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Development of mango stone decorticator

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ABSTRACT : A mango stone decorticator was developed and evaluated for its performance. The developed decorticator consisted of main frame, feeding chute, cylinder assembly, concave, kernel and shell outlets, blower and a drive unit. The decorticator was tested for its performance by varying cylinder speed (200, 250 and 300 rpm), feed rate (150, 200 and 250 kg/h) and moisture content (10, 15 and 18% d.b.). The optimum operation conditions were found to be 250 rpm, 200 kg/h and 10 per cent moisture content. At this combination, the machine was found to have decortication efficiency and kernel breakage of 93.91 and 68.12 per cent, respectively.

KEY WORDS : Mango stone decorticator, Evaluation, Speed, Decortication efficiency, Breakage

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Mango (*Mangifera indica* L.) is one of the important fruit crops grown in India. It belongs to the family Anacardiaceae. India is the largest mango producing country in the world accounting for the production of 12.7 million MT (52% of total world production) during the year 2008-09. Mango fruit, either raw or ripe is greatly valued for its pulp, juice, flavour and taste. After consumption or industrial processing of the fruits, considerable amounts of mango seeds, generally known as stone are discarded as waste.

The mango stone is composed of outer hard and fibrous pericarp, and soft and nutritive inner kernel. According to mango varieties, the seed represents about 10 to 25 per cent of the whole fruit weight. The kernel inside the seed represents about 45 to 75 per cent of the seed and about 20 per cent of the whole fruit (Mirghani *et al*., 2009).

Since there is no exclusive market for the mango stones, they are accumulated and decomposed in the mango processing industries resulting in environmental pollution. These mango stones accumulated at food-processing industry sites can be processed to a product of utility. Decortication of mango stones is the important technological step in utilizing this waste material. Because of the size, shape and tough shell wall, the manual decorticating process is difficult, tedious, time consuming and labour intensive and also high volume of stones available at the factory sites justifies the need of a mechanical device to separate the outer pericarp from the inner kernel. Therefore, objective of this study is to develop a pilot scale mechanical mango stone decorticating machine and test its performance.

METHODOLOGY

Description of the machine:

The mango stone decorticator consists of main frame, feeding chute, cylinder assembly, concave, kernel and shell outlets, blower and a drive unit.

The main frame was fabricated using mild steel angle iron (50x50x6 mm) and well structured and braced to provide rigidity. The feeding chute of trapezoidal shape was mounted on decorticating section at an inclination of 40^{o}. A hallow mild steel cylinder was co-axially fastened at the centre of the solid shaft by using two mild steel circular plates. Along the 15 per cent of the total cylinder length, mild steel flat was fastened in vertical position with a pitch of 102 mm, for positive feeding of mango stone inside the decortication section. Mild steel pegs of 12 mm diameter and 58 mm length were welded on to the cylinder along its length in four equally distributed rows with 17 pegs in each row. Centre to centre distance between adjacent pegs was 50 mm. Pegs of same size were fixed on one side of the top of the frame, such that the pegs on rotating cylinder would pass in between these stationary pegs during rotation. Main shaft was fixed on the top of the frame by means of pillow block bearings. Schematic diagram of cylinder assembly is shown in Fig. A. A cylinder housing was provided over the entire length of main frame top to enclose decortication section. Two semi circular mild steel plates

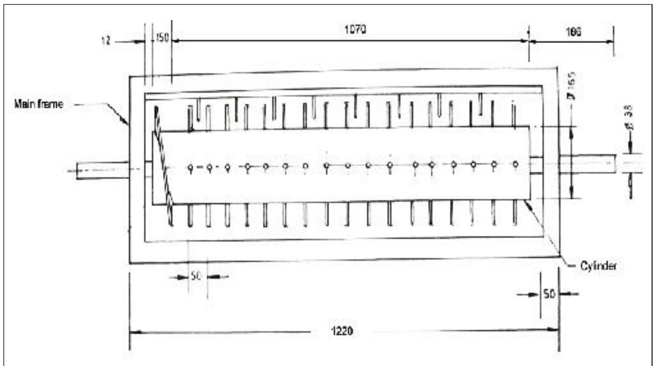

Fig. A : Schematic diagram of decorticator cylinder

formed side walls of the housing cover. A clearance of 25 mm was provided between the cover and tip of the pegs.

Mild steel sheet of 14 gauge thickness with oblong openings (50x17 mm) was used as concave. Clearance of 12 mm was provided between sieve and peg. The concave was fixed to the main frame such that it aligned in line with cylinder cover.

A blower was installed in the unit for the pneumatic separation of shell from kernel. Solid shaft was used in the fabrication of blower. Two metal square blocks of 51 mm with 38 mm bore were fastened to the blower shaft to which fan blades were attached. Flat rectangular metal plates (4 No.) of size 813x102 mm were used as fan blades. Blower shaft was mounted on the side of the main frame by means of pillow block bearings. A Blower housing of 381 mm outer diameter and 914 mm length having an inlet opening of 200 mm on both the sides was made using 18 gauge mild steel sheet. A three phase motor of 5 hp is installed to drive the cylinder and blower. From the motor, the power could be transmitted through V-belts and pulleys.

Principle of operation:

The mango stones are fed into the cylinder and concave assembly through feeding chute. In decorticating the stones, the stationery pegs and cylinder cover hold the stones and the pegs fastened on to cylinder (rotating pegs) imparts impact and shear force on them which leads to failure of mango stone shell. By the time mango stones pass from feed end to discharge end, stones get decorticated and shells will come out through the shell outlet. Kernel will pass through the sieve below. Blower assembly helps in separating kernel from dust and shell which is passing through the sieve. Decorticator is shown in Fig. B.

Performance evaluation:

Raw material preparation:

Mango stones obtained from the dump yard of several mango processing industries were used for the performance test. Moisture content of mango stone shell was considered for tests. The initial moisture content was determined by hot

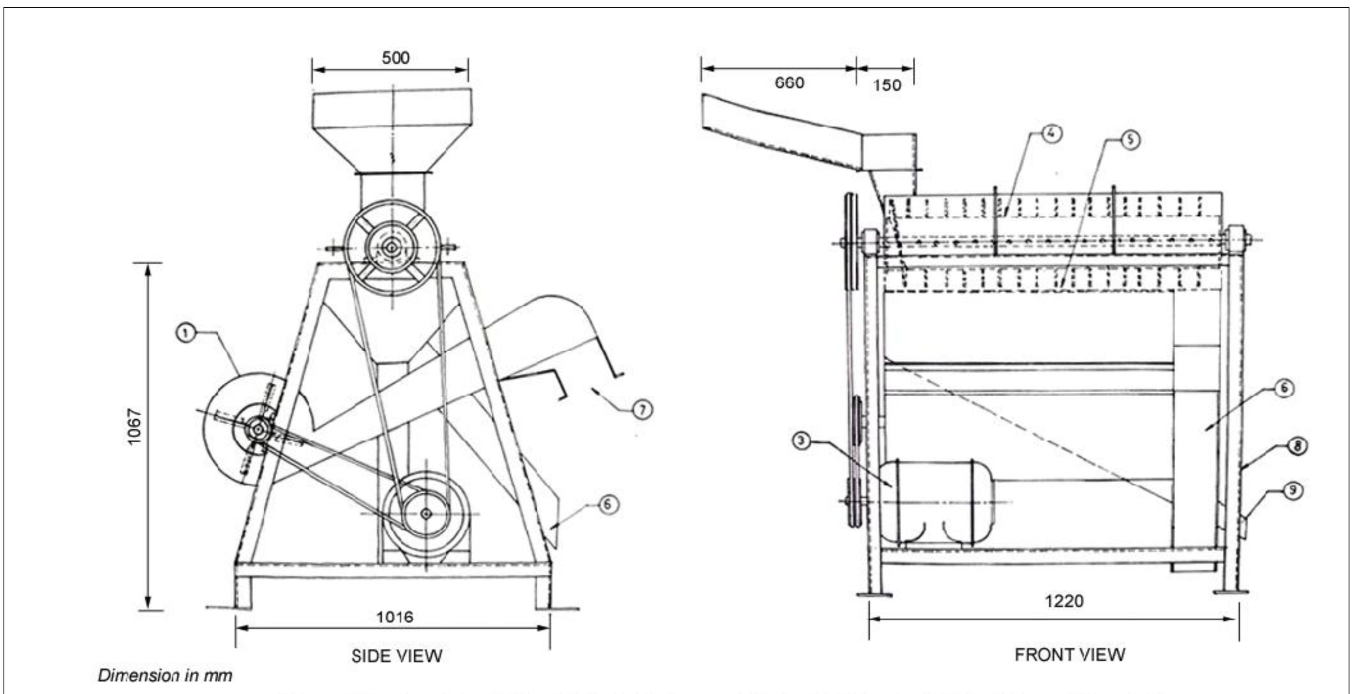

Fig. B : Schematic diagram of mango stone decorticator

air oven method. Samples were moistened with a calculated quantity of water and conditioned to raise their moisture content to desired level.

Experimental design:

A three factorial completely randomized block design was adopted to conduct performance tests.

Variables	Level
Feed rate (kg/h)	150, 200 and 250
Moisture content (% d.b.)	10, 15 and 18
Cylinder speed (rpm)	200, 250 and 300
Performance indicators:	Decortication efficiency Kernel breakage

Experimental procedure:

The developed decorticator was tested for its performance by connecting variable speed motor set up. Feed rate was controlled manually by feeding known quantity of material in known time.

Calculation of performance parameters:

After decorticating known quantity of material (N_0), the material from all the outlets were carefully collected. The collected material was grouped into three categories, namely unshelled mango stones (N_1), whole kernel (N_2) and broken kernel (N_3). Kernels with 3/4th of length were considered as whole kernel. The performance of the decorticator was evaluated on the basis of the following,

Decortication efficiency, η

$$\eta = \left[1 - \left(\frac{N_1}{N_0}\right)\right] x\, 100 \qquad (1)$$

Percentage of kernel breakage, P_{kb}

$$P_{kb} = \frac{N_3}{N_2 + N_3} x\, 100 \qquad (2)$$

RESULTS AND DISCUSSION

The results of the present study as well as relevant discussion have been summarized under following heads:

Effect of moisture content on performance parameters:

The decortication efficiency and kernel breakage decreased with increase in moisture content (Fig. 1). This decrease in decortication efficiency and kernel damage is attributed to the loss of brittleness in mango stone and kernel owning to higher moisture content which makes it soft and resistant to mechanical damage or rupture and hence increases the crushing strength. Studies conducted by Mittal and Singh (1982) have proved similar effects of moisture content on mango stone decortication. The results are also in line with the studies carried out by Daya (2001) on chestnut decortication, Orji *et al*. (2001) on breadfruit shelling, Atiku *et al*. (2004) and Oluwole *et al*. (2007 a and b) on bambara groundnut. Inverse relation between the moisture content and decortications efficiency was evident from the studies done by Pradhan *et al*. (2010) on jatropha fruit, Anil and Sirohi (2003) on linseed crop.

Effect of feed rate on performance parameters:

Fig. 2 reveals the effect of feed rate on decortication efficiency and kernel breakage. From the figure it can be observed that the decortication efficiency decreased with increase in feed rate. This might be due to cushioning effect or reduction in residence time. Results obtained in this study

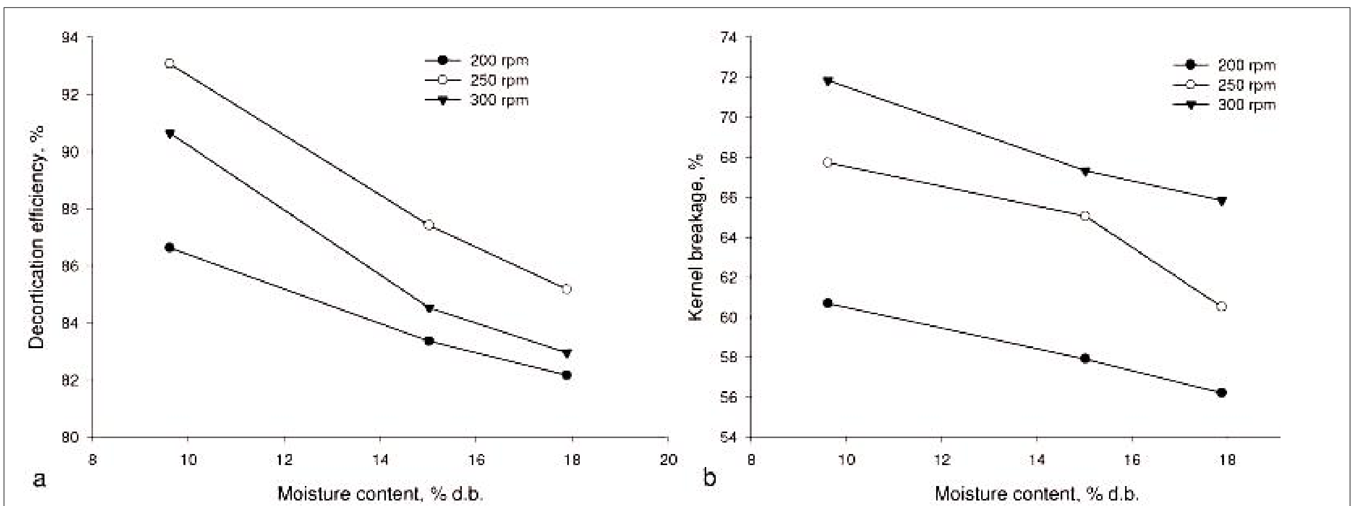

Fig. 1 : Effect of moisture content on performance indices : a decortication efficiency, b kernel breakage

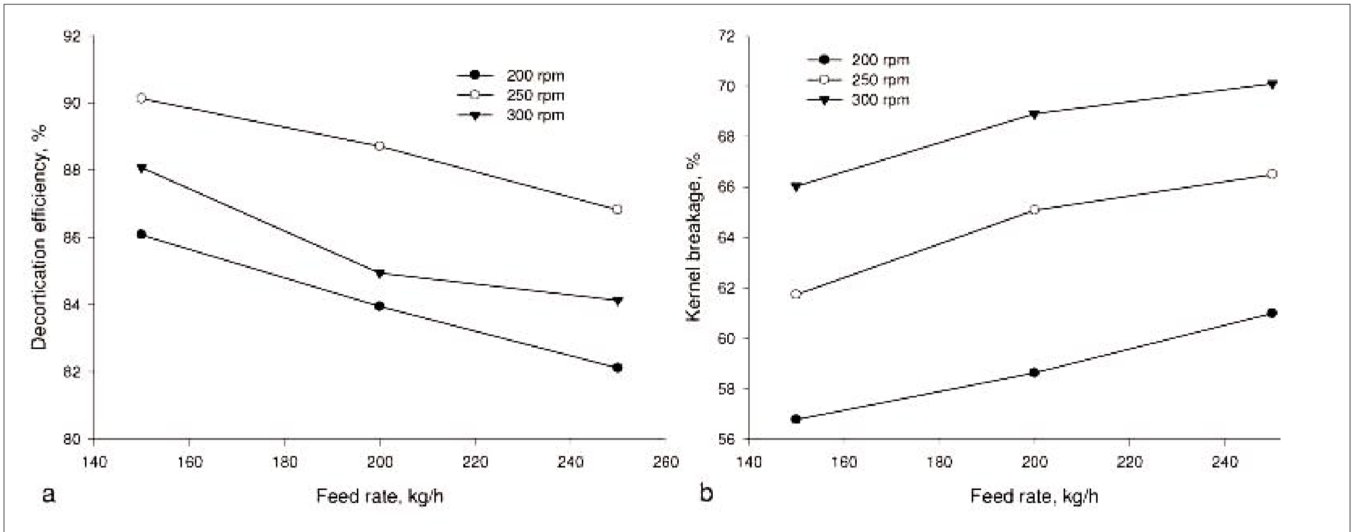

Fig. 2 : Effect of feed rate on performance indices : a decortication efficiency, b kernel breakage

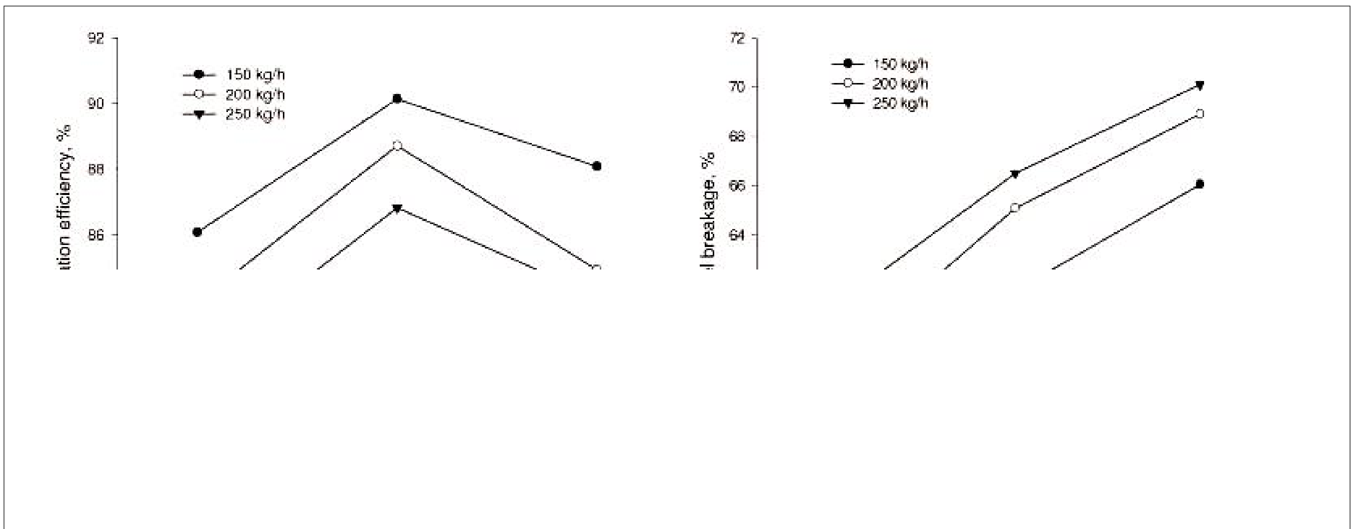

Fig. 3 : Effect of cylinder pseed on performance indices : a decortication efficiency, b kernel breakage

are at par with the results observed by Atiku *et al*. (2004) for bambara groundnut, Oluwole *et al*. (2004) for sheanut, Jekayinfa and Durowoju (2005) for mango stone. With the increase in feed rate kernel breakage also increased. Analogous report of increase in mechanical damage with increase in feed rate was observed by Oluwole *et al*. (2004) for sheanut, Jekayinfa and Durowoju (2005) for mango stone.

Effect of cylinder speed on performance parameters:

The effect of cylinder speed on performance indices is shown in Fig. 3. The decortication efficiency initially increased with an increase in cylinder speed and then decreased. The low decortication efficiency at minimum speed may be due to the low impact force applied on to the mango stones which results in partially shelled or unshelled stones. Reduced efficiency at higher cylinder speed is due to shorter residence time of mango stone in the decortication section. On the other hand, percentage kernel breakage increased with the increase in speed. This may be due to increase in shear and impact force on the mango kernels at higher speed. Analogous results on the effect of cylinder speed were observed by Jain and Kumar (1997) for cashew nut shelling, Singh (2003) for water chestnut, Adewumi *et al*. (2007) for grain legumes.

Conclusion:

A mechanical mango stone decorticator was developed and tested for its performance. The result of the study showed that the decortication efficiency and kernel breakage are inversely proportional to moisture content and feed rate and directly proportional to cylinder speed. Decortication efficiency ranged from 79.84 to 94.83 per cent. The kernel breakage was observed to vary from 54.86 to73.36 per cent. Based on the practical applicability, the cylinder speed, feed rate and moisture content of 250 rpm, 200 kg/h and 10 per cent d.b, respectively, were found optimum for the best performance of the decorticator. At this treatment combination, the machine was found to have decortication efficiency and kernel breakage of 93.91 and 68.12 per cent, respectively.

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