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PERFORMANCES OF ANIMAL DRIVEN SUGARCANE CRUSHER

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ABSTRACT

An experimental study was undertaken to determine the working capacity of the draft animals in driving a suagrcane crusher and the performance characteristics of the crusher. The power requirement for driving a crusher, as obtained from this study, were 0.52 kW to 1.94 kW depending on the feeding rate of sugarcane. Two pair of animals, when driving the crusher, were found to produce 0.57 to 2.11 kW at speeds ranging from 2.3 to 4.3 km/h. The crushing capacity and juice extraction capacity varied within the range of 149 to 205 kg/h and 64 to 110.5 kg/h, respectively. Gur recovery from the sugarcane was from 8 to 9.6 percent.

INTRODUCTION

Unrefined brown sugar (locally called as 'GUR'), is usually produced by the farmers in small scale. For gur making, juice is extracted first from the sugarcane by means of an animal-driven crusher. Then the juice is heated until its water content is removed almost completely leaving a brown, dry and fine crystals of sugar. There are 16 sugar mills in the country which produce white sugar in industrial scale. Average production of sugarcane in Bangladesh is about 6.97 million metric tons (Hossain et al., 1994). About 45% of sugarcane produced in the country is used for gur, 30% for white sugar and the remainder for chewing and seed.

Among the rural population, gur is much more popular than white sugar, because gur is cheaper and more tasty to them. Gur making takes the shape of rural industry during sugarcane harvesting season and many people make their livelihood from this industry and business.

Motor driven crushers are hardly seen except those in the sugar mills. Bullocks or buffalos are generally used for driving suagrcane crushers used for gur making. The low-income farmers cannot afford to purchase power crushers or even animal-driven crushers. Animal-driven crushers are available on hire basis in every season of sugarcane harvest. Buffalos are always preferred to bullocks, because they are capable of giving more energy than the bullocks.

The farmers are traditionally using the sugarcane crushers without knowing how to improve the working capacity of the animals and the crushing efficiency of the crushers. It is the responsibility of the engineers and the manufacturers of the agricultural tools and equipments to improve the crushing technology and the design of the equipment. The improvements in the design of crushers can be achieved through collection of informations on the performance of the existing crushers and their energy requirements.

Locally made animal-driven sugarcane crusher consists of three vertical rollers. The king and the extraction rollers are of 20 to 22.5 cm diameter, each having 20 vertical teeth. A smaller feeder roller has 12 teeth on it. These 3 rollers are

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mounted on an wooden frame such that they maintain a specified gap between them (Fig. 1). The king roller is attached to a beam which is driven by one or two pairs of animals. The other rollers get power from the king roller through gears. The sugarcane, when fed between the king and the feeder rollers (Fig. 2), are squized extracting juice from the stem. Juice is then collected in a container and the bagasse are removed by hand.

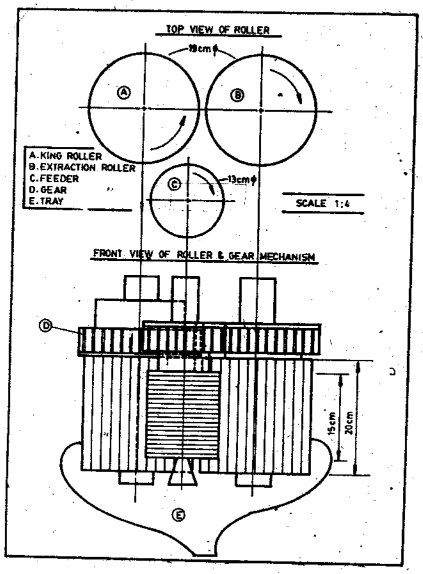

Fig. 1 Top and front view of animal driven sugarcane crusher

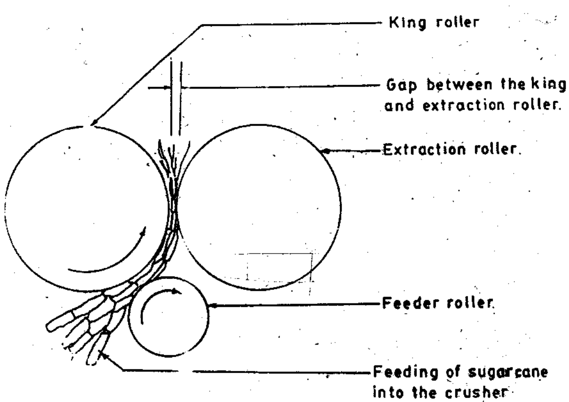

Fig. 2 Feeding of sugarcane through the rollers of the crusher

The power required to drive a crusher depends on the design parameters of the crusher and the linkage and the feeding rate of suagrcane whereas the power given by the animal depends on the animal health, its walking speed and design of the harness and the dimensions of the linkage (Fig. 3).

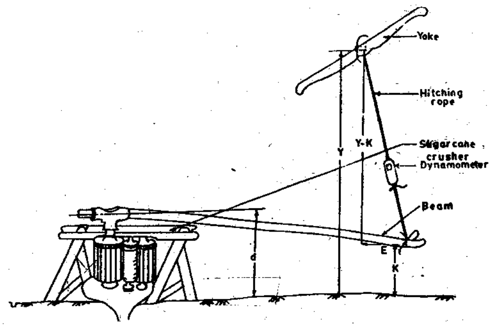

Fig. 3 Linkage between the crusher and animal harness and their alignment

The present work was, therefore, undertaken to study (i) the working capacity of the draft animals, (ii) draft power requirements of the crushers; (iii) design of the crusher-animal linkage and (iv) crushing capacity and juice extraction capacity of the crushers. Possible improvement on the design of the crusher-animal linkage and its installation is suggested.

MATERIALS AND METHODS

The performance study of the animal drawn sugarcane crusher was done in different places of Gazipur, Valuka, Mymensingh and Ishurdi during the sugarcane harvesting season of 1988, 1989 and 1991. The farmers were randomly selected considering their farm sizes including the area under sugarcane and the size and category of animals (bullock and buffalo) they use for the crusher.

The farmers usually rented the animal drawn crushers from the dealers in the locality. Family labours as well as hired labours were utilized for the crushing operation. During the test operations, the following informations were recorded. (i) Design parameters of the animal drawn crusher, (ii) Dimensions of the various components of the linkage used to connect the driving animals with the crusher, (iii) pulling force exerted by the animals, (iv) Pulling force (draft) required to drive the crusher, (v) Time taken by the animals for 10 or 15 revolutions in order to calculate the linear speed of the animals, (vi) Feeding rate of sugarcane to the crusher, (vii) Amount of juice extracted per hour and per day, (viii) Gur produced per hour and per day, (ix) labour required per day.

One man prepared the sugarcane for feeding. Sugarcane was weighed before feeding and the amount of sugarcane fed per hour and per day were recorded. One man fed the sugarcane and another man drove the animals. Time of starting and finishing the crushing operation were taken by hand watch and the time for 10 or 15 revolutions was taken by a stop watch. The juice extracted were collected in a container of known capacity and the amount of juice extracted per hour and per day were recorded. The dimensions of the various components of the linkage were measured by a tape before starting the operation. The neck height of the animals were also measured.

In order to measure the pulling force, a calibrated hydraulic dynamometer was used in between the ropes connecting the free end of the beam and the animal harness.

A self-made chula and a rectangular metalic pan over it were used for heating the juice until it was ready for making spherical lumps of gur weighing one kg each. The bagasse obtained from the crusher was dried and used as fuel for the chula.

The area of land in which sugarcane was grown and the average yield of sugarcane were recorded by interviewing the farmer.

Animal Draft and Draft Available to Crusher

The animal draft (P) was measured by a dynamometer. The actual draft available to the crusher was calculated from the following relationship between the effective draft available to the crusher (G) and the measured pull (P).

Effective pull or draft, $G = P \times \cos\theta$ ....(1)

where, $\cos\theta = E / X$ ....(2)

$E = \sqrt{[X^2 - (Y - K)^2]}$ ....(3)

Power Available to Crusher

The power available to the crusher (P_o) in kW was calculated as follows :

Crusher Power, $P_o = G \times S / 367.1$ ....(4)

Velocity, $S = 2 \times \pi \times R \times N \times 3.6 / T$ ....(5)

Effective radius, $R = \sqrt{L^2 - (D - K)^2}$ ......(6)

Theoretically, the effective pull (G) is less than the measured pull (P) when $Y - K > 0$. The draft given by the driving animal will be fully utilized if $Y = K$. In this situation the measured pull will be equal to the effective pull. The linear speed (S) of the driving animal is directly proportional to the effective radius (R). R will be maximum and equal to X when $D = K$. Thus the linear speed is reduced if $D - K > 0$. The power available to the crusher will be maximum if there is no reduction of pull and linear velocity due to $Y - K$ and $D - K$ values, respectively.

RESULTS AND DISCUSSION

The buffaloes, when driving the crusher, were found to produce pulls in the range of 100 to 180 kg and the bullocks 90 to 110 kg (Table 1). The effective pull and torque given by the driving animal were less than those possible because of the dimensions of the linkage. Fig. 4 shows the variations of the animal height (Y) and the linkage dimensions (D, K, L, X). The effective draft on the crusher ranged from 90 to 174 kg for buffalows and from 84 to 104 kg for the bullocks (Table 1). There was 2.5 to 9.6% loss of draft due to the linkage (Table 1). Fig. 5 shows the variations of the animal pull and effective draft.

Table 1 Draft and power requirement of animal driven crushers

Driving Animal	Number of tests	Pull[1] (kg)	Draft[2] (kg)	Loss of Draft (%)	Animal Power (kW)	Crusher Power (kW)	Loss of Power (%)
Buffalow	27	100—180	90—174	2.5—9.6	0.88—2.11	0.79—1.94	2.7—10.4
Bullock	6	90—110	84—104	3.6—8.1	0.57—1.64	0.52—1.54	3.6—8.5

1 Pull exerted by the animals 2 Draft force available to crusher

The power given to the crusher by two pair of animals was from 0.52 to 1.94 kW at speeds ranging from 2.3 to 4.3 km/h. Power loss due to the linkage was from 2.7 to 10.4 percent (Table 1). The power available to the buffalo driven crushers and the animal speeds are shown in Fig. 5. In order to minimize the losses of draft and power, the crusher could be set on a raised platform such that Y=D=K.

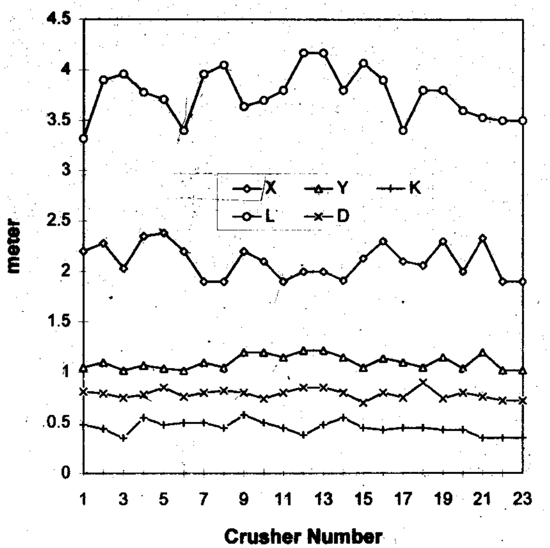

Fig. 4 Variation of animal heights and linkage dimensions (X, Y, K, L and D)

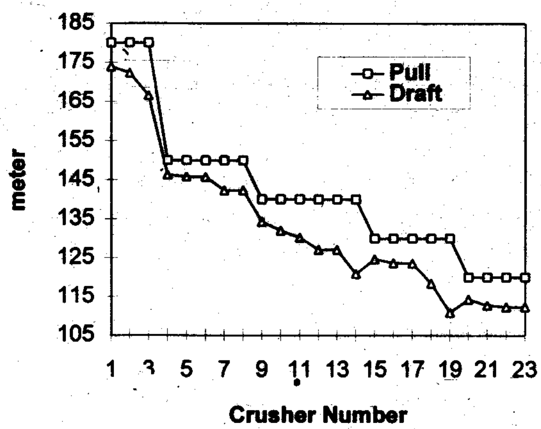

Fig. 5 Variations of the animal pull and effective draft

The crusher capacity ranged from 149 to 205 kg/h with juice extraction capacity of 64 to 110.5 kg/h. From 12.6 to 22.3 kg gur were produced per hour from sugarcane (Table 2). Juice recovery was higher at Ishurdi region (56 to 62% of cane) than that at the Mymensingh and Dhaka region (40 to 49% of cane). Variation of technician's personal efficiency in taking measurements and the crusher condition might be the cause of such discrepancy. Gur recovery in percent of cane was from 8 to 9.6.

Table 2 Crushing and Juice extraction capacities of animal driven sugarcane crushers

Driving Animal	Crusher capacity (kg/h)	Juice Extraction capacity (kg/h)	Juice extraction (% of cane)	Gur production capacity (kg/h)	Gur production (% of cane)
Buffalow	174 — 205	70 — 110.5	40 — 49	14.0 — 22.3	8 — 9.6
Bullock	149 — 182	64 — 77.0	42 — 43	12.6 — 14.8	8 — 8.5

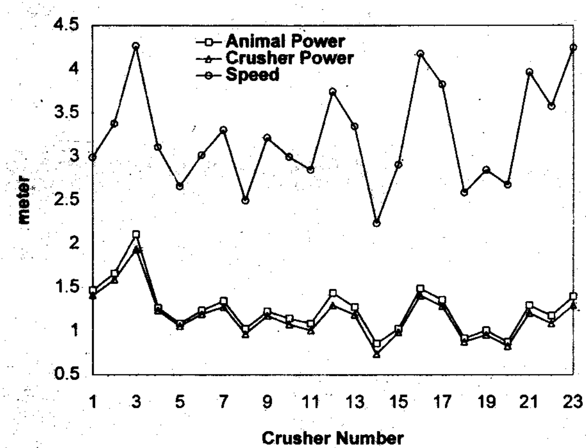

Fig.6 Animal speed, animal power and power available to crushers

CONCLUSION

The power requirement for driving a crusher was within the range of 0.52 kW to 1.94 kW depending on the feeding rate of sugarcane. Two pair of animals, when driving the crusher, were found to produce 0.57 to 2.11 kW power at speeds ranging from 2.3 to 4.3 km/h. The crusher capacity varied from 149 to 205 kg/h with juice extraction capacity ranging from 64 to 110.5 kg/h. Gur recovery from the sugarcane was 8 to 9.6 percent.

There was 2.5 to 9.6% loss of draft and 2.7 to 10.4% loss of power due to the linkage. The losses of draft and power could be minimized by mounting the crusher on a raised plateform such that Y = D = K.

Nomenclature

D = height of the crusher centre from the ground, m
G = effective draft, kg
K= Height of the free end of the beam from the ground,m
L = length of the beam, m
N = number of revolutions made by the animal
P = Pull measured by the dynamometer, kg
R = effective radius of the circle revolving around by the animal, m
S = linear speed of the working animal, km/h
T = time for N revolutions, sec
X = Length of the rope hitching the free end of the beam to the yoke, m
Y = Height of animal neck from the ground, m

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