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Performance evaluation of pedal operated flour mill with multi-applications

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Abstract

The flour mill was developed and evaluated for its performance to make Flour, Rawa (Sooji) and Dhal. The flour mill was evaluated for its performance by selecting different grains such as rice, maize, sorghum and pigeon pea. The clearance between the stones was set as per the requirement. The clearance for making dhal was set (7 mm). The highest yield recovery of flour, rava and dhal was obtained at 3, 5 and 7mm of clearance respectively. The average grinding capacity of developed mill was in the range of 2.0 to 3.0 kg/h for making fine flour. The average capacity of the mill for de-husking of pigeon pea was found to be 8.5 to 10.0 kg/h and for rava 6.6 – 8.5 kg/h. The maximum dhal recovery (60%) was achieved at a pedal speed of 70 rpm and at clearance of 7mm between the two grinding stones. The estimated production cost of developed flour mill was Rs. 5900/- and the cost operation was found to be ₹. 2.50, 2.00, 0.75 and 1.00 per kg of sorghum flour, wheat rava, rice rava and dhal respectively. The machine can also be used for other useful purposes such as for radio, charging the mobile and lighting the CFL bulb of 18 W etc.

Keywords: Flour mill, grinding stone clearance, grinding capacity, cost of operation

Introduction

In India, chapati and other variants of wheat forms the staple food of majority of the population. Wheat and wheat flours are the integral part of daily diet of Indian population. The wheat kernels are processed in chakki (flour mill) to produce wheat flour. The processing of grains to flour is generally carried out in flour mills. Flour obtained from such grains like maize is a staple food in many countries. The majority of milling equipment's in India are operated by electric power. As far as manual process is concerned flour is produced by hand cranking the heavy stone wheels which physically demanding through its energy and postural requirements. It may also lead to clinical and anatomical disorders which may affect the operator's health (Kajogbola, 2010) [3]. A person can generate four times more power (1/4 horsepower (HP)) by pedaling than by hand cranking. At the rate of 1/4 hp, continuous pedaling can be done for only short time about 10 minutes. However pedaling at half of this power (1/8 HP) can be sustained for around 60 minutes. The maximum power produced with legs is generally limited by adaptations within the oxygen transportation system (David, 1984) [1]. The power that can be produced by an average healthy person is a maximum of 75 W (Modak, 1997) [5].

Pedal power is the transfer of energy from a human source through the use of a foot pedal. The thigh muscles are utilized since they are the largest and the most powerful muscles in the body (Kajogbola, 2010) [3]. A person can produce 186 watts by pedaling for 10 minutes. However, pedaling at 93 watts can be sustained for 60 minutes. An average healthy athlete can produce 75W pedaling at 50 to 70 rpm (Tiwari *et al.* 2011) [6]. The optimal power output and pedaling rate for Indian agricultural workers has been worked out as 60 W and 50 rev/min, respectively (Tiwari *et al.* 2011) [6]. The speed of output shaft of dynapod at pedaling rate of 50 rev/min is about 167 rev/min. A simple rule would be that most people engaged in delivering power continuously for an hour would be more efficient when pedaling rate ranging from 50-70 rpm (Wilson, 1983). The mean working heart rate, mean working oxygen consumption rate and mean working energy expenditure rate of all subjects during the operation of maize dehuskersheller were found to be 139 (\pm 22.01) beats/min, 1.40 (\pm 0.20) l/min and 6.83 (\pm 1.07) kcal/min, respectively. Based on energy expenditure rate, the operation of pedal operated maize dehuskersheller was found under 'Heavy' work category (Choudhary *et al.*, 2018) [8]. In the present scenario most of the flour making machines are operated by electric power. The machines with electric motor are faster but those are costly as well as required continuous supply of electricity.

The unit operating by means of electricity has limited applications in the rural areas as the supply of electricity is not continuous. Therefore the pedal operated flour mill machine is having extensive utility in such areas. The traditional methods that are hand operated flour making machine by the rural people taking much more time and required more energy effort than pedal operated machine. Keeping the above facts in view, the present study was undertaken to evaluate the performance of developed flour mill, which uses human power by means of pedal as a source of energy to drive the machine.

Materials and Methods

A concept was developed for the pedal operated flour mill and fabrication and its performance evaluation were undertaken in the Department of Processing and Food Engineering, University of Agricultural Sciences (UAS), Raichur (Karnataka) in the year 2012-13, by using the basic principles of power operated flour mill and engineering properties of grains. 1 kg of each grain samples were used for testing the pedal operated flour mill. A simple pedal operated flour mill is suitable for grinding hard grains and also for making dhal in rural areas. It describes the use of bicycle concept for operating the flour mill by providing support to the operator and also to drive the components of the mill. The mill works at a relatively higher speed for smaller efforts of pedaling compared to the hand operated chakki. The mill is intended to use for a shorter period of time to meet the day to day needs of the household. The developed flour mill consisted of three sub systems viz., (i) Power transmission mechanism (ii) Process unit and (iii) Out let mechanism (Fig. 1 and Fig. 2). The power transmission unit basically consisted of a

conventional bicycle mechanism where a chain drive running over a pair of sprockets and a belt drive running over the pulley mounted on stone wheels were used. The process unit had a pair of stone wheels mounted over one another where the grains are crushed to form flour. A hemispherical bowl collector was fixed below the grinding stone to collect the flour (Fig. 3). All these units were assembled on a supporting frame with provision to fit a seat at the top and pedaling arrangement at the bottom. A trial was conducted on a simple pedal operated flour mill developed with 6 personals from an age group of 25-35 years. The mean (\pm SD) of age, weight, height were 28.5 ± 2.5 years, 62.34 ± 21 kg, 174.8 ± 3 cm, respectively. All the trials were conducted in the laboratory where the room temperature and relative humidity varied from $29-33^{\circ}\text{C}$ and $30-40\%$ respectively. The machine was tested in the pedaling range of 40-50, 50-60 and 60-70 rpm. The developed flour mill was tested and evaluated for its performance to make Flour, Rava and Dhal (Plate 1 and 3). The optimum range of speed was obtained by pre-test using sprockets of different number of teeth (Mark *et al* 2006) [4]. For evaluating the flour mill, the different grains such as rice, maize, sorghum and pigeon pea were used. The clearance between the grinding stones was set higher for making dhal as compared rawa and flour. Two labours were required for operating the flour mill, one for pedaling and the other one for feeding the grains and collecting the product. The speed in terms of rpm was also varied to get the product. The cost of operation of the developed pedal operated flour mill was calculated based on the fixed and variable cost. The price of components estimated for the development of pedal operated flour mill was presented in Appendix I. Economics of the developed flour mill was presented in Appendix II.

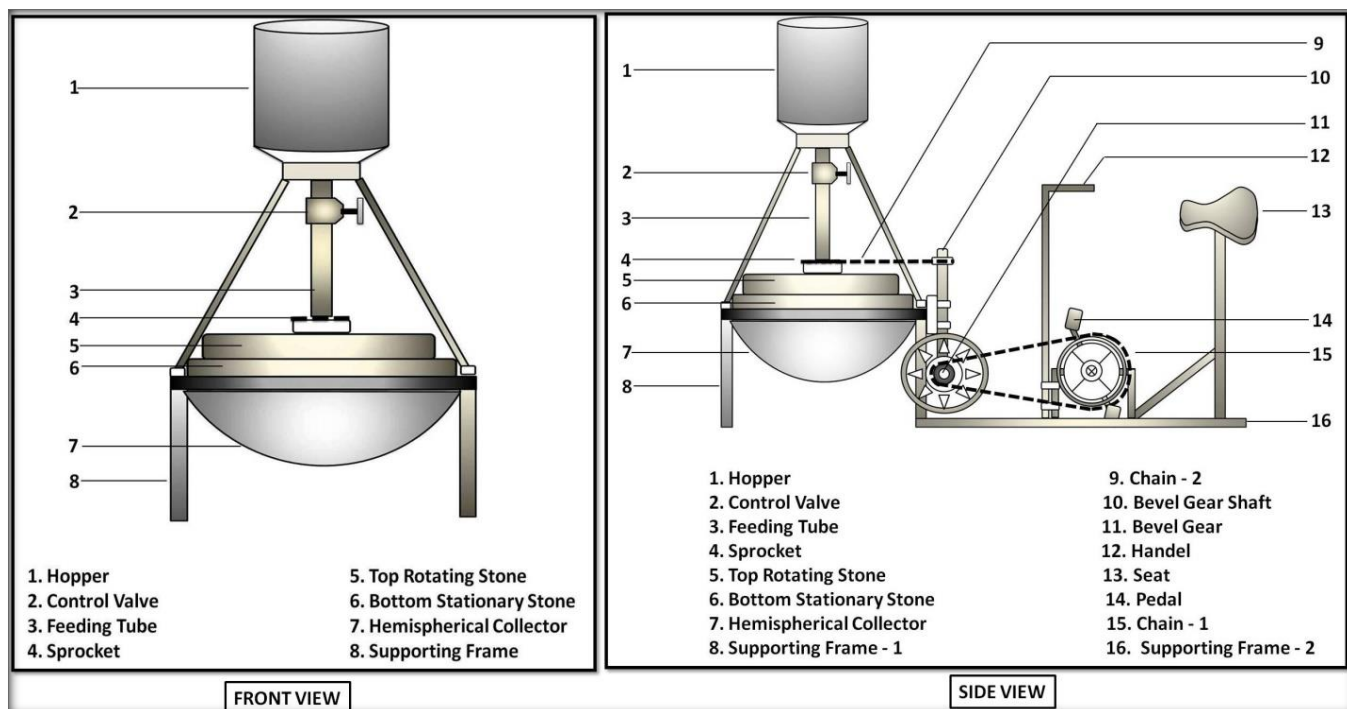


Fig 1: Front and Side view of developed pedal operated flour mill

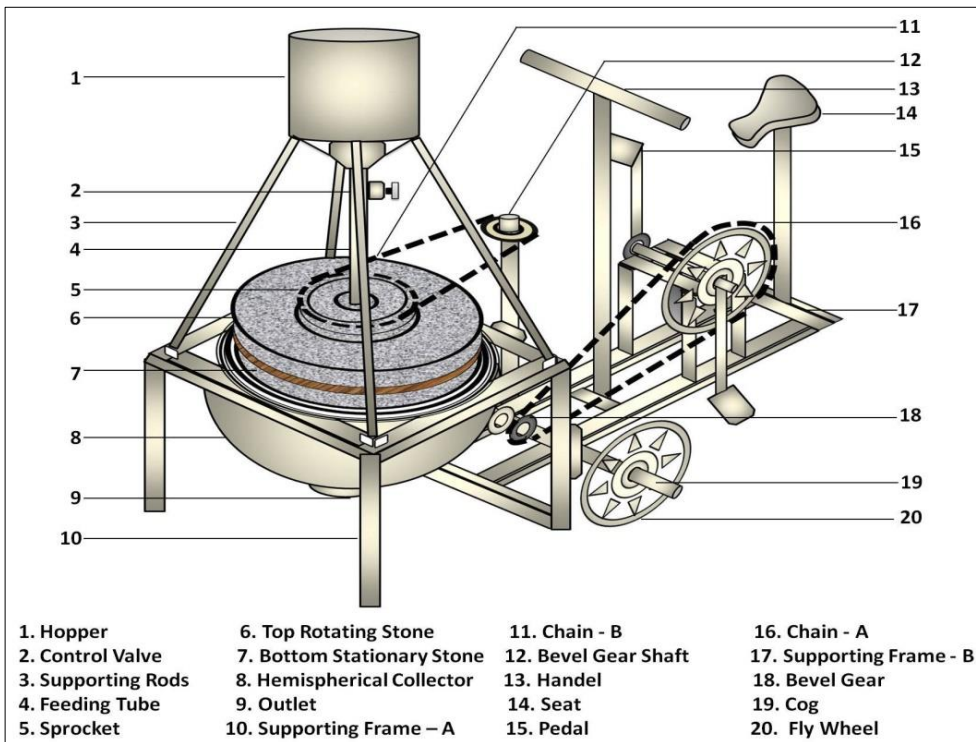


Fig 2: Isometric view of developed flour mill

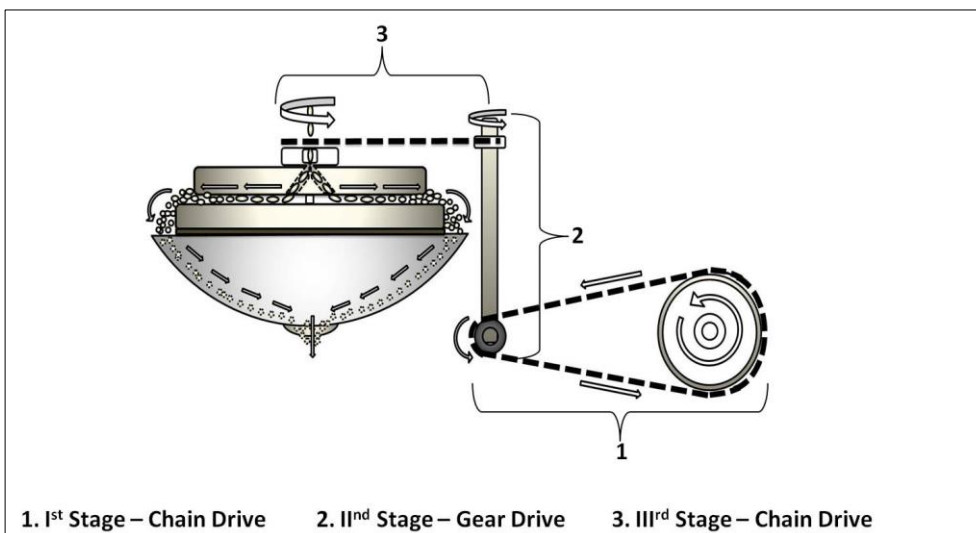


Fig 3: Processing unit flow of developed flour mill



Fig 4: Heap of end product at the outlet of pedal operated flour mill



Fig 5: House hold and small poultry farmer was using pedal operated flour mill.

Results and Discussion

The engineering properties of grains viz, size, shape etc were measured by following standard procedure and presented in table 1. The developed pedal operated flour mill was evaluated for its performance by selecting different grains.

Table 1: Engineering properties of grains

S. No.	Sample	Size (mm)	Shape	Volume (mm ³)	Bulk density (g/cm ³)	Porosity (%)	Angle of repose (°)	Co-efficient of friction
1	Rice	3.23	Oblong	25.9	0.607	43.50%	20.5	0.55
2	Pigeon pea	5.44	Round	67.1	0.833	38.50%	22.8	0.28
3	Wheat	3.88	Oblong	35.3	0.766	42.00%	25.5	0.37
4	Sorghum	3.41	Round	27.3	0.754	41.50%	29.5	0.35
5	Maize	7.43	Oblate	252.3	0.812	30.00%	28.2	0.25

The effect of clearance between the grinding stones on the yield recovery of pigeon pea dhal is shown in figure 4. The highest recovery of dhal was found in 7 mm clearance. From the figure, it is observed that the recovery of dhal and broken were in the range of 330.0 to 597.6 g and 186.0 to 453.2 g, respectively. The unhulled grain and husk were found to be in the range of 9.0 to 20.0 g and 87.0 to 198.0 g, respectively.

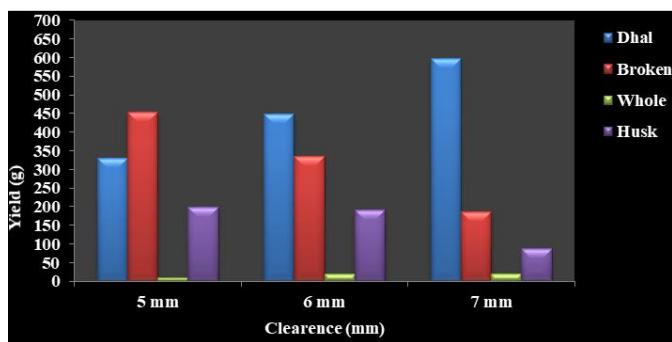


Fig 6: Yield recovery of pigeon pea *Dhal* with different clearance from pedal operated flour mill

The effect of grinding speed on the yield recovery of rice rawa is shown in figure 5. The highest recovery of rawa was found at 60 rpm. It is observed from the figure that the recovery of rice rawa and flour were in the range of 795.0 to 858.5 and 48.6 to 88.0 g, respectively. The unhulled grain was found to be in the range of 80.0 to 140.0 g for different grinding stones speed.

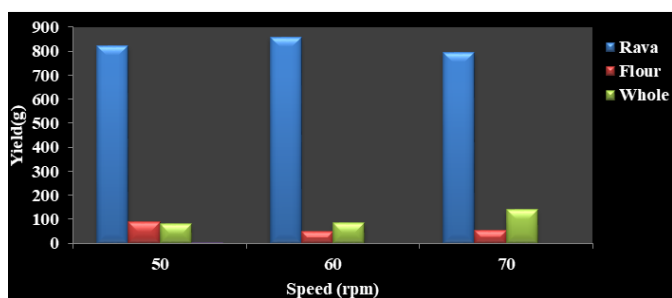


Fig 7: Yield recovery of rice *Rawa* with different speed (rpm) from pedal operated flourmill

The effect of grinding speed on the yield recovery of wheat rawa is shown in figure 6. The highest recovery of rawa was found at 70 rpm. It is observed from the figure that the recovery of wheat rawa and flour were in the range of 779.4 to 835.2 g and 56.0 to 125.3 g, respectively. The unhulled grain was found to be in the range of 86.0 to 95.0 g for different grinding stones speed.

During the testing of the flour mill, the speed of the stone at no load and load conditions were measured. The end products were collected to measure output. The weight of grains milled per hour was recorded to calculate the capacity of the pedal operated flour mill.

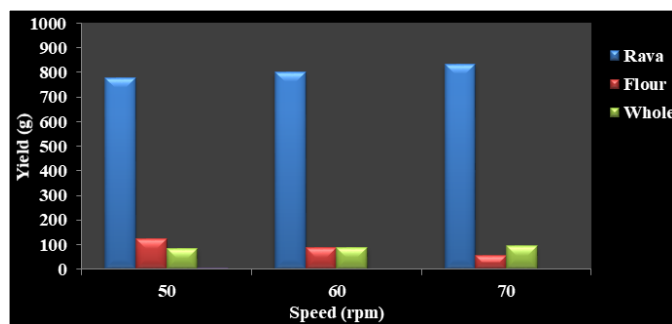


Fig 8: Yield recovery of wheat *Rava* with different speed (rpm) from pedal operated flour mill

The effect of grinding speed on the yield recovery of maize rawa is shown in figure 7. The highest recovery of rawa was found at 70 rpm. It is observed from the figure that the recovery of maize rawa and flour were in the range of 0 to 956 g and 0 to 29.2 g, respectively. The unhulled grain was found to be in the range of 0 to 20.0 g with different grinding stones speed. The yield recovery of maize Rava was nil at 50 rpm because the speed was not enough to move the grains from center to periphery of the stone.

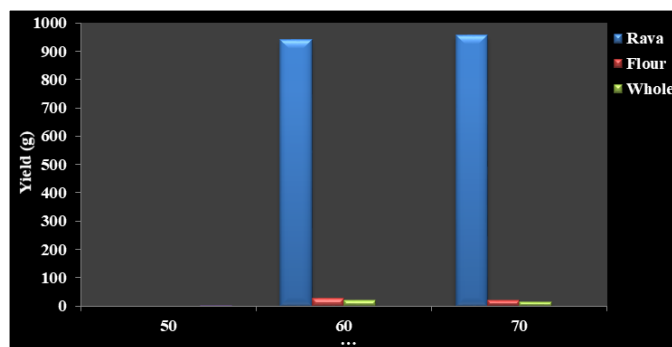


Fig 9: Yield recovery of maize *Rava* with different speed (rpm) from pedal operated flour mill

The effect of grinding speed on the yield recovery of sorghum rawa is shown in figure 8. The highest yield recovery of rawa was found at 50 rpm. It is observed from the figure that the recovery of sorghum rawa and flour were in the range of 430.0 to 620.0 g and 374.0 to 540.0 g, respectively. The unhulled grain was found to be in the range of 0 to 10.0 g with different grinding stones speed. The yield recovery of maize rawa was nil at 50 rpm because the speed was not enough to move the grains from center to periphery of the stone. The Sorghum flour takes more time to get maximum yield in this equipment. The similar results were reported by Hatwalne and Scholor (2012) [2].

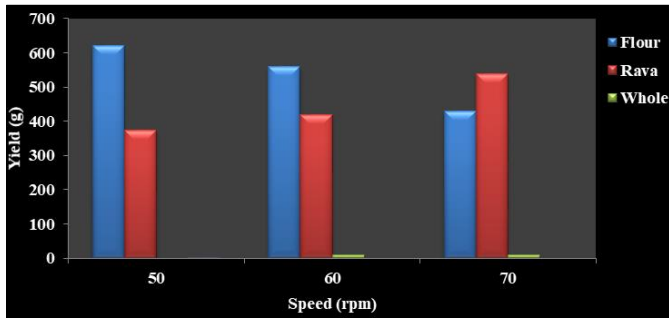


Fig 10: Yield recovery of sorghum flour with different speed (rpm) from pedal operated flour mill

The cost of operation of the developed pedal operated flour mill was calculated based on the fixed and variable cost. The cost of operation of the machine was worked out to make a pigeon pea *dhal*, rice *Rava*, wheat *Rava*, maize *Rava* and sorghum flour were ₹. 1.02/h, ₹.0.63/h, ₹.1.96/h, ₹.2.55/h and ₹.1.27/h, respectively.

Conclusion

The pedal operated flour mill was designed and fabricated for the households in rural areas, where there is acute shortage of electricity. The developed unit can also be used by the small poultry farms in the preparation of poultry feeds.

The highest yield recovery of flour, rava and dhal was obtained at 3, 5 and 7mm of clearance respectively. Average grinding capacity of developed mill was in the range of 2.0 to 3.0 kg/h for making a fine flour depending on the feed material where it ranged from 6.5 to 8.5 kg/h for making rava. Average capacity of the mill for de-husking of pigeon pea was found to be 8.5 to 10.0 kg/h. Maximum dhal recovery of 60% was achieved at 70 rpm peddle speed and at 7mm of clearance between the stones.

The estimated production cost of flour mill was ₹. 5900/- and the cost operation was ₹. 2.50, 2.00, 0.75 and 1.00 per kgs of Sorghum flour, wheat rava, rice rava and dhal respectively.

The developed flour mill would be a boon for the farmers of remote villages and in the villages where there is scarcity of electricity or no electricity at all. The mill could be operated with a very minimum effort and even the women in the households can run the mill easily whenever required. The machine can also be used for other useful purposes such as for radio, charging the mobile and lighting the CFL bulb of 18 W etc.

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