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PERFORMANCE OF MANUALLY OPERATED MUSTARD OIL MILL USED IN NEPAL

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Key words : Oil mill, Mustard, Performance

ABSTRACT

Manually operated mustard oil mill used in Nepal has been described in this paper. Operating procedure and force analysis have been done. The result obtained from force analysis is used to estimate the pressure exerted to crush the mustard seed. The oil extraction pattern under different operating conditions at different batch sizes is determined. 20 kg batch is found optimum and 69.16% of the total oil content is extracted. The pressure developed is only 1.36 MPa which is much less than the recommended value of 7.85 MPa. The efficiency of oil extraction can be increased mainly by increasing the pressure applied on the mustard seeds; increasing the arm length of the crossed beam and/or increasing the compression beam distance would give increased applied pressure. Some physical properties of mustard seed have been described.

INTRODUCTION

Mustard oil is used as cooking oil in rural areas of Nepal. Besides, it is commonly believed that mustard oil is better than the imported soybean oil. Traditional oil mill is widely used by the rural poor farmers because modern electric powered mills are expensive. Cheap and good quality timber is available locally to manufacture the manually operated mill. The machine is very simple to construct and repair technology is available.

This machine is being used traditionally through years without knowing how to improve its performance. Even the performance of this mill is not evaluated. The present study was, therefore, undertaken to study the performance of the manually operated oil mill and to explore the possibility to improve the design so as to increase the crushing efficiency and oil recovery. The specific objectives of the study were :

(1) to analyse the performance of Nepali oil mill.

(2) to analyse the force exerted on the mustard oil seeds for crushing

(3) to study the effect of batch size on the crushing efficiency and oil recovery.

WORKING PRINCIPLE

A perspective view of the manually operated oil mill is shown in Fig. 1. The process of oil extraction includes (a) cracking of the mustard seed by a disc grinder at low pressure, (b) heating of the seed mass up to 60° C in a frying pan, and (c) crushing of the seed mass at high pressure by the oil mill.

A batch of about 20 kg mustard seed is cracked by a disc grinder. The disc grinder applies low pressure on the seeds for cracking only and essentially no oil comes out of the seed at this gentle pressure. Cracked mustard seed comes out of grinder because of rolling and centrifugal action by the disc. The seeds are then taken in a frying pan and heated to about 60°C. At the time of heating little amount of water is sprayed over the seeds and continuous stirring is done for uniform heating and conditioning of the seeds. Heat-treated mustard is taken into a woven leather bag and the bag is placed in between two compression beams of the oil mill (Fig. 1).

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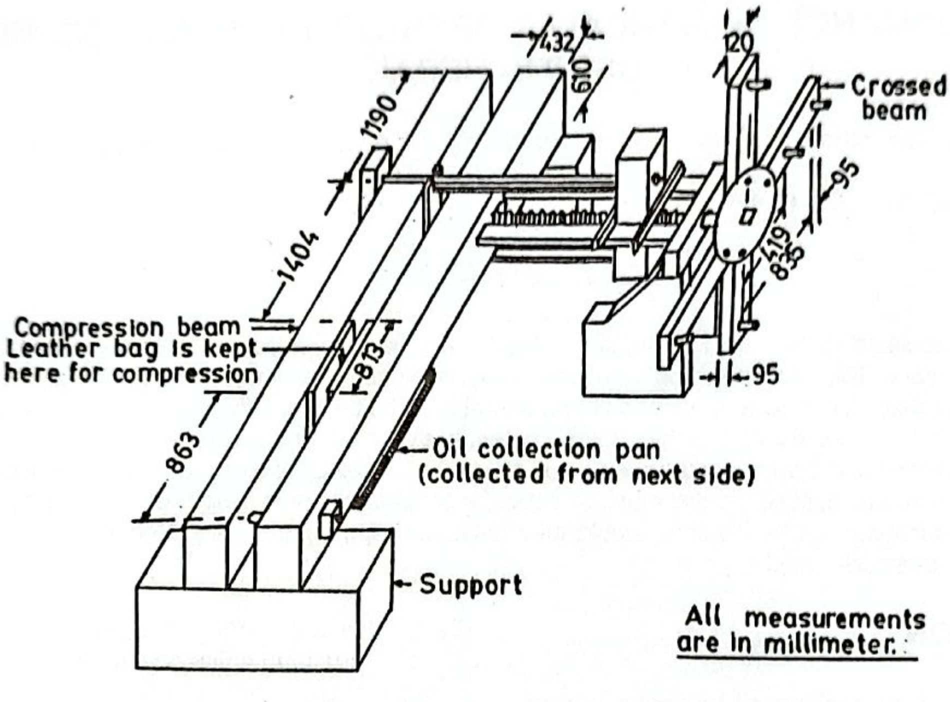

Fig. 1 Manually operated mustard oil mill

The compression beams apply high pressure on the seeds in the bag in order to crush and squeeze them for extraction of oil. The linkage that advances the compression beams to come closer and to apply high pressure on the seeds consists of a crossed-beam wheel, a screw and a sliding guide bar. The rotation of crossed-beam wheel is accomplished manually by an operator (Fig. 2). The screw is rigidly fixed to the wheel shaft and rotating the wheel rotates the screw resulting in advancement of two compression beams inward. The compression beams compress the seed mass and results in oil extraction. Just below the leather bag, there is a sloping flat oil collector pan with a small piece of pipe connected to its end. The extracted oil pours down in the pan and flows out through the pipe to the oil container. After applying maximum possible pressure on the seed mass in the bag, these are kept in that trapped and compressed condition for about 25 minutes to allow all extracted oil to flow out from inner part of seed mass. Then the oil cake is removed and pulverized using a mallet. The pulverized oil cake is heated as before on a frying pan and crushed again in a similar manner as described before. The crushing is stopped when no oil comes out of the pulverized oil cake. Three persons working continuously for 24 hours can handle 400 kg of mustard seed, extracting about 118 kg oil.

METHODOLOGY

Mustard seeds used in the study were collected from local market (local variety found in market), cleaned and ground by a disk grinder. The oil mill was tested separately with 18 kg, 20 kg and 23 kg batches to determine the effect of batch size on the oil extraction.

The dimensions of the mill and other lengths were measured by a steel tape. The weight of mustard seed, oil collected, weight of the operator and other weights were measured by appropriate balances. The oil content of seeds were determined by Nuclear Magnetic Resonance (NMR) method. The moisture content of seed was determined by heating the seeds for 6 hr at 130° C in an oven drier (as recommended by Whitely, 1951). The density of oil was measured using a density bottle. The pulling force required to rotate the crossed-beam wheel at idle condition was measured by a spring balance.

FORCE ANALYSIS

Referring to Fig. 2, the moment about O is

$$M_o = mg[a + r.\sin(\alpha + 45^o)] \quad \text{............. (1)}$$

where, M_o = rotating moment produced at the centre point 0

m = mass of the operator acting at the centre of gravity

g = acceleration due to gravity

a = horizontal distance of the operator's cg from the handle of the wheel

r = effective length of the crossed beam

α = angle that AB makes with Y-axis

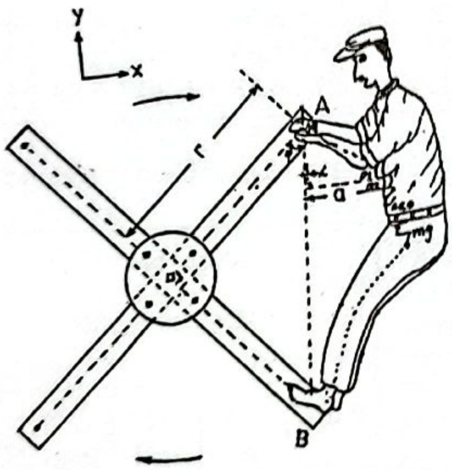

Fig. 2 Rotating the crossed beam

Referring to Fig. 3, the helix angle, β can be expressed as

$$\beta = \tan^{-1}\left[\frac{\text{Screw lead}}{\text{Mean circumference}}\right] \quad \text{............. (2)}$$

If M_f be the moment required to overcome the friction, axial force (Meriam, 1980) exerted on the beam by the screw is

$$F = \frac{M_0 - M_f}{R_s \times \tan(\beta + \phi)} \quad \text{............. (3)}$$

where F = axial force exerted on the beam by the screw

R_s = mean radius of screw

ϕ = friction angle of the screw

Friction angle of the screw, $\phi = \tan^{-1}\theta$ .... (4)

where θ = coefficient of friction of thread.

Friction moment, $M_f = F_o \times r$ .... (5)

where, F_o = force required to start the beam to rotate without load.

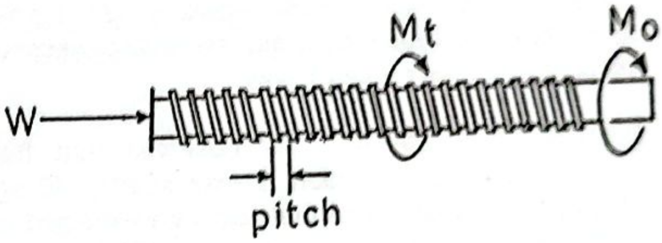

Fig. 3 Free-body diagram of the screw

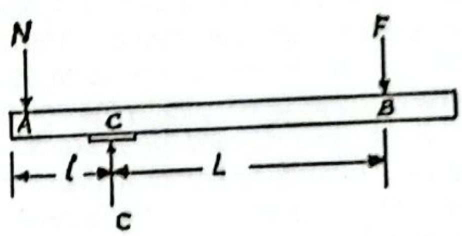

Fig. 4 Free-body diagram of the forces acting on the compression beam

Referring to Fig. 4, the compressive force, C is

$$C = \frac{F(l + L)}{l} \quad .... (6)$$

Compressive pressure, P' is given by

$$P' = \frac{C}{\text{Area of leather bag}} \quad .... (7)$$

RESULTS AND DISCUSSION

Some physical properties of mustard seed are shown in Table 1. Most of the oil content of the mustard seeds was extracted from the first run of crushing and very little amount of oil was recovered from the oil cake in the second run. Oil extracted in the first and second crushing were 5.12 kg and 0.8 kg respectively (Table 2 and 3) making a total of 5.92 kg. NMR result (Table 1) shows that the seed contains 42.8% oil and 69.16% of total oil content could be extracted by the present process;. 30.48% of total oil content would remain unextracted in the oil cake. Total time required for the first and the second run of crushing was about 1 hour.

Referring to Table 4, it is observed that the percentage of oil extraction is maximum at 20 kg batch size. Amount of oil that could be extracted is 0.296 kg per kg of mustard seed at 20 kg batch whereas for 18 kg and 23 kg batches it was 0.286 and 0.277 kg per kg of mustard seed, respectively.

The parameters involved in force analysis are summarized in Table 5. Maximum pressure that can be developed is estimated to be 1.36 MPa, which is much below the optimum level of 7.848 MPa (Reddy, 1993). From moment equation (1), M_0 is proportional to dynamic mass developed by the operator, a, r and sin α. For a given mill and the operator, m and r are constant. To produce higher moment the centre of gravity of the operator must be farthest in horizontal direction from O.

The main problem with this oil mill is the low pressure developed resulting in lower percentage of oil recovery. The pressure may, however, be increased by

1) increasing the arm length of the crossed beam,
2) increasing the compression beam distance between the leather bag and the screw.

Table 1 Some physical properties of mustard seed

Variety	Oil content (w/w)	Density of oil (g/cc)	Moisture content (% w.b)
Local variety	42.8	0.902	10.09

Table 2 Rate of oil collection in first crushing

Weight of seed taken (kg)	Weight of oil (kg) collected after					Weight of oil cake (kg)
	5 min	10 min	15 min	20 min	25 min	
18	2.90	3.54	4.02	4.34	4.50	13.50
20	3.93	4.64	4.88	5.00	5.12	14.88
23	4.46	4.83	5.20	5.38	5.45	17.55

Table 3 Rate of oil collection in second crushing

weight of seed taken (kg)	Weight of oil (kg) collected after					weight of oil cake (kg)
	5 min	10 min	15 min	20 min	25 min	
18	0.30	0.47	0.60	0.67	0.68	17.32
20	0.35	0.55	0.69	0.78	0.80	19.20
23	0.41	0.64	0.81	0.89	0.91	22.09

CONCLUSION

From the study it can be concluded that the 20 kg batch is optimum for maximum oil extraction. The pressure developed by the manual expeller is much

Table 4 Oil extracted per unit weight of mustard

Weight of seed taken (kg)	Oil collected in first crushing (kg)	Oil collected in second crushing (kg)	Total oil collected (kg)	Oil collected per unit weight of mustard (kg)
18	4.50	0.68	5.18	0.286
20	5.12	0.80	5.92	0.296
23	5.45	0.91	6.36	0.277

Table 5 The design parameters that affect the compressive force exerted on the seeds for oil extraction

Dynamic load applied by the operator, m = 130 kg	measured
$g = 9.8\ m/s^2$	
r = 0.835 m	measured
a = 0.4 m	average value
$\alpha = 20°$	measured
Screw pitch = 1.68 cm	measured
Coefficient of friction of thread, $\theta = 0.10$	Meriam (1980)
Mean dia. of screw = 6.83 cm	measured
Force required to start the beam to rotate (in idle condition), $F_o = 16$ N	measured using spring balance
l = 1.27 m	measured
L = 1.81 m	measured
Area of leather bag = $0.4237\ m^2$	Calculated applying graphical method
$M_o = 1473$ N.m	calculated, eqn (1)
$\beta = 4.48°$	calculated, eqn (2)
$\phi = 5.71°$	calculated, eqn (4)
$M_f = 13.4$ N.m	calculated, eqn (5)
F = 237.9 kN	calculated, eqn (3)
C = 577 kN	calculated, eqn (6)
p' = 1.36 MPa	calculated, eqn (7)

lower than the recommended value. The efficiency of oil extraction can be increased mainly by increasing the pressure applied on the mustard seeds; this can be accomplished by increasing the arm length of the crossed beam and/or increasing the compression beam distance between the leather bag and the screw.

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