	-
Blade RPM	-	-	650-800	750-970	900	650-850		
Length of cut (mm)	-	-	11,15,28, 30,37,62	20-150	9,17,32, 60	10,15,24, 30,48,140	6 60	16-150
Power (KW)	1.111	0.927	.736-1.472	1.104	1.104-2.576	0.184-2.208	0.4-0.75	.368-2.208
Capacity (kg/hr f.w)	1737	1144	1350	1000-1500	1800	3000	400	3000
Specific Energy (KWhr/ton)	0.639	0.811	0.545-1.090	0.736-1.104	0.613 1.431	0.061 0.736	1-1.875	0.123-0.736
Type*	F	F	F	F	C	C	C	C
With feeding Device	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Over all Weight	60	61	58	65	59	43	37	45

a,b,c,d - Korean made (Reference: RNAM, 1991); the rest are Japanese made

*F = Flywheel type, C = Cylinder type

Note: Power, specific energy were calculated from manufacturer's leaflets.