

CRUSHING MECHANISM OF OIL SEEDS AND PERFORMANCES OF ANIMAL POWERED GHANI

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ABSTRACT

This paper describes the crushing mechanism of oil seeds, analyses the forces involved and the performance of animal powered ghani used in oil extraction. Comparisons of the performances of animal powered ghani with electrical and diesel powered ghanies are made. There was no significant difference of oil recovery between the various methods of crushing. The oil yield was higher at the beginning than the subsequent operating times and it was reduced very sharply after 2 hours of crushing. The pulling force was increased with crushing time as well as with crushing load.

INTRODUCTION

Animal power is used mainly for tillage purpose and also for oil seed crushing, sugarcane crushing and rural transport systems in Bangladesh (Islam, 1990; Bhuiyan, 1991; Haque, 1990; Miah, 1989 and Saif, *et al.* 1983). Animal powered ghani (oil extractor) was first developed in India for extracting oil from mustard and sesame seeds, but in some places they are used for coconut and groundnut crushing (UNIFEM, 1987). Until the 1950s ghani was used in Bangladesh only for extraction of oil from mustard, sesame and linseed. Recently their use has declined rapidly owing to the introduction of modern technology of oil extraction such as electric and diesel powered oil mills. The advantages of modern oil mills include less time for crushing and higher oil extraction capacity compared to animal powered ghani. In Bangladesh, ghanies are used in rural areas where electric power is not available and the villagers cannot afford diesel powered ghani. Little research work has been undertaken to improve the performance of animal powered ghani. Where owners of animal powered ghanies are unable to acquire electric or diesel powered mills, they will continue to use them for commercial purposes in the foreseeable future. For this reason, some research

work should be undertaken to improve their design, and performance to improve the economics of oil production.

The aim of the present study was to investigate the mechanisms of crushing oil seeds and study of the performances of animal powered ghanies as well as to compare performances with electric and diesel powered ghanies. The specific objectives were to study: (1) the draught power requirement to operate the ghani; (2) oil extraction capacity; (3) mechanism of oil extraction; (4) power transmission system; and (5) the crushing force requirements for oil extraction.

Notations

- T = Tension force on the connecting rope from katari to the top of the pestle, kN
- W_1 = Weight of katari, kN
- W_2 = Added weight on the katari, kN
- L = Length of katari, m
- L_1 = Distance of the tension rope from the mortar body, m
- L_2 = Distance of the added weight W_2 from the mortar body, m
- P = Pulling force required to operate the katari, kN
- N = Normal force acting on the contact end of the katari with the mortar body, kN
- N_1 = Normal force acting on lower end of the pestle, kN

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- N_2 = Side force acting on the lower end of the pestle, kN
 N_3 = Side force acting on the upper crushing end of the pestle, kN
 F = Frictional force acting on the contact point of the katari to the mortar body, kN
 f = Co-efficient of friction between katari and mortar body
 R_1 = Reaction force of the yoke upon the pestle, kN
 R_2 = Reaction of the yoke upon the neck of the bullock, kN
 Y = Total length of the yoke, m
 Y_1 = Distance between R_1 & R_2 , m
 Y_2 = Distance between P & R_1 , m
 S = Speed of animal walk during the operation of the ghani, m/s
 D_p = Draught power developed by the bullock, kW
 Q = Angle of the tension rope with the center line of the pestle, deg
 a = Angle of inclination of the katari with the horizontal, deg
 B = Angle of tension rope with the katari, deg

Working Principle of Animal Powered Ghani

A schematic diagram of a typical animal powered ghani used by the 'Kulus' (local name of ghani owners) in Bangladesh is shown in Fig. 1. This ghani is generally operated by single draught animal (cow, bullock or buffalo). It consists of a wooden mortar (A) and a wood or stone pestle (B). The mortar is fixed to the ground and the pestle is driven by one bullock or other kinds of draught animals. The pestle is supported in the mortar hole where the seeds are crushed by frictional pressure. This frictional force is developed by adding weights (E) on the katari (D). The oil runs through a hole located at the bottom (C) of the mortar while the residue or oil cake is scooped out from the mortar. Depending upon the size of mortar, draught animal pull and type of oil seeds, ghani can crush about 8-10 kg seeds in every hr. For the continuous operation of an animal powered ghani, two bullocks and 2 to 3 man-days are required. Some times, human power is also used for operating the ghani and it requires 3 to 4 man-days.

MATERIALS AND METHODS

Oil extraction using animal powered ghanies are small scale industry usually found in the non-

electrified villages of Bangladesh. In order to collect information on the mechanisms of crushing and performances of animal powered ghani, detailed studies were carried out in different villages of Mymensingh district and experiments were performed with four ghanies. A spring loaded dynamometer was used to record the pulling force, while the rotational speed of the katari and crushing time were recorded using a stopwatch. The radius of the circle of rotation of the draught animal and the dimensions of different components of the ghani were measured with a tape. From the radius of the circle of rotation and rev/min of draught animal, the linear speed of animal walk was calculated. From this speed and measured pulling force, the draught power required to operate the ghani was estimated. A balance was used to measure the oil yields and oil cake production from 5 kg of mustard seeds. The loss in gross weight was calculated by subtracting the total weight of oil and oil cake from input weight of mustard seeds. Percent of oil recovery was calculated by dividing the oil production rate by oil seeds crushing capacity. Efficiency of oil extraction was calculated by dividing the percentage of oil recovered by the extract oil content in mustard seeds. Mustard seeds contain 40-44% oil of total weight (DAE, 1985; BBS, 1990). Weight of katari (W_1) and variable weights (W_2) placed time to time on the katari during crushing were recorded. Some information regarding performances of electric and diesel powered ghanies were also collected to compare their performance with animal powered ghanies.

Mechanics of oil seed crushing

The position of different parts of animal powered ghani are shown in Fig. 1. Based on the free body diagram (Figs. 2 & 3), theoretical equations of forces acting on the connecting rope between katari and pestle, pulling force to operate the katari and the crushing force developed underneath the pestle can be obtained as:

$$T = \frac{1/2 LW_1 \cos\alpha + L_2 W_2 \cos\alpha}{L_1 \sin\beta} \dots\dots\dots (1)$$

$$N = T \cos\beta + (W_1 + W_2) \sin\alpha \dots\dots\dots (2)$$

$$F = fN \dots\dots\dots (3)$$

$$\text{and } F = \frac{1/2 LW_1 \cos\alpha + L_2 W_2 \cos\alpha}{L_1 \sin\beta} f \cos\beta + f(W_1 + W_2) \sin\alpha \dots\dots\dots (4)$$

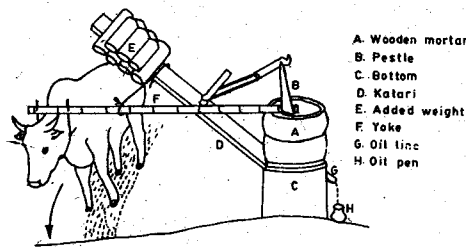


Fig.1 Schematic diagram of animal powered ghani showing different parts.

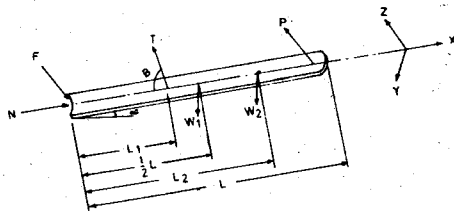


Fig.2 Free body diagram of forces acting on Katari.

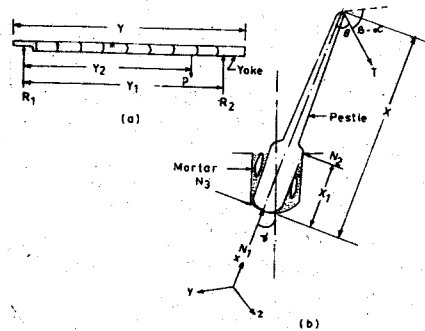


Fig.3 Free body diagram of forces acting upon the yoke and pestle.

Forces acting upon the pestle at stationary condition (Fig. 3.b) can be represented by the following equations:

$$N_1 = T \cos\alpha \dots\dots\dots (5)$$

$$N_2 = (X/X_1) T \sin\alpha \dots\dots\dots (6)$$

$$N_3 = \frac{(X - X_1)}{X_1} T \sin\alpha \dots\dots\dots (7)$$

When the katari rotates frictional force will develop between the oil seeds and pestle and between oil seeds and mortar. Oil extraction will take place due to the simultaneous action of friction and pressure (UNIFEM, 1987). As oil extraction continues there will be a decrease of oil content in the crushed oil seeds paste and this will make the paste hard. This hardness will raise the frictional force which will need more crushing force to extract the remaining oil. Equations 5, 6, and 7 show that the crushing force is directly proportional to T and hence with W_2 (Eqn. 1). Thus with the increase of crushing time, W_2 will need to increase.

Also, the relationship between the reaction forces acting upon the neck of the draught animal and the pulling force required to operate the katari (Fig. 3.a) can be represented by the following equations:

$$P = R_1 + R_2 \quad \dots\dots\dots(8)$$

$$R_1 = \frac{(Y_1 - Y_2)}{Y_2} P \quad \dots\dots\dots(9)$$

$$R_2 = (Y_2/Y_1) P \quad \dots\dots\dots(10)$$

The actual force supplied by the draught animal is R_2 . The draught power developed by the draught animal can be obtained from the following equations:

$$D_p = R_2 S = (Y_2/Y_1) PS \quad \dots\dots\dots(11)$$

RESULTS AND DISCUSSION

Oil Yield

The oil production and crushing time were recorded and the result is shown in Fig. 4. Oil production began within 10 min of starting. After 30 min, the oil production was 34.5%. It increased to 36.81% after 60 min of operation, then the production reduced very sharply to 16.11% after 90 min of operation and it further reduced to 8.74% after 120 min operation. Finally oil production was 3.83% after 150 min of operation. The sharp reduction in oil production was due to the rapid decrease in oil content of the seeds.

Besides, after 150 min of operation, the oil extraction was totally ceased because the applied compressive force on the oil cake was not sufficient to extract any more oil from the oil cake. It was observed that the seeds were forming cake as the operation proceeded and ultimately hard cake was formed at the end of operation.⁵⁰

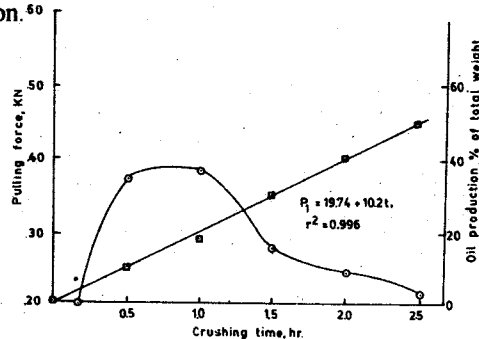


Fig. 4 Variation in oil yield and pulling force with crushing time $\square$, Oil production $\circ$, Measured pulling force (P)

Comparative performances of animal, diesel engine and electric motor powered ghanies are shown in Table 1. The results showed that the crushing capacity of animal powered ghanies was small in comparison to engine or motor powered ghanies. The results also showed that the oil recovery for animal, diesel and electric powered ghanies were 31.25, 32.5 and 35.0 of the total weight respectively.

Table 1. Performances of different types of oil seed crushing machines

Crushing method	Rotational speed (rev/min)	Crushing capacity (kg/d)	Oil extraction (kg/d)	Oil cake production (kg/d)	Oil recovery (%)
Animal powered ghani	4-6 (katari)	13.60	9.30	4.25	31.25
Diesel Powered ghani	50-60 (grinder)	80.00	53.20	26.00	32.50
Electric powered ghani	50-60 (grinder)	100.00	64.50	35.00	35.00

Pulling Force and Draught Power

The pulling force required to pull the katari and hence to drive the pestle is shown in Fig. 4. Initially the pulling force required by the katari was 0.20 kN

and it increased linearly with the elapse of time. As the crushing proceeded, the frictional force increased due to the small particles of broken seeds and as a result more pulling force was required to pull the katari. A maximum of 0.45 kN was required to pull

the katari. At the beginning of the crushing 152 kg load was placed on the katari and it was increased to 256 kg at the end of the crushing. As crushing proceeded, the oil content in broken seeds reduced and the extraction of oil from the seeds was not possible using the same crushing load. Hence, further increase of crushing load for the extraction of more oil was required.

The draught power developed during the crushing period in different ghanies by different power sources such as cow, bullock and man were calculated from the average pulling force using the eqn. 11 and are shown in Table 2. The minimum power developed by man at ghani G4 was 0.095kW and the maximum power developed by bullock at ghani G2 was 0.308 kw. The power developed varied depending on the required pulling force and the speed of operation of the respective ghanies.

Table 2 Draught power developed by different power sources in different ghanies

Identity of ghanies	Power source	Crushing capacity kg/d	Speed (AV) (m/s)	Pulling force (kN)	Y_1 m	Y_2 m	R_2 kN	Power developed D_p kW
G1	Cow	11.50	0.86	0.338	1.47	1.16	0.267	0.229
G2	Bullock	18.63	0.94	0.396	1.75	1.45	0.328	0.308
G3	Bullock	16.78	0.88	0.343	1.41	1.12	0.272	0.240
G4	Man	7.46	0.74	0.221	1.41	0.82	0.129	0.095

Rotation of katari and pestle

The direction of rotation of the katari was opposite to the rotation of the pestle. Katari was pulled and rotated by the draught animal in the anti-clockwise direction and the average speed of rotation was 5 rev/min. The pestle rotation was observed opposite to its own vertical axis due to the frictional forces acting upon the surface of its raised end into the mortar hole and one complete rotation of the pestle required 15 corresponding rotations of the katari.

CONCLUSIONS

The following conclusions are made on the basis of the experimental results:

- (1) At least 2.5 hours were needed to crush a batch of 5kg seeds by a ghani.
- (2) Pulling force increases with time of operation. Average pulling force was about 0.34 to 0.40 kN and power requirement was 0.24 to 0.3 kW for bullock ghani.
- (3) A pair of bullock was needed for continuous operation of the ghani.

- (4) The oil recovery was 31.25%. The ratio of oil production to the total recovery of oil after 2 hours of operation was very low and more extraction of oil could be done only by increasing the crushing load. But under this condition, the bullock was severely strained to pull the katari and sometimes it could not walk.

- (5) Diesel or electric operated ghanies are suitable where enough quantity of seeds are available. On the other hand, animal powered ghani requires low initial investment and feasible for the places where modern mills are not available.

SUGGESTIONS

Animal powered ghanies will remain in use in the families called 'Kulu' for years to come. As such its performance should be improved by improving the design parameters of mortar, pestle and katari of the ghani. Following suggestions can be made to improve the performance of ghani:

- (1) The performance of the ghani can be sufficiently improved by introducing cast iron surface

between the katari and the ghani bottom. This will reduce the pulling force requirement. The pestle surface which crush the seeds can also be changed with cast iron.

- (ii) The mortar hole size should be made large so as to accommodate a good volume of seeds which would necessitate the design improvement of load transmission system and crushing ability.

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