Original Research Article

ENGINEERING PROPERTIES OF SELECTED GRAINS FOR DEVELOPMENT OF PEDAL OPERATED FLOUR MILL

UNDER PEER REVIEW

ABSTRACT

The study was aimed to determine engineering properties of food grains which play an important role in the design of functional componenets of pedal-operated flour mill. The crops namely rice, pigeon pea, wheat, sorghum, and maize were selected for the study. Pedal operated flour mill comonents were designed and developed based on the variation of the engineering properties *viz.,* size, shape, aspect ratio, volume, geometric mean diameter, sphericity, bulk density, true density, density, porosity, weight of 1000 grains, angle of repose, static coefficient of friction and hardness. These properties were determined and considered for the design of functional components *viz.,* design of hopper, selection of drive mechanism, design of supporting frame, selection of grinding stones, power transmission, processing unit, safety, and ergonomics for easy and effective operation were made. The engineering properties are of great importance towards proper design, efficient process and equipment development. The developed pedal-operated flour mill is suitable for grinding almost all cereals and pulses to produce *Rawa,* Flour (*Atta),* and *Dhal* for human consumption and also for producing poultry/fish feed by grinding agro by-products and wastes.

Key words: Engineering properties, pedal operated flour mill, theoretical consideration, milling of grains

Introduction

India is the second largest producer of food grains in the world next to China (FAO in India, 2020). The total food grain production in India was around 297.50million tonnes during the year 2019-20 covering all the major food grains like rice, wheat maize, barley, pulses and millets (Press Information Bureau, GoI 2019). India witnesses nearly 5% wastage in cereals and pulses majorly due to lack of storage, processing infrastructure and primitive grain handling mechanism (Indiastat agriculture 2018). Low level of processing and lower value addition in food processing have been major factors hindering export performance despite India’s huge production base and competitive advantages. The nature of India's food export basket, which primarily comprises of primary products like rice, flour, sugar, meat, fish, etc., reflects a low level of processing. Nearly 84% of our food exports are made up of primary commodities, with only 16% of them being processed food. As a result, despite being one of the leading producers of food, India ranks 12 in the export of food goods because we are unable to advance along the value chain. The largest industry within the food sector in India is grain processing. 96% of processing is primary, with the secondary and tertiary sectors making up the remaining portion (Future of Food and Agriculture, 2017).

The engineering properties of food grains play an important role in the design of primary processing equipment and also for optimisation of flour, dhal, and rawa making process. It is necessary to consider these properties in the design and effective utilization of the equipment used in the processing of food grains. Size, form, volume, density, porosity, angle of repose, and static coefficient of friction are the engineering factors that have the greatest impact. Some seeds, fruits, and vegetables have spherical shapes with variations along one or both axes, according

UNDER PEER REVIEW

to reports. In general, three basic dimensions—length, breadth, and thickness—must be identified in order to characterise the shape of a food substance (Lgathinathane and Hana, 1998). The physical properties of the seed must be taken into consideration when choosing the right separating and cleaning machinery, and the primary dimensions must be taken into account when choosing and creating the appropriate size of the screen perforations (Fawalet al., 2009). It is crucial to identify and comprehend the engineering characteristics of these agricultural grains because these characteristics are crucial for the construction and advancement of pedal-operated flour mill machines. Therefore, the goal of this study was to identify the ideal grain engineering qualities that might be used in the design and development of pedal-operated flour mill machinery (Kleninet al., 1985).

Hard grains can be processed in a pedal-powered flour mill, which can also be used to make dhal in a village place. It shows how to operate a flour mill using the bicycle concept, supporting the operator while also powering various mill parts. When compared to the hand-operated chakki, the pedal flour mill operates at a considerably greater speed with less pedalling effort. The mill is made to be used for a shorter amount of time to fulfil daily household demands. As a result, the pedal-operated flour mill equipment is extremely useful in these locations. Traditional methods, such as hand-operated flour mills used by rural residents, take far longer to finish and need more energy than pedal-operated equipment.

The transfer of energy from a human source via a foot pedal is known as pedal power. Because they are the largest and strongest muscles in the body, the thigh muscles are used when pedalling (Kajogbola, 2010). According to calculations made by Tiwari et al. (2011), the ideal power output and pedalling speed for Indian

UNDER PEER REVIEW

agricultural labourers are 60 W and 50 rpm, respectively. The present study was carried out to determine the engineering properties of food grains and design of functional components of flour mill, keeping in mind the demand of rural people for initial processing of the grains and their lack of electricity.

MATERIALS AND METHODS

To achieve the target of this experimental work, random samples of 1 kg of food grains namely rice – BPT-5204, (moisture: 11.4 %), wheat - T.aestivum (moisture: 12.2%), sorghum- SPV-2217 (moisture: 10.9 %), pigeon pea – TS-3R (moisture: 11.2 %). All the grains were procured from the local wholesale (APMC) market, Raichur, Karnataka to determine the engineering properties. Determining the engineering characteristics of cereal and pulses is very important to optimize the design parameters of food processing equipment funational components.

Grains engineering properties relevant to the design of functional components of pedal operated flour mill were identified, *viz.,* size, shape, volume, density, porosity, specific gravity, angle of repose and static coefficient of friction.The shape of grain is an important parameter which affects conveying characteristics of solid materials by air or water (Krishnakumar, 2019). The engineering properties of grains were determined by following the standard procedures and the experimental set up used for purpose were described below.

Physical properties

Size

UNDER PEER REVIEW

It is the geometric average of the three dimensions, namely length, width, and thickness, which were measured with a digital micrometre (make: Mitutoyo, least count: 0.001 mm) to an accuracy of 0.01 mm (Ganachari et al., 2010). Twenty randomly chosen grains were subjected to the measurement, and the average of the replications was recorded (Shivabasappa et al., 2012). Size of grain was calculated using the following expression.

$$\text{Size} = (\text{Length, mm} \times \text{Breadth, mm} \times \text{Thickness, mm})^{1/3} \tag{1}$$

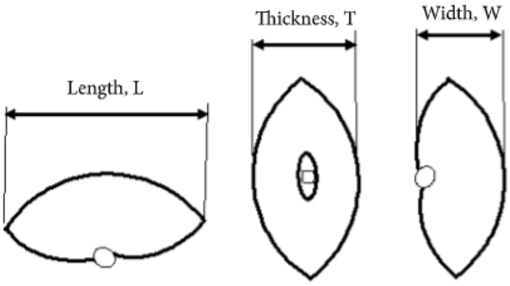


Fig. 1: Food grain principal dimensions

Shape

The dimensional characteristics of an object must be assessed for the longitudinal and lateral cross sections of the grains in order to compare them with the standard shape chart and obtain the standard shape chart for grains in order to define the shape of the grains (Balasubramanian and Viswanathan, 2010).

Aspect ratio

It is a highly important grain property that is mostly determined by the aspect. Aspect ratio is essentially the ratio of a seed's length to its breadth. In millimetres, aspect ratio is often measured (Maduako and Faborode, 1990).

Volume

UNDER PEER REVIEW

Volume of the grains were obtained by using following formula,

$$Volume = l \times b \times h \quad (2)$$

Where,

l= length of the grains, mm

b= breadth of the grains, mm

h= thickness of the grains, mm

Geometric Mean Diameter

It was calculated using the following formula (Mohsenin, 1986)

$$GMD = [LBT]^{1/3} \quad (3)$$

Where,

L= longest intercept (Length), mm

B= longest intercept normal to L (Width), mm

T=longest intercept normal to L and B (Thickness), mm

Sphericity

The ratio of the diameter of a sphere with the same volume as the particle to the diameter of the smallest enclosing sphere, or typically the biggest diameter of the seed, is known as sphericity. The relationship provided by Mohesenin, (1986), was utilised to compute the sphericity, which is used to define the grain's form.

$$\text{Sphericity, } F = GMD/ L \quad (4)$$

Where,

GMD = Geometric mean diameter, mm and

L = longest intercept (Length), mm

Bulk density (ρ_b)

UNDER PEER REVIEW

The bulk density is calculated using a container whose volume is known. The seed sample was placed into a container with a known volume, weighed, and the bulk density was determined using Mohsenin's (1986) methodology.

$$\text{Bulk density}, \rho b\left(\frac{\text{kg}}{\text{m3}}\right) = \frac{\textit{Weight of the grains (kg)}}{\textit{Volume of the grains including void space or rise in toluene level (m3)}} \qquad (5)$$

True Density (ρ_t)

A measuring cylinder with a known volume of toluene was filled with a grain sample with a known weight, and the rise in toluene level was noted. The Mohsenin, (1986) formula was used to determine the grain's actual density.

$$\text{True density}, \rho t\left(\frac{\text{kg}}{\text{m3}}\right) = \frac{\textit{Weight of the grains (kg)}}{\text{Volume of the grains excluding void space (m3)}} \qquad (6)$$

Porosity

Porosity is the ratio of percentage of volume occupied by pore space to total volume of sample (De Figueiredo *et al*., 2011). It can be calculated by using formula

$$P = \left(1 - \frac{\rho}{\rho_0}\right) \qquad (7)$$

Where,

P=Porosity, %

ρ = Density of the grains, kg/m^3

ρ_0 =True density of the grains, kg/m^3

Weight of 1000 grains

Randomly selected hundred grains were weighted using an electronic balance (make – citizen, max – 200g) of accuracy of 0.001 g (Ghadge and Prasad, 2012). The average weight of 100 grains was used to calculate the weight of 1000 grains (Ixtaina *et al.,* 2008).

UNDER PEER REVIEW

Frictional properties

Angle of repose

The angle of repose, which is useful in material handling equipment, was used to measure the flow-ability of the grain. In an experiment, two cylindrical diameter containers with known measurements were utilised, one of which had a top that was hollow and the other had one closed side (Palilo et al., 2018). Both containers were filled with the grain samples. According to Koochekie et al. (2007) and Plange et al. (2012), the hollow container was gradually removed in an upward orientation to allow grains to flow down the closed container and form a conical shape. The apex height was measured, and the trigonometry rule shown in (8) was used to compute the angle repose (Φ). Fig. 2 depicts the experimental configuration for determining the repose angle.

$$\Phi = \tan^{-1}\left[\left(\frac{h}{r}\right)\right] \tag{8}$$

Where,

Φ = Angle of repose, °

h = height, mm

r = radius, mm

UNDER PEER REVIEW

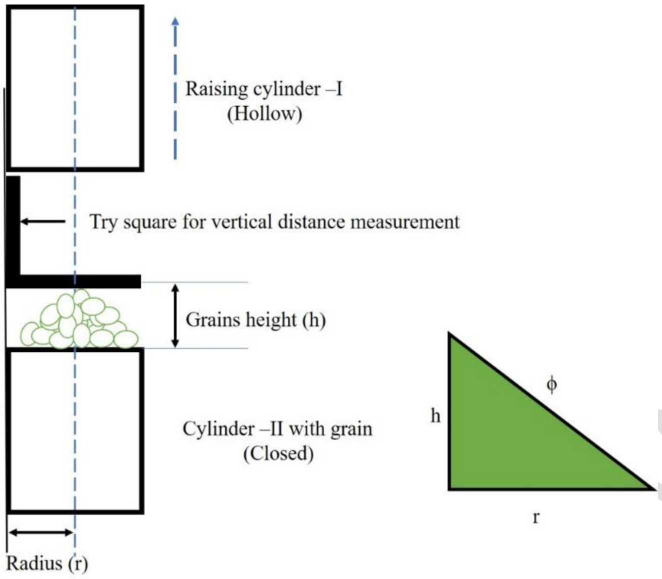


Fig.2: Experimental setup for angle of repose measurements

Static coefficient of friction

As shown in Figure 3, an apparatus setup was used to estimate the frictional characteristics of grains for the sliding surfaces made of plywood, plastic, aluminium, mild steel, and stainless steel (Palilo et al., 2018). A sample of ten grains was placed on a sliding surface when the equipment setup was horizontal and a spirit level was used to level it. The first seed began to slide down as the sliding surface was gradually elevated. At the instant the seed began sliding, the surface angle was noted. The surface was raised during the test until all of the remaining seeds began to slide downward, at which point the angle was noted. Equation 9, in where Φ is the sliding angle (tilt angle) and is the static coefficient friction, was used to derive the coefficients of friction.

UNDER PEER REVIEW

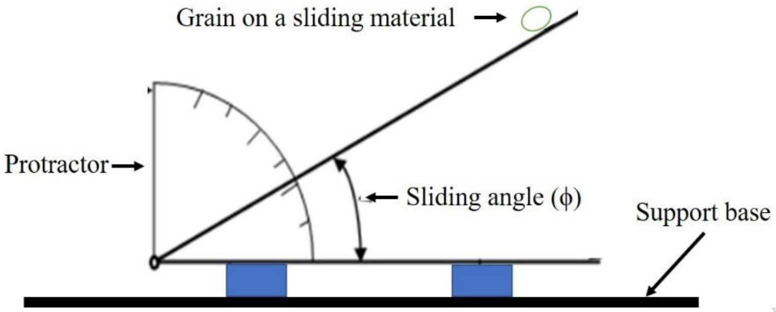


Fig. 3: Setup for measuring grains sliding angle

The static coefficient friction was calculated as,

$$\mu_e = \tan \Phi \tag{9}$$

Where,

μ_e = Static coefficient of friction

Φ = sliding angle/tilt angle

Mechanical Property

The hardness of the grains were measured using a double-column texture analyser (TA-HD Plus, Make-Stable Microsystems) with the load cell of 5 kg capacity in a test mode of measure force in compression, test option are return to start, pre-test and post-test speeds of 2 mm/sec, test speed of 0.1 mm/s and strain of 70% using the P2 test probe (Sunil *et al.,* 2016).

Design of functional components of pedal opeated flour mill

By utilising the engineering characteristics of grains and the fundamentals of a power operated flour mill, a functioning pedal-operated flour mill was conceived and constructed in the Department of Processing and Food Engineering at the College of Agricultural Engineering in Raichur, Karnataka. According to Modak and Moghe

UNDER PEER REVIEW

(1998), an average healthy athlete may produce up to 75 W of power. A person could cycle at a specific rate and produce more or the same amount of power for a longer period of time. A general rule would be that most persons would be more effective while pedalling at a rate between 50 and 70 revolutions per minute (rpm) for an hour of continuous power delivery (Wilson, 1983). The proposed equipment, which included three subsystems including (i) a power transmission mechanism (ii) a process unit, and (iii) an outlet mechanism, was created with these human capacities in mind.

The design of functional components of pedal operated flour mill machine was well considered in such a manner that it can be produced within the technology of sorounding environment. These engineering properties of grains were helps in design of finctional components *viz.,* design hopper, selection of drive mechanism, design of supporting frame, selection of grinding stones, safety and also ergonomics considerations for easy and effective operation.

Hopper

Mild steel sheet was used to construct a cylindrical hopper. Based on the frictional qualities, including the static coefficient of friction and angle of repose, the hopper's intake and outlet diameters and slope were estimated. The slope of the hopper was a key factor in the flow of the grains. The slope of hopper is decided by taking the average angle of repose of all the selected food grains so that the grains flow freely from the hopper to feed inlet of flour mill. The dimensions of hopper are shown in Figure 4.

UNDER PEER REVIEW

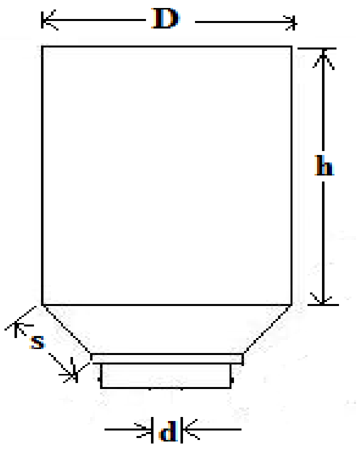


Fig. 4: Dimensions of hopper

$$V=\frac{\pi}{4}\times D^2\times h \tag{10}$$

Where,

D = Top diameter of the hopper, mm

d = Top bottom diameter of the hopper, mm

h = Height of the hopper, mm

s = Slant height, mm

Supporting frame

Fabrication of supportive frame and operator seat were considered based on operator ergonomics parameters. In order to accommodate various components at the necessary places, 1 ½˝ x 1½˝x ¼˝ inch mild steel (M.S.) angle iron was chosen for the frame's construction. The dead weight and load from the milling operation were supported vertically by 1600 mm M.S. angle iron. To support the hopper on the main frame, appropriate M. S. iron rods (¾˝ - 316 gauge size and 4 numbers) of 640 mm length of each were employed. Grain was transported from the hopper to the inlet of the flour mill's processing unit using a PVC pipe (50 x 3 mm). During the milling process, a PVC ball valve (50.8 x 5mm) was employed to regulate the flow

UNDER PEER REVIEW

rate of grains. An M. S. flat iron (1 ½˝ x ¼˝ in.) ring with a 3010 mm length was made to hold the stones on the main frame. A useful location for the pedalling mechanism was installed on the equipment's back side. For simple pedalling, a seat was attached at an appropriate height and horizontal distance from the crank shaft (Prasad et al., 2012). The pedal-powered flour mill is depicted in Figs. 6 and 7, respectively, in its side and front views.

Grinding stones

The selection of grinding stones based on hardness properties of selected grains. The grinding stones were chosen so that they would be able to produce flour, rava, and dhal with the desired fineness at the highest production rate while not being too heavy to cause the operator early fatigue (Modak and Bapat, 1987). Two rigid stones (450 x 50 mm) were placed one above the other. The bottom stone was stationary while the top stone was rotatingand provided with an opening at the centre for feeding the grains. The clearance (7 mm) between the two stones were adjusted by changing the position of the top stone vertically.

Drive mechanism

The selection of power drive system was based on operator ergonomics parameters and as well has hardness properties of selected grains. The power was transferred from the pedal to the top stone in stages. First, a chain drive was used to transfer power from the pedal to the large crank axle. Bevel gears were used by the little crank axle to transfer the horizontal drive to the vertical drive. For the top stone to rotate through the chain drive mechanism, the power was transferred from vertical drive to horizontal drive and back again. In order to power the shaft and maintain a spinning mass (inertia) that aids in rotation and offers a more consistent application

UNDER PEER REVIEW

of torque while operating, a suitable flywheel was used. With a velocity ratio of 2.66, the larger and smaller sprockets had 48 and 18 teeth, respectively.

Power transmission unit

Three phases, namely chain drive, gear drive, and chain drive, were used to transmit power from the operator to the processing unit. A pedal is rotated around a crank axle by the operator using his feet and legs. The bicycle's continuous chain runs between the sprockets, where the pedals are attached to a chain ring. The front sprocket rotates as a result of the front pedal movement being transmitted through the chain to a cog on the front wheel hub, driving the horizontal shaft that the bevel gear is placed on (Kajogbola et al., 2010). this initial phase of electrical transmission. Another bevel gear positioned on the second stage's vertical shaft served as the means by which this drive was transferred to the vertical shaft. The power was finally transferred to the top stone in the third stage of gearbox using larger sprockets and chain drive configurations (Mark et al., 2006). 186 watts can be generated by pedalling for 10 minutes. However, 60 minutes of continuous pedalling at 93 watts is possible. According to Tiwari et al. (2011), a typical healthy athlete may generate 75W while pedalling at 50 to 70 rpm.

Processing unit

The grains, which fall on the bottom stone through the central opening outlet, are pulled along by its rotation and moved outwards by centrifugal force. The crushing of grains takes place in between the two stones due to rubbing and shearing action. The crushed grains are discharged along the periphery of lower stone and collected in a hemispherical collector (Fig 5).

UNDER PEER REVIEW

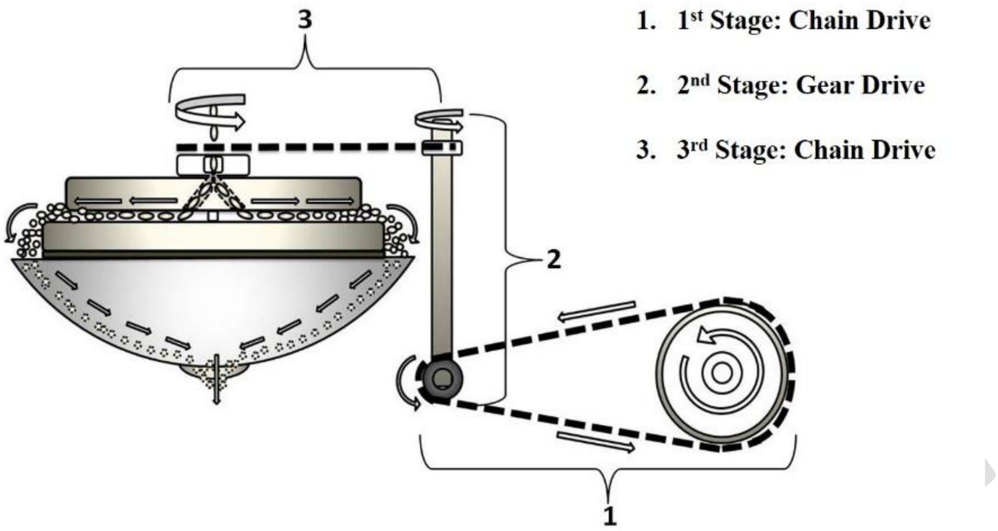
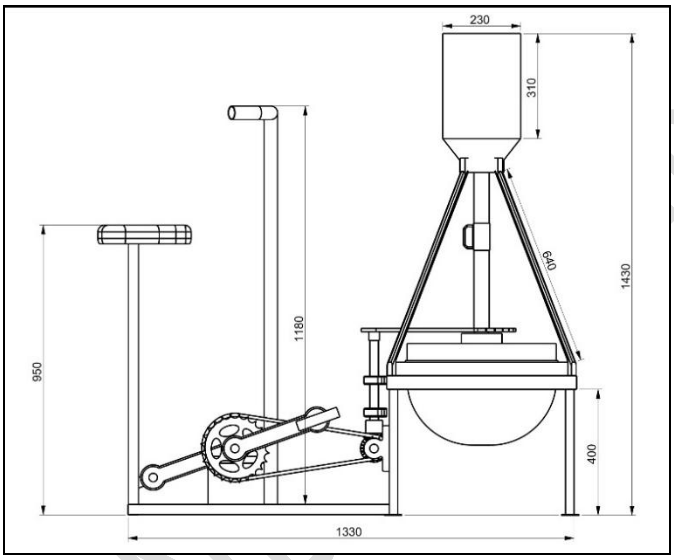


Fig. 5: Power transmission and processing unit flow of developed flour mill



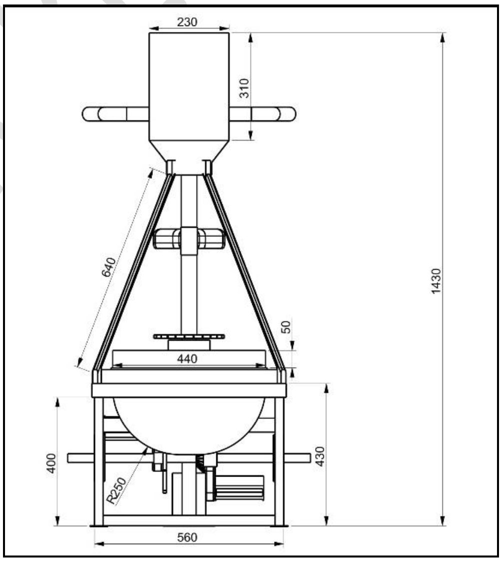


Fig. 6: Side view of flour mill

Fig. 7: Front view of flour mill

Safety considerations

Stability of the unit was also considered to ensure that the equipment remains upright at all time, i.e., it should not drift or bend to one direction and it should remain stationary (Deshmukh *et al.,* 2017).

UNDER PEER REVIEW

RESULTS AND DISCUSSION

The important physical properties of grains viz., size, shape,aspect ratio, volume, geometric mean diameter, sphericity, bulk density, true density, density, porosity and weight of 1000 grains were measured by following standard procedure and presented in Table 1.

Table 1: Physical properties of grains

Sl. No	*Particulars*	*Rice*	*Pigeon pea*	*Wheat*	*Sorghum*	*Maize*
1	Size (mm)	3.23±0.14	5.44±0.24	3.88±0.14	3.43±0.11	7.45±0.31
2	Shape	Oblong	Round	Oblong	Round	Oblate
3	Aspect ratio (%)	0.34±0.02	0.62±0.03	0.64±0.02	0.81±0.03	0.73±0.02
4	Volume (mm^3)	25.90±1.13	68.12±1.18	35.30±1.27	27.39±0.88	255.47±1.57
5	GMD (mm)	3.67±0.19	5.44±0.37	3.45±0.13	3.60±0.16	6.48±0.18
6	Sphericity (%)	0.45±0.10	0.83±0.02	0.53±0.04	0.83±0.02	0.82±0.02
7	Bulk density (g/cm^3)	0.61±0.03	0.83±0.04	0.77±0.03	0.76±0.02	0.81±0.03
8	True density (g/cm^3)	1.49±0.03	1.22±0.02	1.35±0.04	1.42±0.03	1.22±0.02
9	Porosity (%)	43.50±1.90	38.50±1.68	42.00±1.51	41.64±1.33	30.10±1.25
10	Mass of 1000 grains (g)	20.63±1.66	97.92±1.57	38.58±1.45	33.09±1.71	235.33±1.22

UNDER REVIEW

The average values of size for rice, pigeon pea, wheat, sorghum and maize were found to be 3.23±0.14, 5.44±0.24, 3.88±0.14, 3.43±0.11 and 7.45±0.31 mm respectively and the results were similar to those reported for rice, wheat, (Fawal*et al.,* 2009); pigeon pea (Ashwin *et al.,* 2017); maize (Nisha and Amarjeet, 2017) and sorghum (Surpam*et al.,* 2019). Shapes of the rice and wheat were recorded to be oblong. Pigeon pea and sorghum were found to be round and maize was found to be oblate. Similarly the average values of aspect ratio for rice, pigeon pea, wheat, sorghum and maize were found to be 0.34±0.02, 0.62±0.03, 0.64±0.02, 0.81±0.03 and 0.73±0.02 per cent respectively and the values were within the same range to those reported for rice and wheat (Vengaiah*et al.,* 2015); maize (Ashwin *et al.,* 2017) and sorghum (Shashikumar *et al.,* 2018).

The average value of volume for rice, pigeon pea, wheat, sorghum and maize were found to be 25.90±1.13, 68.12±1.18, 35.30±1.27, 27.39±0.88 and 255.47±1.57 mm^3 respectively and the values reported were similar to those reported for rice, wheat and maize (Vengaiah*et al.,* 2015); pigeon pea (Ashwin *et al.,* 2017) and (Shashikumar *et al*., 2018). The average values of geometric mean diameter for rice, pigeon pea, wheat, sorghum and maize were found to be 3.67±0.19, 5.44±0.37, 3.45±0.13, 3.60±0.16 and 6.48±0.18 mm respectively and the results reported were in agreement for rice and wheat (Vengaiah*et al.,* 2015); sorghum (Surpam*et al.,* 2019) and maize and pigeon pea (Ashwin *et al.,* 2017) and (Inderpal *et al.,* 2017).

The average values of sphericity of rice, pigeon pea, wheat, sorghum and maize were found to be 0.45±0.10, 0.83±0.02, 0.53±0.04, 0.83±0.02 and 0.82±0.02 per cent respectively and the values were within the same range to those reported for rice and wheat (Fawal*et al.,* 2009); pigeon pea (Ashwin *et al.,* 2017); wheat (Gursoy and Guzel, 2010); sorghum (Shashikumar *et al.,* 2018) and (Adinoyi*et al*., 2017) and maize (Inderpal *et al.,* 2017) and (Yenge *et al.,* 2018). Similarly, the average value of bulk density for rice, pigeon pea, wheat, sorghum and maize were found to be 0.61±0.03, 0.83±0.04, 0.77±0.03, 0.76±0.02 and 0.81±0.03 g/cm^3 respectively.The values reported were similar to those reported for rice (Prashant and Prasad 2012);wheat (Gursoy and Guzel, 2010); pigeon pea (Ashwin *et al.,* 2017); sorghum (Surpamet al., 2019) and maize (Nisha and Amarjeet, 2017). The average values of true density of rice, pigeon pea, wheat, sorghum and maize were found to be 1.49±0.03, 1.22±0.02, 1.35±0.04, 1.42±0.03and 1.22±0.02 g/cm^3 respectively and

UNDER PEER REVIEW

the values reported were similar to those reported for rice and wheat (Vengaiah*et al.,* 2015); wheat (Gursoy and Guzel, 2010); sorghum (Surpam*et al.,* 2019) and maize and pigeon pea (Ashwin *et al.,* 2017).

The average value of porosity for rice, pigeon pea, wheat, sorghum and maize were found to be 43.50±1.90, 38.50±1.68, 42.00±1.51, 41.64±1.33 and 30.10±1.25 % respectively and the values reported were similar to those reported for rice (Prashant and Prasad 2012); sorghum (Surpam*et al.,* 2019) and maize (Nisha and Amarjeet, 2017). The average value of mass of 1000 grains for rice, pigeon pea, wheat, sorghum and maize were found to be 20.63±1.66, 97.92±1.57, 38.58±1.45, 33.09±1.71 and 235.33±1.22 gm respectively and the values were within the same range to those reported for rice (Prashant and Prasad 2012); wheat (Gursoy and Guzel, 2010); sorghum (Shashikumar *et al.,* 2018) and maize (Inderpal *et al.,* 2017) and pigeon pea (Ashwin *et al.,* 2017).

The average value of angle frictional properties of the rice, wheat, maize, sorghum, pigeon pea were determined using standard procedure for the design and development of pedal operated flour mill and presented in Table 2.

Table 2: Frictional and Mechanical properties of grains

Particulars	*Rice*	*Pigeon pea*	*Wheat*	*Sorghum*	*Maize*
Angle of repose (°)	20.50±0.89	22.80±0.99	25.50±0.92	29.60±0.95	28.63±0.88
Static coefficient of friction	0.55±0.02	0.28±0.01	0.37±0.01	0.34±0.03	0.25±0.02
Hardness (N)	4888.39±14.48	2952.19±22.73	5330.53±37.52	4434.43±3.41	9831.08±2.66

UNDER PEER REVIEW

From the Table 2, it is observed that the average values of angle of repose for rice, pigeon pea, wheat, sorghum and maize were found to be 20.50±0.89, 22.80±0.99, 25.50±0.92, 29.60±0.95 and 28.63±0.88˚ respectively and the values were within the same range to those reported for rice (Prashant and Prasad 2012);rice wheat and maize (Vengaiah*et al.,* 2015); pigeon pea (Ashwin *et al.,* 2017); sorghum (Surpam*et al.,* 2019) and maize (Nisha and Amarjeet, 2017). Similarly the average value of coefficient of friction for rice, pigeon pea, wheat, sorghum and maize were found to be 0.55±0.02, 0.28±0.01, 0.37±0.01, 0.34±0.03 and 0.25±0.02 respectively and the results reported were in agreement forrice, wheat and maize (Vengaiah*et al.,* 2015) and rice (Prashant and Prasad 2012); sorghum (Shashikumar *et al.,* 2018) and maize (Inderpal *et al.,* 2017) and pigeon pea (Ashwin *et al.,* 2017). Average values of hardness for rice, pigeon pea, wheat, sorghum and maize were measured and the values were within the same range to those reported for rice (Patel *et al.,* 2017).

The hopper was designed by using engineering properties of selected grains and capacity was calculated with standard equation. The volume, diameter, height of the hopper were calculated to be 0.023 m^3, 230 mm and 310 mm, respectively. The power transmission unit was selected to transmit power from vertical drive to horizontal drive for rotation of the top stone through the chain drive mechanism. The number of teeth on larger and smaller sprockets were 48 and 18 teethes respectively with the velocity ratio of 2.66. The vertical support was provided to hopper and main frame with M.S. angle iron of 1600 mm for the increasing the stability and bear the dead weight. The emery stones were selected and fitted in the equipment for delivering the required finesse of Flour, *Rava*, *Dhal* at optimum production rate (Modak and Bapat. 1987). Stability of the unit was also considered to ensure that the

UNDER PEER REVIEW

equipment remains upright at all time, i.e. it should not drift or bend to one direction and it should remain stationary (Deshmukh *et al.,*2017).

CONCLUSION

The engineering properties of selected food grains play an important role in milling of grains into flour, dhal and rawa. These properties are necessary considerations in the design, fabrication and effective utilization of the equipment in the processing of food grains. These engineering and ergoninimical parameters were considered for the design and fabrication of functional componets pedal perated flour mill *viz.,* design hopper, selection of drive mechanism, design of supporting frame, selection of grinding stones. These selected ergonomic parameters were considered for easy and effective operation by the operator. The pedal operated flour mill is suitable in grinding almost all cereals and pulses to produce Rawa*, Atta* (Flour) and *Dhal* for human consumption and also for producing poultry/fish feed by grinding agro by-products and wastes. A novel idea to create a machine to produce flour, dhal and rawawhich would not be dependent on electricity but could be done with minimum human effort.

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