

DEVELOPMENT AND TESTING OF A MANUALLY OPERATED MAHUA STAMEN REMOVER

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CERTIFICATE-I

This is to certify that the thesis entitled “**Development and Testing of a Manually Operated Mahua Stamen Remover**” submitted in partial fulfillment of the requirements for the award of the degree of **Master of Technology (Agricultural Engineering)** in **Processing and Food Engineering** of Orissa University of Agriculture and Technology, Bhubaneswar is a faithful record of *bonafide and original* research work carried out by **Krishna Chandra Nayak** under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help received by him from various sources during the course of investigation has been duly acknowledged.

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CERTIFICATE-II

This is to certify that the thesis entitled “**Development and Testing of a Manually Operated Mahua Stamen Remover**” submitted by **Krishna Chandra Nayak** to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfillment of the requirement for the degree of **Master of Technology (Agricultural Engineering) in Processing and Food Engineering** has been approved by the student’s advisory committee and the external examiner.

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ABSTRACT

A study was undertaken to develop manual mahua stamen remover and testing for its performance evaluation. Freshly collected mahua flowers were procured from Pallahara, Angul District of Odisha. The flowers were dried in a tray dryer to achieve the desired moisture levels of 5, 10, 15 and 20% (wet basis) to measure the physical properties of mahua flower. A pedal operated mahua stamen remover was fabricated. It was tested at four moisture levels (10, 12, 14, and 16 % d.b.) and three feed rates (12,14,16 kg/h). The stamen removal efficiency and whole flower recovery were determined to optimize feed rate and moisture content of mahua flower for better performance of the machine. The geometric mean diameter of mahua flowers increased from 10.83 mm to 11.62 mm and arithmetic mean diameter from 11.80 mm to 12.54 mm as moisture content increases. The sphericity of flower decreased from 0.52 to 0.51 with an increase in moisture content from 5.2% to 21% w.b. Thousand flower weight (TFW) increased from 1190 g to 1540 g as the moisture content increased from 5.2% to 21% w.b. The values of bulk density for different moisture levels varied from 491.8 to 553.63 kg/m³ and indicated a decrease in bulk density with an increase in moisture content from 5.2 to 21% w.b. The true density of mahua flower was found to increase from 1000.12 to 1055.89 kg/m³ with the moisture content. Porosity values were decreased with increase in moisture content. The values of the angle of repose were found to increase from 35.26° to 42.56° in the moisture range of 5.2% to 21% w.b. Terminal velocity and Static coefficient of friction increased with the increase of the moisture content of mahua flower on mild steel surface. Stamen removal efficiency varied significantly ($p<0.05$) with moisture content and feed rate. Stamen removal efficiency increased with decrease in moisture content of mahua flower. Stamen removal efficiency was higher at low feed rate at constant flower moisture content. Whole flower recovery varied significantly with moisture content ($p<0.05$), whereas feed rate had no significant effect. Whole flower recovery percentage decreased with decrease in sample moisture content and it decreased steadily below 12 % moisture content. The optimum flower moisture content and feed rate were found to be 12% and 18 kg/h, respectively with stamen removal efficiency of 95.6 % and whole flower recovery of 79.6 %. The operating cost for removing stamen from one kg of mahua by the developed manual stamen remover was found to be Rs 2.17/kg as against Rs 8.33 in traditional method. From the above study, it could be concluded that the developed pedal operated manual mahua flower remover performed well at 12 % sample moisture content and 18 kg/h feed rate. The machine will be useful to the tribal people in drudgery reduction of stamen removal operation.

Keywords: Mahua flower, stamen, manual stamen remover, whole flower recovery

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LIST OF SYMBOLS AND ABBREVIATIONS

Abbreviations	Description
%	Percentage
/	Per
µg	microgram
cm	Centimeter
g	Gram
kg	Kilogram
min	Minute
h	Hour
rpm	Revolutions per minute
i.e.	That is
ml	milliliter
mm	millimeter
°C	Degree Celsius
w/w	Weight by weight
MT	Million tone
Rs	Rupees
m	meter
s	Second
m/s	Meter per second
WFR	Whole flower recovery
TFW	Total flower weight
SRE	Stamen removal efficiency
abs	absolute
cm	centimeter
Fig.	Figure
Eqn	Equation

Mahua (*Madhuca Indica*) of Sapotaceae family is a large tree found in the deciduous forest of India. It is also known as “Butter Nut tree”. Every part of the Mahua tree is used by the tribals for their livelihood. Its flower is used as foods & can be fermented to alcoholic drinks due to its high sugar content. Mahua tree has many vital socio- economic value. It belongs to the family *Sapotaceae*. It is a multipurpose tree providing food, fuel, timber, green manure, oil, oil cake, liquor and raw materials for several products and is one of the most Important tree of Indian forest. It also has a religious and a high bio-aesthetic value in the tribal culture. It is one of those multipurpose forest tree species that provide an answer for the three major Fs i.e., food, fodder and fuel (Banerjee and Mitra, 1996). It is also known as Mowra Butter tree in some regions. It is very important from the point of view that it can help in promoting nutritional and economic security in backward areas. Its seed is used to extract oils which can be used as cooking oils by tribals and also used to manufacturer soaps and detergents. Its leaves and bark is used as medicine by tribals to cure different types of diseases like chronic bronchitis, diabetes mellitus, ache, swell, verminosis, gastropathy, dermatopathy etc.

The estimated annual production of mahua flower is around 85 million tonnes. Mahua tree produces edible flowers and fruits. The ripe flowers, which fall from the tree, are collected. The yield per tree ranges from 100-200 kg. Mahua is also famous for its seed oil. The Chemical composition of mahua flower is given in Table 1.1 (Neha Prasad, 2015).

Table 1.1 Chemical composition of Mahua flower

Constituents	Amount, w/w (%)
Moisture	18.6
Protein	4.4-7.0
Fat	0.09-1.3
Total sugar	40-70
Fibre	1.7
Ash	2.7

Calcium	0.14-0.25
Phosphorus	0.13-0.14
Iron	0.015-0.03
Potassium	1.2
Sodium	0.02
Magnesium	0.21

Mahua flower can be utilized in a variety of ways in home, as animal feed and also as raw material for industrial products. They can be used as a sweetener in preparation of many local dishes like halwa, kheer, puri and burfi (Patel and Naik, 2008). It is also used for preparation of bakery and confectionary goods. Tribal people also use it for brewing alcohol. It contains tannin as tannins are excellent antioxidant that helps in giving the structure, texture and flavour to wine. Mahua flowers are also considered good for cooling, and are used as a tonic and demulcent. However an estimated 90 per cent of the production goes into brewing beverages. Mahua has various types of medicinal uses due to its tannin content. It is used as Anti diabetic, antiulcer, hepato protective, anti pyretic, anti fertility, analgesic, anti oxidant, swelling, inflammation, piles, emetic, dermatological, laxative, tonic, anti burn, anti earth worm, wound healing headache and many more problems (Patel P. K. et. al., 2012). On account of various advantages of mahua flower in terms of composition, it can be exploited for the nutritional benefits and value added nutritive health foods.

Mahua flower if exploited can yield products of superior nutritional and technological characteristics but till now it has remained as the food, fodder and fuel for the people of lower economic strata in rural areas. The utilisation has remained limited to village levels only. Hence there is an ample scope for diversified uses of mahua at household level and value added products through appropriate processing technology for incoming generation which can provide alternate employment to rural community. A systematic scientific effort is needed for mahua flower to use it conveniently. By proper harvesting and post harvest operations market demand for the flower can be enhanced.

Mahua flower has wide range of scope for value addition. Of the total mahua flower collected some of them can be used for preparation of products like jam, jelly,

RTS, biscuits, candies, etc. Some of them can be used for preparation of country liquor.

However, due to the lack of proper scientific investigation and post harvest processing technologies, these are collected and sun dried till about 80% moisture is lost, before storage (Patel and Naik, 2008). This process results in heavy microbial load and degrades their food value, finally making them suitable only for the liquor distillation units and as cattle feed. This way a precious, organic and easily available source of natural sugar is being under-utilized. Physical properties of mahua flowers are essential for the design of equipments for drying, cleaning, grading, storage and value added products.

It has been found that the flower contains hairy stamens inside it which is very bitter in taste and inedible. From the preliminary experiments it is observed that 1 kg of dried flower contains about 100 g of stamen. Therefore, for preparation of any value added products for human consumption this stamen has to be removed.

Traditionally, people dry the flower in hot summer in courtyard for a day or two. Then they beat the flower with a wooden plank and aspirate the flower to remove the detached stamen. In this method, most of the flowers get broken / damaged and pressed. Hygienic condition is also not maintained. For preparation of candy or glazed flower, whole and cleaned flower is most suited. Therefore several methods have been tried with combination of different pre-treatments to remove the stamen from the flower and to reduce the broken.

Considering all these aspects and identifying the existing knowledge gap, the present study was undertaken with the following specific objectives.

1. To study the physical properties of mahua flower.
2. Development of a manually operated mahua stamen remover.
3. Testing and performance evaluation of the developed manually operated mahua stamen remover.

REVIEW OF LITERATURE

Even though mahua flower is used as a common food material by the tribal people, the published literature on different aspects of production and processing of mahua is scanty. Till now it has remained as an alcohol ingredient and is also used for preparation of some local foods like puri, burfi, etc. for its high sugar content. A little research has been done in India on processing aspects of mahua. The chapter is a compilation of the available information on the topic.

2.1 Mahua flower

2.1.1 Botanical features

Mahua tree has a large spreading root system, Many of them are superficial. Hardwood is reddish brown in colour. Its leaves are oblong shaped, rigid, clustered at the end of branches. Its bark is thick grey to black with vertical cracks and wrinkles. Mahua flowers are pale yellow in colour with rusty, pubescent calyx and fleshy corolla. The plum-coloured calyx is also furry and divides into four or five lobes; within them lies the globular corolla, thick, juicy and creamy white. The stamens are very short and adhere to the inner surface of the corolla; the pistil is a long, protruding green tongue. Most of leaves fall from February to April, and during that time musky-scented flowers appear. It is at night that the tree blooms and at dawn each short-lived flower falls to the ground. A couple of months after the flowering period the fruit opens. They are fleshy, green berries, quite large and containing from one to four shiny, brown seeds. Mahua is a slow growing species, attains a minimum height of 3 to 4 feet at the end of fourth year.

2.1.2 Origin and distribution

It is believed that Mahua is of Indian origin. It is much planted in the planes of northern India, also common on river banks and streams (Chandy, 2012). It is commonly available in areas like Eastern Uttar Pradesh, Chhattisgarh, Maharastra, Bihar, Jharkhand, Odisha and Andhra Pradesh. *Madhuca laongifolia* is a large evergreen tree found in South India and in evergreen forests of the Western Ghats from Konkan Southwards. The tree is planted in most part of India, either by

propagating by itself or sown seeds. *Madhuca latifolia* is a medium sized to large deciduous tree, distributed in Andhra Pradesh, Gujarat, Madhya Pradesh, Odisha, Bihar and Uttar Pradesh.

2.1.3 Climatic and Environmental Requirements

Mahua is a plant of dry tropical and sub tropical climatic conditions. It grows well on a variety of soils but prefers sandy soil. It can grow on very rocky, hardy and unfertile land. It is occasionally planted as an avenue tree. The trees grow under normal annual rainfall which varies from 750 to 1875 mm. Mean relative humidity varying from 40-80% in January and 60-90% in July provides an optimum atmospheric moisture range for the growth of Mahua trees. They are found in areas with maximum shade temperature varying from 41-48 °C and absolute minimum temperature is between 1-80 °C. The tree is strong light demander and gets readily suppressed under shade (Chandy, 2012).

2.1.4 Production of mahua flower

The estimated annual production of mahua is 85 million MT, out of which production potential is of 4.9 million MT only. During the production season the collectors sell mahua flowers on a daily basis, after preliminary drying or sometime in raw form also, to meet their daily needs. Average trade volume of mahua flowers in Madhya Pradesh, Odisha and Andhra Pradesh is around 5,730 MT, 2,100 MT, 13,706 quintals (worth Rs 8.4 million) and 6,188 quintals of mahua seeds (worth Rs 6.5 million).

2.1.5 Harvesting and Storage

Das (2010) has studied to determine the cause of spoilage and to develop the measures to check it. He collected the flowers and stored it using two methods in his investigation. First, under normally practiced conditions (NPS), i.e., the practice adopted by the flower's collectors, and secondly, oven dried, powdered with liquid nitrogen, and stored at 00C (± 10 C) in different small airtight sterilized vials labelled as laboratory processed samples (LPS). Both LPS and NPS were stored for a year i.e. from one harvesting season to the next. Experiments were carried out, at every month interval, to identify the factors responsible for spoilage of flowers during storage. LPS

did not exhibit deterioration in the nutrient value throughout the year of storage, but NPS showed spoilage due to various biotic and abiotic factors comprised of moisture, temperature and microorganisms. To check postharvest spoilage various innovative storage techniques like physical and chemical treatments were experimented. Results revealed that storage at low temperature by liquid nitrogen treatment and chemical conversion to oxalic acid were the most effective techniques for a long-term storage.

Das et al. (2010) reported that when the matured flowers fall on the ground, it is collected and dried under the sun for 2-3 days, packaged in gunny bags and stored in normal environment. In every fortnight interval, the bags were opened and flowers were spread on the neatly washed ground under the direct sunlight for its drying. This is a traditional practice. However, a few months after harvesting, flowers lose its lustre and become bitter in taste as the precious corollas cannot retain its food value for long duration due to many extrinsic and intrinsic factors. It is also reported that the nutritional content deteriorated quickly just after storage of this flower for a year. So, a major part of the collected flowers become unsuitable for food and flowers' economic potential is simply wasted. Mostly the sugar content decreased up to 70% within a year of storage along with deterioration of other essential nutrients.

2.1.6 Nutritional and medicinal aspects of mahua

2.1.6.1 Nutritional aspects

Neha Prasad (2015) and Das et al. (2010) had found out that Mahua flowers of the plant are rich of sugars (both reducing and non-reducing). In fact, it is the second richest source of sugar after sugarcane, polysaccharides, proteins, fibres, amino acids, minerals, vitamins, enzymes and organic acids. And in . However, its nutrient quality deteriorates during the postharvest storage and thus, poses a serious problem of adequate storage.

2.1.6.2 Medicinal aspects

Sujatha and Das (1988) observed that the mahua flowers show anti bacterial activity against *E. coli* and also are used against rice pest diseases.

Neha Prasad (2015) studied that adequate quantity of different vitamins like thiamine, riboflavin, niacin, folic acid and ascorbic acid are also found in mahua flowers. Some enzymes like amylase, maltase, invertase, catalase and oxidase were

also present in different phases of maturity of flowers. The flower was reported to have strong aroma which is musky and heady. Apart from this, the extract of flower is used for the treatment of heart diseases, TB, Asthma, Blood diseases, thirst, burning sensation and is also beneficial for eyes. Not only is this the distilled juice of the flower used to get rid of the parasitical internal worms, tonsillitis and bronchial problem. However, juice can be used directly on the skin to treat skin problems and as a nasal drop in sinusitis.

Patel et al. (2012) studied the medicinal effect of mahua flowers. The fresh flower of Mahua contains 2 acetyl 1 pyrroline, the aroma molecule. They also contain polysaccharide which on hydrolysis give D-galactose, D-glucose, L-arabinose, L-rhamnose, D-xylose and D-glucuronic acid. In skin diseases, the juice of flowers is rubbed for oleation. It is also beneficial as a nasal drops in diseases of the head due to pitta, like sinusitis. It increases the production of milk in woman. It is also used in Diuretics, Anthelmintic, Strangury, Verminosis, Hepatoprotective. Gastropathy. To establish the pharmacological activity of particular crude drug is known as the pharmacological screening, and it is important for prediction of activity.

2.1.7 Uses

Adhikary and Adhikary (1989) had found out that majority of the tribal population who comprise more than 23 per cent of total population of Odisha depends on this plant product for their livelihood.

Mishra and Pradhan (2013) had discussed various health benefits of Mahua. It is widely known as 'Butter nut tree' is a large size tree. It is both wild and cultivated. Mahua flower are used as a food as well as used as an exchanger in tribal and rural areas. The flowers are used as vegetable, for making cake, liquor etc. Mahua fruits are used as vegetable and widely consumed by the tribes of western Odisha. It is also considered as medicinal herbs and is useful for external application in treating skin diseases, rheumatism, headache, chronic constipation, piles, and haemorrhoids and sometimes used as an emetic and galactagogue. Mahua oil is used for manufacturer of laundry soaps and detergent, and also used as cooking oil in various tribal region of India. It is reported by various scientist that it contain sapogenins, triterpenoids,

steroids, saponins, flavonoids and glycosides. The tree is considered a boon by the tribal's who are forest dwellers and keenly conserve this tree. The tribes consider the mahua tree and the mahua drink as part of their cultural heritage. So it is very much necessary to create awareness among the people to conserve the wild forest.

Jha et al. (2013) had undertaken studies of fermentation of mahua flower for ethanol production and its estimation. As flower is having high sugar and important mineral content we prepared jam from flower which can be used as food source at house hold purpose for poor people. The remains of fermentation used as fertilizer and its effect are demonstrated by growing seeds. The characterisation of fermentation remains by XRD and FT-IR shows the presence of several important minerals which are responsible for the plant growth.

Neha Prasad (2015) mentioned that due to high sugar content it is used for the preparation of different kinds of sweet dishes like halwa, kheer, puri, barfi, laddu (Indian sweet)

Patel et al. (2012) had found out mahua flowers used as Refrigerant, Expectorant, and Stimulant.

Yadav et al. (2009) had studied that Mahua (*Madhuca indica* J. F. Gmel.) has been used for liquor production, for centuries, by the tribals and local people. However, wine from mahua flower is not common. Wine made from different mahua germplasm showed no significant difference in terms of biochemical and sensory quality. Wine fermented at 16°C had higher content of alcohol (9.9%) and ascorbic acid (0.9 mg) compared to that at 20 and 25°C. Nutrients in the form of yeast extract, added to the must, improved wine quality while tannin addition lowered its sensory quality. Sweetened wines scored better than dry wines. Lemon peel addition improved aroma and acceptability of these wines. HPLC analysis reflected the presence of phenolics, viz. gallic acid, chlorogenic acid, catechin, epicatechin, caffeic acid, 4-hydroxybenzaldehyde, ascorbic acid and tannic acids in mahua wines.

Yadav et al. (2012) has reviewed traditional uses of mahua flower in different parts of India which are given below in table 2.2.

Table 2.1 Traditional uses of mahua flower

Used Ethno medical	Uses Preparation(s)	Reference(s)
Analgesic activity	Aqueous and alcoholic extracts	Chandra <i>et al</i> 2001
Hepatoprotective activity	Methanolic activity	Umadevi <i>et al</i> 2011
Skin diseases	Juice	Prashanth <i>et. al</i> 2010
Tonic, analgesic and diuretic	Not defined	Saluja <i>et al</i> 2011
Cure cough	Roasted flowers	Palani <i>et al.</i> 2010

Jha et al. (2013) has found out that people in small villages did not have sufficient money for various resources to earn their living, and hence, they are fully or partially dependent on the natural resources which are easily available, cheap and renewable. It was concluded that Mahua flower had potential to satisfy few needs of rural people. High sugar content of Mahua flower allows it to be consumed as jam, jelly or raw. The dried Mahua flower can be sold to the local distillery and hence they can make good money from it. The fermentation waste can also be used as bio fertilizer which is eco-friendly and cheap in comparison to the expensive fertilisers.

2.2 Physical and aerodynamic properties of mahua flower

Patel et al. (2010) analysed that the initial moisture content (d.b.) of fresh mahua flowers was found to be constant at 79.82%. The average arithmetic and geometric mean diameters of fresh mahua having scaly corolla were higher as compared to mahua without scaly corolla. The average value of surface area, 1000 unit mass, densities, angle of repose, terminal velocity and coefficient of friction were higher for mahua with scaly corolla, whereas sphericity and aspect ratio were higher in the case of mahua without scaly corolla.

2.3 Components of stamen remover

Since mahua flower is used as a common food material by the tribal people, the published literature on different aspects of processing of mahua is scanty and there is no research had been conducted on manually operated stamen remover. From preliminary study it was found that its removing principle is based on decorticators and threshers. As the objective of this research was to develop a manually operated mahua stamen remover, different kind of literature was collected on some threshers and decorticators to fix cylinder type, cylinder speed, sieving assembly, hopper for mahua stamen remover.

Pradhan et al. (2009) had studied the performance parameters of the machine designed and developed by him including Percentage of whole seed, broken seed, partially shelled fruit, unshelled fruit, machine efficiency and decortications efficiency, were evaluated at four different moisture content (7.97%, 10.53%, 13.09% and 15.65% d.b.) with a combinations of concave clearance (18 mm, 21 mm, 24 mm and 27 mm) between concave sieve and rotating blades. The best set of conditions under which the decorticator can be operated is at fruit moisture content of 7.97% d.b. with concave clearance of 21 mm between the concave and the blade at which the maximum whole seeds of 67.94% can be achieved and machine efficiency of 90.96% can be obtained.

Ramteke and Sirohi (2003) studied the design criteria to develop the linseed thresher by taking two types of threshing cylinder (rasp bar and spike tooth), three moisture content (8.10, 10.75, 13.80 percent), three cylinder speed (22.56, 16.96, 13.56 m/s) and three concave clearance (5.0, 7.5, 10.0 mm). They resulted that threshing efficiency was maximum at 8.10 percent moisture content. Similarly threshing efficiency was maximum (97.18 percent) at 22.56 m/s cylinder speed and lowest (84.12 percent) at 13.56 m/s. Grain damage was maximum (6.82 percent) at 22.56 m/s cylinder speed and no damage at 13.56 m/s. Energy consumed for threshing operation with rasp bar thresher was 40.8 kW-hr and for spike tooth type 35.2 kW-hr. It was obtained that for best operation with maximum threshing efficiency, minimum grain damage and minimum energy consumption 8-10 percent moisture content of

Pods, 15-20 m/s cylinder speed, 5-7.5 mm concave clearance and rasp bar threshing mechanism is required.

Kamble *et al.* (2003) evaluated pearl millet thresher developed by him at cylinder speed (450, 700, 850 rpm), concave clearance (5, 10, 15 mm), moisture content (10.2, 14.5, 17.2 percent) and feed rate (300, 400, 500 kg/h). The result indicated the maximum threshing efficiency of 96.8 percent, minimum grain damage of 2.75 percent, and grain loss of 2.10 percent and maximum germination of 87 percent. The minimum energy consumption of 0.8 MJ and cost of operation was Rs 8.50 per quintal.

K. N. Agrawal (2013) developed a thresher drive linkage design on human physiology workload of a pedal operated thresher. The thresher gave a maximum grain output of 537 Kg per hour with a threshing efficiency of 99.2% at a cylinder speed of 500 rpm (peripheral speed- 17.3 m/sec) and crop feed rate was 1300 kg/h.

Dhananchezhian *et al.* (2013) designed a low cost portable paddy thresher and evaluated at three levels of concave clearance (15, 20 and 25 mm), cylinder peripheral speed (11.7, 14.1 and 16.5 m/s), grain moisture (13.5, 16.5 and 19.5 percent) and feed rate (200, 400 and 600 kg/h). They got maximum threshing efficiency (99.95 percent), minimum grain damage (2.76 percent) and maximum output capacity (248.27 kg/h) at the combination of 20 mm concave clearance, 16.5 m/s cylinder speed, 13.5 percent moisture content and 600 kg/h feed rate with rasp bar threshing cylinder. The cost of threshing was Rs. 13.5 per 100 kg of grains. The cost saved was 86.5 percent and time saved was 95 percent compared with the conventional method of manual threshing.

The forces involved in breaking the cocoa pods could be compressive, impact or shearing forces depending on the type of machine and process (Audu *et al.*, 2004).

2.4 Performance Evaluation

As discussed earlier that review on stamen remover was NIL, so performance evaluation was done on the basis of reviewed literature on performance evaluation of some threshers.

Hollatz and Quick (2003) reported that at low feed rates, aerodynamic separation of grain from straw and chaff took place over the sieve and at higher feed

rate, material particles were no longer supported aerodynamically, which forms a mat on sieve, increasing grain losses.

Rothaug *et al.*, (2003) also reported that feed rate is an important parameter in separation.

Hollatz and Quick (2003) reported that a combination of aerodynamic-mechanical process is used for grain cleaning and that it would be a simple mechanical sieving process without fan. They also postulated that the cleaning process would turn to an aspiration process when air speed is high thereby separating grains and chaff by differences in terminal velocity and drag coefficient.

Adewumi (2006) suggested studying the distribution and spread pattern of grain relative to the distance from the plane at which materials are discharged as an approach to investigating the separation of grain from materials other than grain in a horizontal air stream.

Simonyan and Yiljep (2008) reported that grain separation along the sieve can be divided into three sections: increasing, peak and decreasing sections. Cleaning efficiency decreased with increasing sieve oscillations frequency and feed rate respectively. Cleaning loss increased with increasing sieve oscillation frequency, feed rate and air speed

Vejasit and Salokhe (2004) studied the effect of machine crop parameters of an axial flow thresher for threshing soybean. They used a peg tooth type threshing drum. They got the result that threshing efficiency was 98 to 100 percent. The best combination of feed rate, drum speed at 14.34 percent (w.b) seed moisture content to obtain higher output capacity, threshing efficiency, lower grain damage and grain losses was 600 to 700 rpm drum speed (13.2 to 15.4 m/s) at a feed rate of 720 kg/h. The power requirement was 1.85kW.

Sessiz and Ulger (2003) conducted the threshing test of wheat by using axial flow thresher with rasp bar type threshing unit. The effect of feed rate, drum peripheral speed, concave clearance and crop moisture content was studied. They got result that by increasing the concave clearance threshing loss was increased and also the unthreshed grain ratio and husked grain ratio increased. When peripheral speed increased the grain loss increased for all feed rates. By increasing the moisture content

the threshing losses decreased and broken grain ratio and husked grain ratio decreased. Maximum threshing efficiency of 99.6 percent was obtained at peripheral speed of 30.3m/s, moisture content of 14.85 percent, feed rate of 1250 kg/h and concave clearance of 20 mm.

Vejasit and Salokhe (2004) studied the effect of machine crop parameters of an axial flow thresher for threshing soybean. They used a peg tooth type threshing drum. They got the result that threshing efficiency was 98 to 100 percent. The best combination of feed rate, drum speed at 14.34 percent (w.b) seed moisture content to obtain higher output capacity, threshing efficiency, lower grain damage and grain losses was 600 to 700 rpm drum speed (13.2 to 15.4 m/s) at a feed rate of 720 kg/h. The power requirement was 1.85kW.

Kushwaha *et al.* (2004) conducted a study on the effect of different speed (5, 6, 7 m/s), concave clearance (7, 10, 13 mm), moisture content (12.3, 15.8, 18.8 percent d.b) and threshing mechanism on the seed quality. Square head bolted drum, rubberised and rasp bar were used and feed rate was 70 kg/h. Percentage of dead seeds were increased and germination decreased. Best performance was obtained at 12.3 percent moisture content, 7mm concave clearance, 5 m/s cylinder speed with square head bolt.

Prasanna kumar and Naveen kumar (2012) studied the performance evaluation of threshing of finger millet by mechanical method by taking two varieties of ragi (MR1 and HR911), moisture content (18-19, 13-15, 10 percent w.b), threshing drum speed (800 and 1000) and concave clearance (4,7,10 mm) as parameters and got maximum output of 140.5 kg/h for MR1 and 130.3 kg/h for HR911, maximum threshing efficiency of 79.63 percent for MR1 and 76.38 percent for HR911, minimum grain damage of 0.43% for both varieties and cost of operation for MR1 was Rs 18.4 and for HR911 Rs 19.5/q. For the threshing operation of finger millet the recommended moisture content was 10 to 13 percent.

Lohan *et al.* (2007) conducted a study to compare hammer mill, spike tooth and rasp bar threshing cylinder in three cylinder speeds (400, 450 and 500 rpm) and three concave clearance (5, 10, 15 mm) to maintain the quality of pigeon pea seeds. The result was obtained that maximum seed damage (16.54 percent) with hammer

mill type cylinder with 500 rpm speed and 5 mm concave clearance. The threshing efficiency decreases (99 to 91 percent) with decreases with decreasing of cylinder speed. Minimum damage was obtained at 400 rpm drum speed, 15 mm concave clearance and rasp bar and spike tooth type cylinder.

Spokas *et al.* (2008) studied the effect of feed rate of cereals (wheat), movement speed of rasp bars and clearance between drum and concave and also the grain moisture content on grain damage in a combine harvester. They obtained the result that when the feed rate increases the crop flow rate increased up to permissible level grain damage reduces. For wheat at a permissible flow rate (0.70 - 0.96 kg/h) and low moisture content grain (12-14 percent) drum speed was low (25m/s) and at high moisture content grain (>18 percent) the drum speed was high (31-34 m/s). Grain separation and grain damage were increased through all concave length increased when the clearance between the drum and concave at the beginning and at the end of the threshing apparatus were reduced. At low moisture content (<12 percent) high concave clearance (12mm) and at high moisture content (>16 percent) low clearance (10 mm) were required.

Saiedirad and Javedi (2011) studied the effect of thresher variables (cylinder type, cylinder speed, feed rate, concave clearance) including the crop variables (moisture content) on shattered seeds, shattered stems and damaged seeds during the threshing of cumin. The result showed that when the moisture content increased from 7 to 13 percent, separated seeds and damaged seeds decreased from 92.8 to 90.4 percent and from 10.1 to 7.6 percent. By increasing the cylinder speed from 12.8 to 16.5 m/s separated seed, shattered stems and damaged seeds percentage increased. They concluded that the rub bar cylinder produced less damaged seeds and shattered stems due to less impact by the smoother surface of rubber plates than the iron surface of rasp bar cylinder. So rub bar cylinder was better than the rasp bar cylinder. The separated seed percentage was highest (96.7 percent) at 5 mm concave clearance and 500 kg/h/m feed rate. Rub bar cylinder, 16.5 m/s cylinder speed and 7 percent grain moisture content were best condition for cumin threshing.

Asli-Ardeh *et al.* (2009) studied the effect of performance parameters of a threshing unit in a single plant thresher. They studied the effect of crop moisture content, drum speed, variety on threshing loss, grain damage and power requirement. They resulted that by increasing the drum speed of all varieties threshing loss decreased and damaged grain percentage increased. At all drum speed the mean of power requirement at wet condition of paddy was higher than the dry paddy. By decreasing the moisture content damaged grain percentage increased.

Sinha *et al* (2009) studied the effect of machine parameters on threshing quality for chickpea seed crop. This found that threshing element, cylinder speed and feed rate affects the seed quality and performance of the thresher. Teflon coated iron beater threshing element at 8.94 m/s cylinder speed at 200 kg/h feed rate was best for minimum damage and negligible damage to the seeds. Threshing efficiency, thrower loss and cleaning efficiency was obtained from the evaluation was 98.96 percent, 0.95 percent and 91.93 percent.

Alizadeh and Khodabakshipour (2010) studied the effect of threshing drum speed and moisture content by taking five levels of drum speed (450, 550, 650, 750 and 850 rpm) and three levels of moisture content (17.0, 20.0 and 23.0 percent). The result obtained that maximum broken grains obtained (0.677 percent) at 850 rpm and 17 percent moisture content and least at 450 and 550 rpm drum speed and 23 percent moisture content. Similarly the cracked grains increased from 7.0 to 37.0 percent, 6.67 to 25.0 percent, and 4.0 to 17.30 percent at 17.0, 20.0 and 23.0 percent moisture content when drum speed increases from 450 to 850 rpm.

Kavak *et al.* (2012) studied the effect of moisture content and threshing methods on bean seed quality. They got the result that bean should not be threshed at below 14 percent moisture content. At low moisture content percentage of cracked seeds and abnormal seedlings were more and lower percentage of normal seedlings. Threshing should be done by hand threshing at low moisture content to obtain good quality of seeds.

Vejasit and Salokhe (2006) studied the effect of machine crop parameters which affects the threshing operation with the thresher consisting peg tooth type threshing drum. The study was conducted at four cylinder speeds (400,500,600 and

700 rpm), three feed rates (360, 540 and 720 kg/h), three crop moisture contents (32.88, 22.77 and 14.34 percent d.b). They got the result that 600 to 700 rpm and 540 to 720 kg/h feed rate was best for the operation. The output capacity, threshing efficiency, grain damage and grain loss at 700 rpm, 720 kg/h feed rate were obtained as 214 kg/h, 99.49 percent, 0.22 percent and 0.80 percent. The average power requirement was 1.85kW.

DESIGN CONSIDERATIONS

This chapter deals with the calculation steps and formulae used in determination of design values for the manually operated mahua stamen remover.

3.1 Design of the stamen remover

The design analysis was carried out with a view to evaluate the necessary design parameters, strength and size of materials for consideration in the selection of the various machine parts in order to avoid failure by excessive yielding and fatigue during the required working life of the machine.

3.1.1 Design of hopper

The design criterion for the hopper is as follows:

To ensure smooth and continuous gravity flow of the mahua flower from the hopper to the cylinder

$$\theta > \theta \quad (3.1)$$

Where

θ_h = Angle of inclination of the feed hopper to the horizontal, degrees = 43°

θ = Angle of repose of the flower, degrees = 45°

3.1.2 Revolutions of cylinder

$$N = \frac{v}{\pi D} \quad (3.2)$$

Where, v = Peripheral speed

N = No. of revolutions

D = Diameter of cylinder, m

We have 106 stroke/minute i.e., $106 \times 4 = 424$ revolutions/minute

Therefore,

$$N = \frac{1}{2\pi} \frac{v}{d}$$

$$\text{OR } 424 = \frac{1}{2\pi} \frac{v}{0.247}$$

$$\text{OR } v = 424 \times 3.14 \times 0.247$$

$$= 328.84 \text{ m/min.}$$

$$= 5.48 \text{ m/sec.}$$

3.1.3 Design of shaft

This was determined to know the shaft diameter that can withstand the applied loads. For a solid shaft with little or no axial load, the diameter of the shaft was determined using the following formula:

$$d = \sqrt[3]{\frac{16}{\pi F_s} \left(\frac{M}{2} + \sqrt{\left(\frac{M}{2}\right)^2 + T^2} \right)} \quad (3.3)$$

$$= \sqrt[3]{\frac{16}{\pi \times 500} \left(\frac{100}{2} + \sqrt{\left(\frac{100}{2}\right)^2 + 100^2} \right)} \quad (3.4)$$

$$= \sqrt[3]{\frac{16}{\pi \times 500} \times 100} \quad (3.5)$$

Where,

W= Weight of the removing unit on the shaft, kg

l = Distance between two bearings, m

M=Maximum bending moment, kg-m

Te= Equivalent torque, kg-m

d = Diameter of the shaft, m

F_s= the allowable stress =500 kg/cm²

Calculation for dimensions of diameter of shaft

The weight of shaft = 1.93 kg

The weight of cylinder over it = 4 kg

The weight of bearing and bush over it = 1.5 kg

The dynamic load on it during operation of the machine = 10 kg

Hence total weight on the shelling shaft (W) = 4+1.5+10+1.93 =17.43 kg

As the shaft is supported on two bearings, the maximum bending moment produced on it is given by ,

$$\begin{aligned} &= \frac{W}{2} \times \frac{L}{2} \\ &= (17.43/2) \times (0.24/2) \\ &= 1.04 \text{ kg-m} \end{aligned}$$

Mild steel rod of 1.22 cm, size of shaft 25 mm has been taken.

Chapter IV

MATERIALS AND METHODS

The major objective of this study was to develop a manually operated mahua stamen remover. The study was planned in the following sequences:

- 1) Study of physical properties of mahua flower
- 2) Development of a manually operated mahua stamen remover
- 3) Performance evaluation of the developed mahua stamen remover

4.1 Determination of physical properties

4.1.1 Moisture content

Freshly collected mahua flowers were procured from Pallahara, Angul District of Odisha. Its initial moisture content was determined by oven drying method by keeping the samples at 105°C for 24 h (i.e. until there was no reduction in weight of the sample). The flowers were dried in a tray dryer (Fig. 4.1) to achieve the desired moisture levels of 5, 10, 15 and 20% (wet basis).

$$\text{MC \% ,w.b} = \frac{\text{Weight loss}}{\text{Initial weight}} \times 10 \quad (4.1)$$

4.1.2 Size

In order to determine flower size, ten flowers were selected randomly from each sample at different moisture levels for conducting the experiment. The flower size, in terms of the major, intermediate, minor diameter was measured using a vernier calliper reading to 0.02 mm. Measurements were repeated ten times and mean values were calculated. The D_a and D_g values for the flower were calculated by using the formula given in equation 4.2 and 4.3 (Mohesin, 1980).

$$D = \frac{L}{\pi} \quad (4.2)$$

$$= \left(\frac{L}{\pi} \times \frac{W}{T} \right)^{-1} \quad (4.3)$$

Where,

L= Length of mahua flower

W=Width of mahua flower

T=Thickness of mahua flower

4.1.3 Sphericity

To obtain the sphericity of mahua flower, the area of the flowers were traced on a graph paper by the help of the projector. Then largest inscribing circle and smallest circumscribing circle were traced and diameters were measured. The sphericity was determined by using the formula given in equation 4.4. The procedure was repeated ten times for each sample of different moisture content. The mean was taken as characteristic value of sphericity.

$$S_p = \frac{d_i}{d_c} \times 100 \quad (4.4)$$

Where,

S_p = Sphericity

d_i = Diameter of the largest inscribed circle, mm

d_c = Diameter of the smallest inscribed circle, mm

The size and shape of the flower was considered relevant to the selection of the separating screen to be used in the sieving unit of the remover. Bulk density was determined to specify the volume of the feed hopper. Slope of the feed hopper was selected on the results of angle of repose of mahua flower.

4.1.4 Flower weight

The weight of one hundred numbers of flowers was taken on a digital electronic balance (Plate 4.6) having an accuracy of 0.001 g. The weight was expressed as thousand flower weight by multiplying by 10 to the values. The procedure was replicated ten times at different moisture contents and the mean values were reported.

4.1.5 Bulk density

Bulk density of flowers was measured using a 250 ml measuring cylinder. Cylinder was filled with flowers without compaction with slight tapering and then weight was taken. The procedure was repeated five times and the average bulk density of the flowers was calculated.

$$B.D. = \frac{W}{V} \quad (4.5)$$

Where,

B.D. = Bulk density, gcm^{-3}

W= Weight of flower, g

V= Volume of flower, cm³

4.1.6 Particle density

The particle density of the flower was determined by toluene displacement method. The weight of the sample was recorded. The sample was immersed in a 250 ml measuring cylinder containing toluene. The displaced volume of toluene was recorded for each sample. Particle density was calculated as the ratio of weight of the sample to its volume. Observations were taken for five times for each sample of different moisture content and the mean was calculated separately for particle density of flower.

4.1.7 Porosity

The porosity of the mahua flower was calculated using the equation 4.6. Bulk density and particle density values obtained from earlier experiments were used to calculate the percent porosity of the flower.

$$= 1 - \frac{\text{BD}}{\text{TD}} \times 100 \quad (4.6)$$

Where,

BD=bulk density, g cm⁻³

TD= Particle density, g cm⁻³

4.1.8 Coefficient of static friction

The coefficient of static friction of mahua flower was determined with respect to mild steel surface by an apparatus (Plate 4.2) consisting of a frictionless pulley fitted on a frame, a container with both end open made of wood, a loading pan and test surface. The container placed on mild steel surface was filled with a known quantity of material and weights are added to loading pan until the container began to slide. The experiment was performed with flowers of different moisture content. The coefficient of static friction was calculated by using the formula given in equation 4.7.

$$= \frac{W}{F} \quad (4.7)$$

Where,

μ= Coefficient of static friction

F=Frictional force

N=Normal force

The experiment was repeated five times and means value was calculated.

4.1.9 Angle of repose

The angle of repose was determined by using an apparatus (Plate 4.3), consisted of a funnel with an adjustable throat opening mounted on a stand. A circular plate, with four centring arms, was mounted in the funnel above the adjustable throat. The funnel was filled with flower by keeping its adjustable throat closed. The throat was fully opened to allow free flow of flower over and around the plate mounted in the funnel. At the end, a heap-cone of the flower was formed on the plate. The base diameter and height of cone was measured. The angle of repose was calculated using the formula given in equation 4.8.

$$\phi = \frac{h}{d} \times 90 \quad (4.8)$$

Where,

Φ = Angle of repose, degrees

h = Height of cone, cm

d = Base diameter, cm

The average angle of repose was calculated of five replicates of flower and mean value was calculated.

4.1.10 Terminal velocity

Terminal velocity was measured for mahua flowers at different moisture content by an apparatus consisted of a mild steel box fitted with a long glass tube, blower and a motor to regulate the speed. An Anemometer and a stopwatch were used to measure the air velocity. The air velocity in the glass tube was regulated by the throttle provided with the blower and motor. The material was provided from the top of the glass tube and upward velocity was regulated. The velocity to regulate the flower to suspend in air at middle of the tube was recorded (Plate 4.4). This procedure was repeated for five times and average values were calculated.

4.2 Development of manually operated mahua stamen remover

Stamen remover is required to detach stamen from flower and separate them from flower. As per the conventional practice, the mahua flower is laid on a floor in the form of a heap and then it is beaten with the help of wooden planks to remove the stamens. After detaching the stamens, the winnowing removes the stamens from the flowers. In the present development also, it was planned to use impact force to remove the stamens from the flower. The machine was planned in such a manner that there would be continuous separation of stamens for higher throughput capacity. The components of this remover, their functions and influences are included in the Table 4.1.

Table 4.1 Components of stamen remover, their function, material of construction and Size

Sl. No.	Remover Components	Primary function	Material of construction	Size (mm)
1	Hopper	Feeding flower into the cylindrical chamber	22 Gauge mild steel sheet	Upper Hopper Size- 330x225x225
				Lower Hopper Size - 120x120
				Outlet size - 90x30x205
2	Rotor/Cylinder	Detaching stamen from flower	MS sheet 50mm	Length-250
			2" rubber blade	Diameter – 140
3	Flat Bars	Beats flower to remove stamen	MS blade bolted with Canvas strips	250x25
4	Housing	Holds the flower during process of stamen removal	22 Gauge CI sheet	550x330x190
5	Stationary sieve	Separates removed stamens from Mahua	Steel angles 30×30×5 mm.	660×290×62
				Openings:20×5
6	Main Frame	give support to cylinder and concave assembly	40×40×3 mm MS angle	465x520
7	Stands	Supports all components of the remover	MS angle 30x30x5	700mm
8	Pedal	To run the equipment	MS flat 25x5	430x320
9	Gear Pinion system	To give power to the machine	Cast Iron	Crank gear-200
				Pinion gear-50
10	Gear Shaft	Helps to rotate the pinion	25mm MS rod turning into	1050 (with gear box)

			16mm	
11	Pedal shaft	Helps to oscillate the pedal	MS flat with wooden pedal	450
12	Handle	Gives support during operation	MS rectangular flat	480x445
13	Overall Dimension			470x520x1050

The requirement was to obtain design values of different components of stamen remover to obtain maximum Stamen Removal Efficiency (SRE) and Whole Flower Recovery (WFR).

4.2.1 Hopper

The hopper is made up of 24 gauge GI sheet. The hopper is supported by $25 \times 25 \times 3$ mm mild steel angle which is welded to main unit. The upper part of hopper is of rectangular shape. Lower part is tapered with a uniform slope of 45° towards the concave chamber, so that the flowers can flow freely and choking does not occur. The length, width and height of the upper hopper are 230 mm, 225 and 330mm respectively. The length, width and of the lower hopper are 120 mm and 330mm respectively. The size of outlet of hopper is $200 \text{ mm} \times 40 \text{ mm}$. At the joint, the sheets are double folded to give more strength to the jointing (Plate 4.8)

4.2.2 Cylinder

The cylinder is generally expressed by its length, diameter, beating element and its speed. The cylinder was selected as flat bar type with canvas strip lining (Plate 4.6), and fitted longitudinally along the cylinder length to apply impact force to the flowers and was shown in Fig. 4.7. The cylinder (250 mm length and 140 mm diameter) is made up of 2 mm mild steel sheet. Stainless steel lining was provided throughout the surface of the cylinder and the flat bar, and the contact portion of the housing was made up of stainless steel sheet of thickness 22 gauge. The forward portions of top housing cover was made corrugated for creating uneven impact force on the flower for easy removal of the stamen. On the top of cylinder, six MS flats ($20 \times 5 \text{ mm}$) of 250 mm length were

welded longitudinally with uniform gap between them. It was observed that the clear gap between the bars was 48 mm. On the edge of flats, canvas strips of 4 mm thickness and 25mm width were bolted to provide cushioning effect and to avoid excessive physical damage to the flowers. This unit was attached with two bushes in both sides which were connected to the shaft.

4.2.3 Flat Bars

Flat bars of length 250mm, width 25mm and thickness 5mm are made up of mild steel bolted with Canvas strips. Its main function is to beat the flower on the inner portion of housing to remove stamen.

4.2.4 Cylinder Housing

Cylinder Housing is made up of 22 Gauge of stainless steel which holds the flower during the process of stamen removal. The length and width of the housing is 330mm and 247mm respectively. Height of the housing from the centre of the structure is 550mm.

4.2.5 Stationary Sieve

The function of the stationary sieve is to separate the removed stamen from the Mahua flower after it is discharged from the stamen removal chamber. It is inclined at 60° with the horizontal for easy flowing of mahua flower from the sieve. The size of the stationary sieve is 660mm by length and 290mm by width. The opening size of the sieve is 20mm x 5mm.

4.2.6 Main Frame with stands

The main frame was made from 40×40×3 mm mild steel angle iron. The overall size of the frame is 470×520×1050 mm. Four legs of length 700 mm of M.S. angles 30×30×3mm were welded to the frame. All components of the remover were assembled on the main frame.

4.2.7 Pedal

The pedal is made up of MS flat of 25x5mm angles bolted with a wooden flat. It is connected with the crank gear and pinion gear which helps to run the machine. The length and breadth of the pedal is 430mm and 320mm respectively.

4.2.8 Power supply and transmission

Transmission system was developed for proper power transmission from pedal to main shaft of cylinder through a shaft. The power transmission system consists of a pedal operated oscillator (424 rev/min), two numbers of pinion and a pedal shaft.

4.3 Working principle of manually operated mahua stamen remover

A pedal operated oscillator is connected to the cylinder shaft. The shaft which rotates with the help of bearings provides drive to the shaft of separating unit through the pedal shaft and pulleys. As the mahua flowers are being fed into the removing chamber through the hopper, the stamens are beaten out of the flower and separated. This is done by a cylinder fitted with flat bars that rotates above a stationary concave/housing. The bulk of the flower falls through the concave into the separating unit which consists of one sieve and one tray that undergoes to and fro oscillating motion. The sieve, which has longitudinal holes helps to retain flowers and allows the passage of stamens to fall on the ground. Flowers and stamens are collected then to study further.

4.4 Testing of the developed machine

The developed machine was tested at different flower moisture content of 10, 12, 14 and 16% (db) and feed rate of 12, 18 and 24 kg/h to evaluate its performance.

Two kg of mahua flower at desired moisture content was fed to the machine at the desired feed rate. The output from the machine was collected, sorted manually for stamen, whole and broken flower. The weight of each fraction was taken to determine the stamen removal efficiency and whole flower recovery.

Table 4.2 Design Layout of Experiment

Factor	Particulars
Feed Rate (F)	3 Levels (12, 18, 24 kg/h)
Grain Moisture (M)	5 Levels (10,12,14,16%)
Concave Clearance(C)	Fixed
Cylinder Speed (S)	Fixed
Replications	3 levels

The stamen removal efficiency was calculated as follows.

$$\eta = \frac{M_0}{M_i} \times 100 \quad (4.9)$$

Where, η = Stamen removal efficiency

M_0 = Weight of stamen removed, kg

M_i = Weight of stamen actually present, kg = A x Xs

Xs = Stamen to flower ratio

Xs was determined by removing stamen from known amount of flower manually and taking the ratio of the weight of stamen and flower.

The whole flower recovery (X) was found out as follows.

$$X = \frac{S}{A} \times 100 \quad (4.10)$$

Where,

S = Quantity of whole flowers collected, kg

A = Total flower input, kg

4.5 Comparison of traditional and mechanical methods of stamen removal

Stamen was removed from mahua flower manually by beating method and its performance was compared with mechanical stamen removal. Total cost of the mahua stamen remover was determined based on fixed and variable cost. The cost of operation of the stamen remover was compared with the cost of operation of the conventional method (beating method).

The experiments were conducted as per the objectives mentioned and the results obtained during experiment have been discussed in this chapter. Physical properties of the mahua flower at different moisture contents were evaluated. A mahua stamen remover was fabricated with provision of varying the moisture content and the feed rate. The performance of the equipment to determine the optimal moisture content of flower and feed rate at different moisture content for maximum stamen removal efficiency, percentage whole flower recovery and percentage of small broken flowers. The optimization of the equipment parameters was carried out by Full Factorial Method.

5.1 Physical Properties of the Flowers

Physical properties like size, shape, thousand flower weight, bulk density, true density, porosity, and angle of repose, coefficient of static friction, terminal velocity of flower and minimum carrying velocity of the stamen, compressive strength were evaluated at moisture levels of 5.2, 9.4, 15.6, 20.4% (wb). The observed values are given in the Table 5.1.

5.1.1 Size

The summary of observations on dimensions of mahua flower was shown in table 5.1. the mean dimensions of ten samples at a moisture content of 5.2% (w.b) were: length 17.91 mm, width 10.90 mm, thickness 6.58 mm. All dimensions were increased with increase in moisture content from 5.2% to 20.4% w.b. The increasing trend in axial dimensions is very negligible with flower moisture content and it was due to filling of capillaries and voids upon absorption of moisture and subsequent swelling. The geometric mean diameter of mahua flowers increased from 10.83 mm to 11.62 mm and arithmetic mean diameter from 11.80 mm to 12.54 mm.

5.1.2 Sphericity

The sphericity of flower decreased from 0.52 to 0.51 with an increase in moisture content from 5.2% to 20.4% (w.b).

Table 5.1 Physical properties of mahua flower considering moisture content.

Physical properties	M.C (%, wb)			
	5.2	9.4	15.6	20.4
Length (mm)	17.91±1.70	17.86±1.71	18.44±1.43	18.85±1.27
Width (mm)	10.50±1.05	11.05±0.98	11.41±1.01	11.54±0.92
Thickness (mm)	6.58±0.54	6.66±0.67	8.20±6.99	7.24±0.36
Arithmetic Mean Diameter (mm)	11.80±0.48	11.86±0.55	12.28±0.41	12.54±0.63
Geometric Mean Diameter (mm)	10.83±0.48	10.92±0.41	11.34±0.44	11.62±0.59
Sphericity (decimal)	0.52±0.13	0.50±0.08	0.50±0.10	0.51±0.10
TFW (g)	1190±82.11	1270±75.43	1470±83.74	1540 ± 92.61
Bulk density (kg/m³)	553.63±29.46	527.85±23.67	518.18±25.45	491.80±28.91
True density (kg/m³)	1000.32±11.45	1030.12±10.73	1042.89±9.92	1055.89±11.26
Porosity (%)	50.84±0.25	49.7±0.34	49.39±0.51	47.04±0.61
Angle of repose (°)	35.26±1.51	38.2±1.67	41.88±1.32	42.56±1.54
Terminal velocity (m/s)	9.9±0.12	13.2±0.05	17.5±0.28	21.2±0.21
Coefficient of static friction (Mild steel sheet)	0.31±0.04	0.4±0.02	0.51±0.03	0.58±0.02

5.1.3 Thousand flower weight

One thousand flower weights (TFW) increased from 1190 g to 1540 g with the increase in moisture content from 5.2 to 20.4% (w.b) as shown in Fig 5.1.

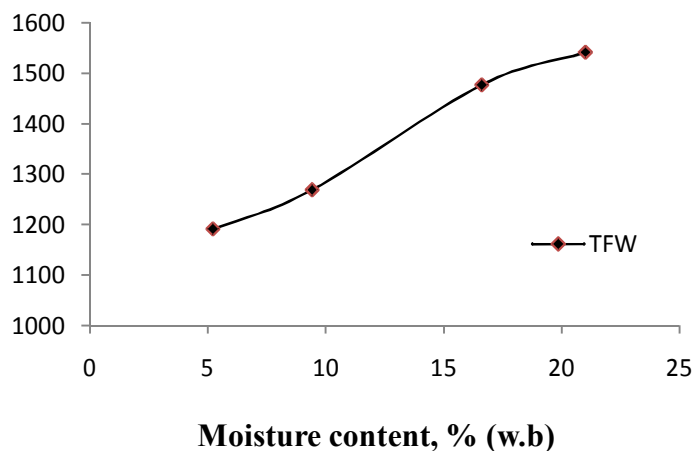


Fig.5.1 Effect of moisture content on thousand flower weight

5.1.4 Bulk and true density

The values of bulk density for different moisture levels varied from 491 to 553 kg/m³ (Fig 5.2) and indicated a decrease in bulk density with an increase in moisture content from 5.2 to 20.4% (w.b). This was due to the fact that an increase in mass owing to moisture gain in the sample was lower than accompanying volumetric expansion of the bulk.

The variation of true density with moisture content for mahua flower is shown Figure 5.3. The true density of mahua flower was found to increase from 1000.12 to 1055.89 kg/m³ with the moisture content. The increase in true density with increase in moisture content might be attributed to the relatively lower true volume as compared to the corresponding mass of mahua flower attained due to adsorption of water.

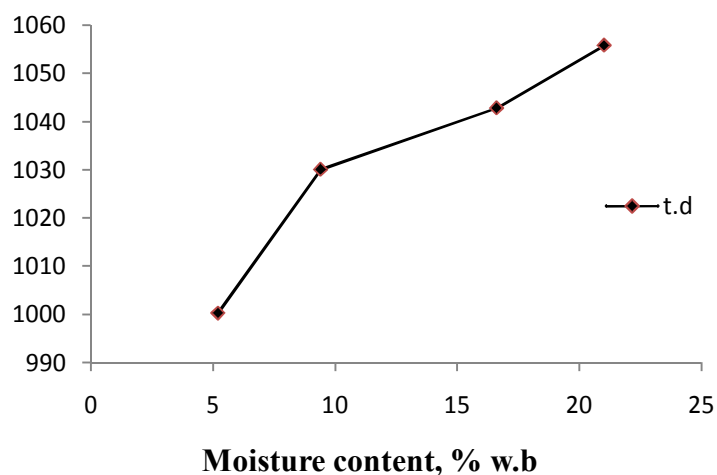


Fig. 5.3 Effect of moisture content on true density

5.1.5 Porosity

The experimental results of porosity with respect to moisture content were shown in Figure 5.4. Porosity values are decreased with increase in moisture content.

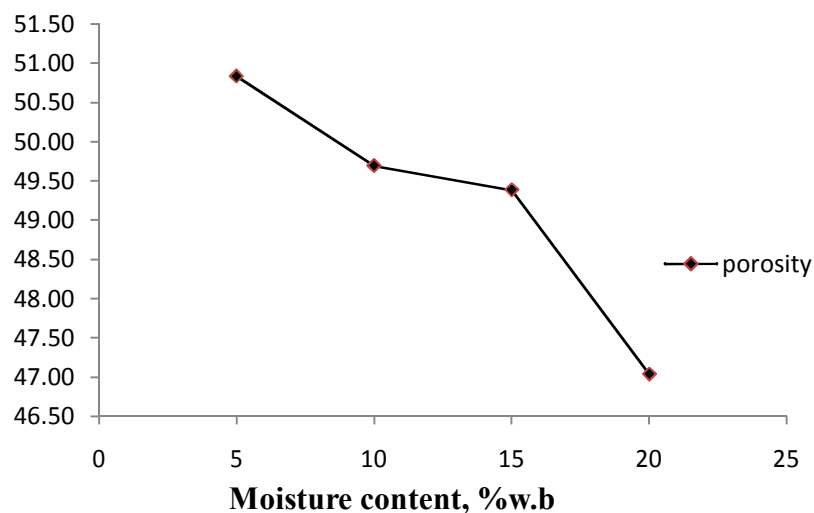


Fig.5.4 Effect of moisture content on angle of repose

5.1.6 Angle of repose

The experimental results of angle of repose with respect to moisture content were shown in Figure 5.5. The values of the angle of repose were found to increase from 35.26 to 42.56° in the moisture range of 5.2% to 20.4% w.b.

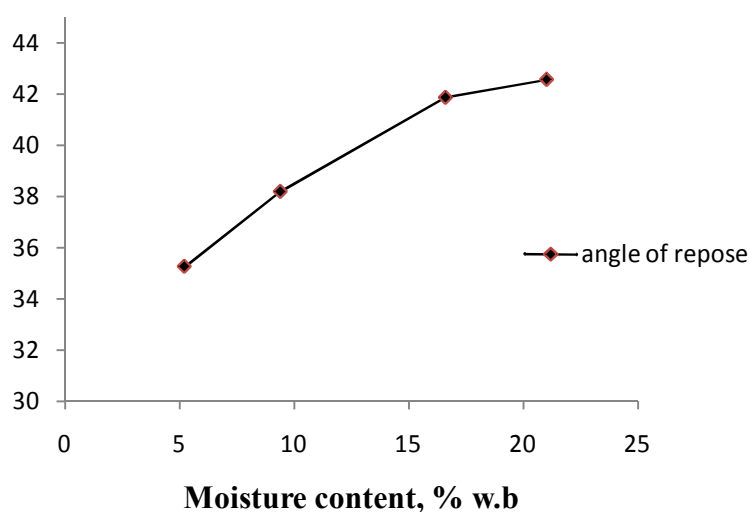


Fig.5.5 Effect of moisture content on angle of repose

5.1.7 Terminal velocity (m/s)

The experimental results of terminal velocity with respect to moisture content were shown in Figure 5.6.

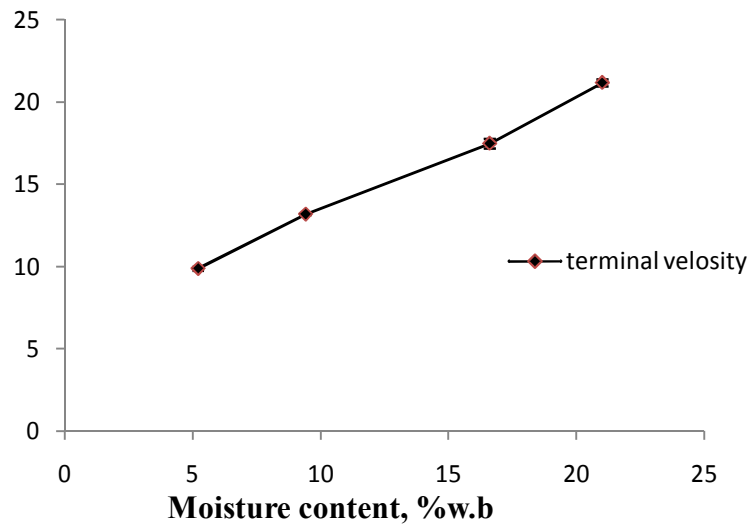


Fig. 5.6 Effect of moisture content on terminal velocity

5.1.8 Coefficient of static friction

Figure 5.7 shows the static coefficients of friction for mahua flower on mild steel surface at different moisture contents. It was observed that the static coefficient of friction increased linearly with the increase of the moisture content of mahua flower on test surface. While the highest value (0.58) for the static coefficient of friction was recorded 21% moisture content, the lowest value (0.31) was recorded for mild steel surface at 5% moisture content.

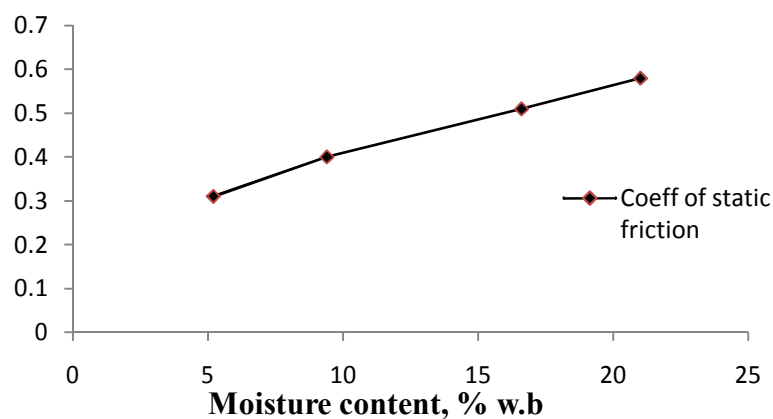


Fig. 5.7 Effect of moisture content on coefficient of static friction

5.2 Development of pedal operated mahua stamen remover

The pedal operated mahua stamen removal machine has been developed. The detailed specifications of the machine is given in Table 5.2.

Table 5.2 specifications of the manually operated mahua stamen remover

Sl. No	Components	Dimensions
1	Weight	42.4 kg
2	Overall Length × Width ×Height	520 x 470 x 1050 mm
3	Upper Hopper Height	330 mm
4	Upper Hopper Size	225 x 225×330 mm
5	Lower Hopper Height	205 mm
6	Lower Hopper Size	120 x 120 x 205
7	Cylinder	250 x 140 mm
8	Canvas Size	310 ×51×4 mm
9	Oscillating Sieve Size	660 x 290 mm
10	Power transmission	Paddle operated (424rpm)

5.3 Testing of pedal operated mahua stamen remover

The developed pedal operated mahua stamen remover was tested at different moisture contents and feed rate to evaluate its performance.

5.3.1 Stamen Removal Efficiency (SRE)

Stamen removal efficiency increased with decrease in moisture content of mahua flower (Fig. 5.8). There is no significant difference in stamen removal efficiency with different feed rate at 10 % sample moisture content. At low feed rate of 12 kg/h, there is no significant difference in stamen removal efficiency at 10 and 12 % flower moisture content. Stamen removal efficiency was higher at low feed rate at constant moisture content of flower. Stamen removal efficiency varied significantly ($p<0.05$) with moisture content and feed rate. The interaction effect of moisture content and feed rate was found to be not significant on

stamen removal efficiency. The co-efficient of variance was found to be 1.24 % indicating significant effects of variables (Table 5.4).

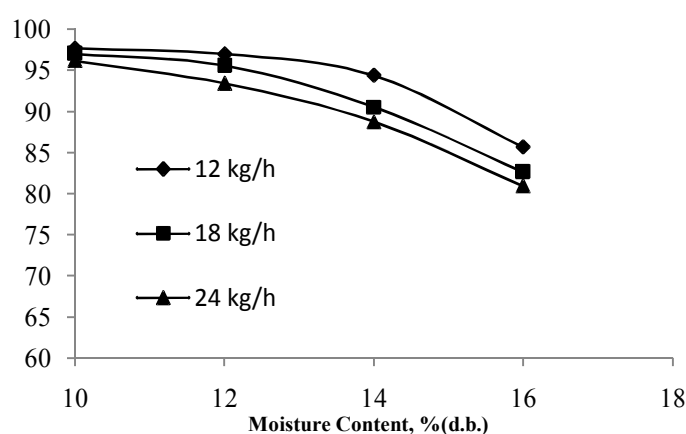


Fig. 5. 8 Effect of moisture content on the stamen removal efficiency at different feed rate

Table 5.3 Mean value of stamen removal efficiency at different moisture content and feed rate

Moisture content, (% d.b.)	Feed rate, kg/h		
	12	18	24
10	97.700	97.067	96.200
12	97.007	95.600	93.433
14	94.400	90.567	88.767
16	85.700	82.667	80.933

Table 5.4 Analysis of variance for stamen removal efficiency

ANOVA					
Source	df	SS	MSS	Fcal	
Rep	2	45.23047	22.61523	17.5128	S
Moisture	3	1038.91	346.3034	268.1706	S
Feed rate	2	90.46847	45.23423	35.02852	S
MxF	6	16.97118	2.82853	2.190359	NS
Error	22	28.4098	1.291355		

Table

	Moisture contnet	Feed rate	MxF
Sem	0.379	0.328	0.656
CD 5%	1.111	0.962	1.924
CV %	1.24		

5.3.2 Whole flower recovery

Whole flower recovery percentage decreased with decrease in sample moisture content (Fig. 5.9). From analysis of variance, it was observed that whole flower recovery varied significantly with moisture content ($p < 0.05$), whereas feed rate had no significant effect (Table 5.6). Whole flower recovery decreased steadily below 12 % moisture content. The whole flower recovery varied from 66.7 to 86.2 in the feed rate and moisture content range under study.

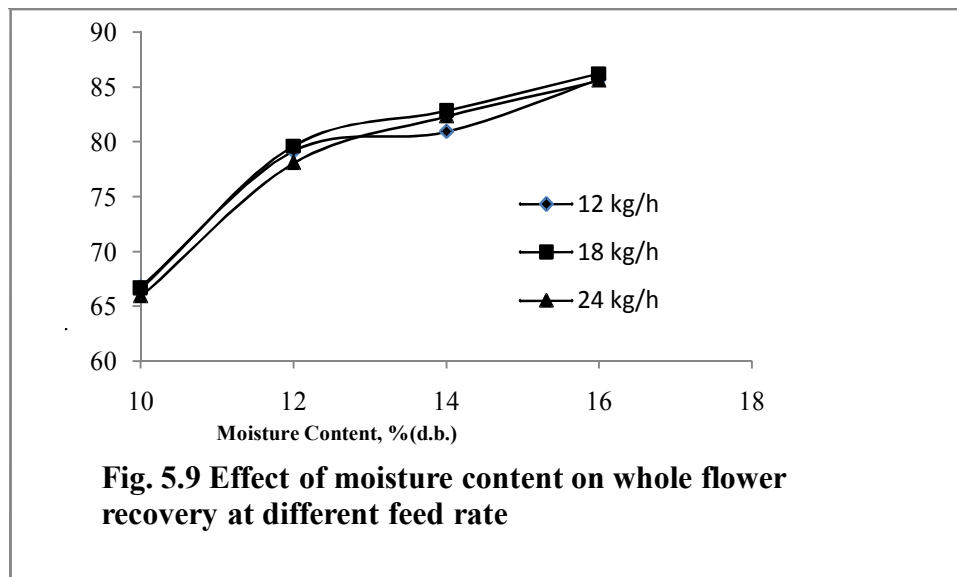


Table 5.5 Mean value of whole flower recovery at different moisture content and feed rate

Moisture content, (% d.b.)	Feed rate, kg/h		
	12	18	24
10	66.767	66.633	65.933
12	79.167	79.633	78.067
14	80.933	82.833	82.333
16	85.700	86.233	85.600

Table 5.6 Analysis of variance for whole flower recovery

ANOVA					
Source	df	SS	MSS	Fcal	
Rep	2	3.933889	1.966944	1.815683	NS
Moisture	3	1906.55	635.5166	586.6444	S
Feed rate	2	4.903889	2.451944	2.263386	NS
MxF	6	6.696111	1.116019	1.030195	NS
Error	22	23.83278	1.083308		
	35				

	Moisture contnet	Feed rate	MxF
Sem	0.347	0.300	0.601
CD 5%	1.017	0.881	1.762
CV %	1.33		

5.4 Optimization of performance parameters

As stamen removal efficiency did not increase much and whole flower recovery decreased steadily below 12 % moisture content of flower, this moisture level was found to be optimum for stamen removal (Fig.5.8). Though stamen removal efficiency was 1.46 % more at 12 kg/h feed rate as compared to 18 kg/h, the optimum feed rate was chosen to be 18 kg/h taking higher capacity into consideration. The stamen removal efficiency and whole flower recovery were found to be 95.6 and 79.6 %, respectively at 18 kg/h feed rate and 12 % flower moisture content (Fig 5.9).

5.5 Comparison of manual and mechanical methods of stamen removal

Stamen removal by traditional method was compared with pedal operated stamen removal machine (Table 5.7). Capacity of stamen removal in traditional method was found to be 3 kg/h whereas in case of pedal operated stamen removal machine it was 18 kg/h.

The economic evaluation of the developed stamen remover was done with comparison to the traditional method (beating) to make acceptable by the farmers. The machine cost was calculated as Rs 2560.00. The total operating cost of the machine was calculated as Rs 39.13 per hour. The operating cost for removing stamen from one kg of mahua by the developed machine was calculated as Rs 2.17/kg. The operating cost of the operation by the manual method was calculated as Rs 25.00 per hour. The operating cost for removing stamen from one kg of mahua by beating method was calculated as Rs 8.33. Thus, there was a saving of 283 per cent over local method. The payback period was calculated as one year four months.

Table 5.7 Comparison of manual and mechanical methods of stamen removal

Parameters	Traditional	Pedal operated
Capacity, kg/h	3	18
Stamen removal efficiency , %	98.8	95.6
Whole flower recovery, %	82.3	79.6
Cost of operation per kg of flower (Rs.)	8.33	2.17

CHAPTER V

SUMMARY AND CONCLUSIONS

Mahua (*Madhuca Indica*) of Sapotaceae family is a large tree found in the deciduous forest of India. Mahua flower can be utilized in a variety of ways in home, as animal feed and also as raw material for industrial products. They can be used as a sweetener in preparation of many local dishes like halwa, kheer, puri, burfi, bakery and confectionary goods. Mahua has various types of medicinal uses due to its tannin content. It is used as Anti diabetic, antiulcer, hepato protective, anti pyretic, anti fertility, analgesic, anti oxidant, swelling, inflammation, piles, emetic, dermatological, laxative, tonic, anti burn, anti earth worm, wound healing headache and many more problems. It has been found that the flower contains hairy stamens inside it which is very bitter in taste and inedible. Therefore, for preparation of any value added products for human consumption this stamen has to be removed. In traditional method, most of the flowers get broken / damaged and pressed. Hygienic condition is also not maintained. For preparation of candy or glazed flower, whole and cleaned flower is most suited. Considering all these aspects and identifying the existing knowledge gap, the present study was undertaken with the following specific objectives.

1. To study the physical properties of mahua flower and its stamen.
2. Development of a manually operated mahua stamen remover.
3. Testing and performance evaluation of the developed manually operated mahua stamen remover.

Freshly collected mahua flowers were procured from Pallahara, Angul District of Odisha. Its initial moisture content was determined by oven drying method by keeping the samples at 105°C for 24 h. The flowers were dried in a tray dryer to achieve the desired moisture levels of 5, 10, 15 and 20% (wet basis). The physical properties of mahua flower at four moisture levels were measured and compared. A pedal operated mahua stamen remover was fabricated. It was tested at four moisture levels (10, 12, 14, and 16 % d.b.) and three feed rates (12,14,16 kg/h). The stamen removal efficiency and whole flower recovery were determined to optimize feed rate and moisture content of mahua flower for better performance of the machine.

Based on the experimental results, the following conclusions could be obtained:

1. The geometric mean diameter of mahua flowers increased from 10.83 mm to 11.62 mm and arithmetic mean diameter from 11.80 mm to 12.54 mm as moisture content increases.
2. The sphericity of flower decreased from 0.52 to 0.51 with an increase in moisture content from 5.2% to 21% w.b.
3. Thousand flower weight (TFW) increased from 1190 g to 1540 g as the moisture content increased from 5.2% to 21% w.b.
4. The values of bulk density for different moisture levels varied from 491.8 to 553.63 kg/m³ and indicated a decrease in bulk density with an increase in moisture content from 5.2 to 21% w.b. The true density of mahua flower was found to increase from 1000.12 to 1055.89 kg/m³ with the moisture content.
5. Porosity values were decreased with increase in moisture content.
6. The values of the angle of repose were found to increase from 35.26° to 42.56° in the moisture range of 5.2% to 21% w.b.
7. Terminal velocity and Static coefficient of friction increased with the increase of the moisture content of mahua flower on mild steel surface.
8. Stamen removal efficiency varied significantly ($p < 0.05$) with moisture content and feed rate. Stamen removal efficiency increased with decrease in moisture content of mahua flower. Stamen removal efficiency was higher at low feed rate at constant flower moisture content.
9. Whole flower recovery varied significantly with moisture content ($p < 0.05$), whereas feed rate had no significant effect. Whole flower recovery percentage decreased with decrease in sample moisture content and it decreased steadily below 12 % moisture content.
10. The optimum flower moisture content and feed rate were found to be 12% and 18 kg/h, respectively with stamen removal efficiency of 95.6 % and whole flower recovery of 79.6 %.
11. The operating cost for removing stamen from one kg of mahua by the developed manual stamen remover was found to be Rs 2.17/kg as against Rs 8.33 in traditional method.

From the above study, it could be concluded that the developed pedal operated manual mahua flower remover performed well at 12 % sample moisture content and 18 kg/h feed rate. The machine will be useful to the tribal people in drudgery reduction of stamen removal operation.

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Botanical description of mahua flower

Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Ericales
Family	Sapotaceae
Genus	Mahoe
Species	Indica (syn. <i>Bassia latifolia</i>)
	Longifolia (syn. <i>Bassia laongifolia</i>)

Physical properties of mahua flowers

Sphericity at different moisture content

Sl. No.	M.C, % (w.b)	20.4			16.6			9.4			5.2		
		D _c	D _i	S _p	D _c	D _i	S _p	D _c	D _i	S _p	D _c	D _i	S _p
1		4.7	2.4	0.51	4.8	2.6	0.54	5.1	2.1	0.41	4.4	2.4	0.55
2		4.4	2.8	0.64	4.6	2.7	0.59	4.9	2.5	0.51	4.2	2.8	0.67
3		4.4	2.9	0.66	4.5	2.8	0.62	5.5	3.5	0.64	3.9	2.9	0.74
4		5.9	2.6	0.44	4.9	1.9	0.39	5.9	2.6	0.44	5.1	2.6	0.51
5		4.8	1.9	0.40	5.7	2.1	0.37	4.9	2.3	0.47	4.7	1.9	0.40
6		4	1.9	0.48	4.4	1.9	0.43	5.1	2.8	0.55	5	1.9	0.38
7		5.1	2.9	0.57	5.5	2.9	0.53	5.2	2.9	0.56	5.1	2.9	0.57
8		4.2	1.8	0.43	4.3	2.3	0.53	4.9	2.1	0.43	4.2	1.8	0.43
9		4.6	2.7	0.59	4.9	2.9	0.59	4.6	1.9	0.41	4.6	2.7	0.59
10		4.6	1.7	0.37	5.9	2.3	0.39	5.1	2.9	0.57	4.9	1.7	0.35
Mean				0.51			0.50			0.50			0.52
S.D				0.10			0.10			0.08			0.13

Bulk density at different moisture content

S.I no.	M.C, % (w.b)	5.2	9.4	16.6	20.4
1		559.21	521.3	517.45	488.9
2		558.57	525.21	515.98	485.85
3		541.46	527.9	520.05	490.57
4		554.91	530.71	519.9	495.91
5		554.02	534.14	517.5	497.78
mean		553.63	527.85	518.18	491.80
min		541.46	521.3	515.98	485.85
max		559.21	534.14	520.05	497.78
s.d		7.17	4.94	1.75	4.95

True density at different moisture content

S.I No.	M.C, %(w.b)	5.2	9.4	16.6	20.4
1		881.75	1041.28	1030.22	1000.12
2		1110.80	1041.27	1030.38	1000.21
3		1113.70	1038.15	1029.01	1000.01
4		1025.56	1042.57	1031.02	1000.15
5		1147.62	1051.21	1030.12	1001.12
mean		1055.89	1042.89	1030.15	1000.32
min		881.75	1038.15	1029.01	1000.01
max		1147.63	1051.21	1031.02	1001.12
s.d		107.26	4.92	0.73	0.45

Porosity values at different moisture content

S.I No.	M.C, % (w.b)	5.2	9.4	16.6	20.4
1		36.57	49.93	49.77	51.11
2		49.71	49.56	49.92	51.42
3		51.27	49.14	49.46	50.94
4		45.89	49.09	49.57	50.41
5		51.72	49.18	49.76	50.27
mean		6.28	0.36	0.18	0.48
min		47.04	49.39	49.70	50.84
max		36.58	49.10	49.46	50.28
s.d		51.72	49.94	49.92	51.43

Angle of repose values at different moisture content

Sl. No.	M.C, % (w.b)	5.2	9.4	16.6	20.4
1		35.2	38.2	41.9	42.4
2		35.1	38.1	41.8	42.6
3		35.3	38.2	42	42.5
4		35.3	38.3	41.8	42.7
5		35.4	38.2	41.9	42.6
Mean		35.26	38.2	41.88	42.56
S.d		0.11	0.07	0.08	0.11

Experimental results of testing of mahua stamen remover

Experimental data on testing of manual mahua stamen remover for stamen removal efficiency

	R1	R2	R3	Total	Mean
M1F1	98.5	97.9	96.7	293.1	97.700
M1F2	97.6	97.3	96.3	291.2	97.067
M1F3	96.3	96.2	96.1	288.6	96.200
M2F1	97.5	97.02	96.5	291.02	97.007
M2F2	96.6	95.9	94.3	286.8	95.600
M2F3	94.3	93.8	92.2	280.3	93.433
M3F1	95.4	93.2	94.6	283.2	94.400
M3F2	93.2	89.7	88.8	271.7	90.567
M3F3	91.7	87.7	86.9	266.3	88.767
M4F1	87.2	85.3	84.6	257.1	85.700
M4F2	85.3	83.2	79.5	248	82.667
M4F3	83.4	81.8	77.6	242.8	80.933
Total	1117	1099.02	1084.1	3300.12	91.670

CF 302522 TSS **1219.99**

Experimental data on testing of manual mahua stamen remover for stamen removal efficiency

	R1	R2	R3	Total	Mean
M1F1	67.6	65.9	66.8	200.3	66.767
M1F2	67.4	66	66.5	199.9	66.633
M1F3	66.8	65.7	65.3	197.8	65.933
M2F1	78.9	79.1	79.5	237.5	79.167
M2F2	79.7	79	80.2	238.9	79.633

M2F3	78.4	77.5	78.3	234.2	78.067
M3F1	80.7	81	81.1	242.8	80.933
M3F2	82.3	83.2	83	248.5	82.833
M3F3	81.8	82.7	82.5	247	82.333
M4F1	83.4	86.7	87	257.1	85.700
M4F2	84.4	87	87.3	258.7	86.233
M4F3	83.2	86.9	86.7	256.8	85.600
Total	934.6	940.7	944.2	2819.5	78.319

CF 220821.7 TSS **1945.916**

Where

M1=10% m.c.(db), M2=12% m.c.(db), M3=14% m.c.(db), M4=16% m.c.(db)

And F1= 12 kg/h feed rate, F2= 18kg/h feed rate, F3= 24 kg/h feed rate

Annexure IV

Data sheet and bill of material for fabrication of mahua stamen remover

Sl. No.	Component	Material of construction	Size	Weight, (kg)	Unit Cost (Rs.)	Cost (Rs)
1	Main frame	MS angle	40×40×3 mm	26	45	1170
2	Hopper	MS sheet, 24 gauge	2 mm	1.2	27.5	33
3	Cylinder cover	Stainless steel	2 mm	1.3	30	39
4	Main shaft	MS round	25 mm ϕ	1.93	26.5	51.145
5	Flat (6)	MS flat	20×5 mm	2.5	29	72.5
6	Canvas	Canvas	250×50×4	0.75	1	0.75
7	Bush	MS round	30/40 mm inner/outer ϕ	0.9	28	25.2
8	Sieve frame	MS Angle	30×30×3 mm	2.4	45	108
9	Screen	M.S. Sheet	2 mm	1.47	27.5	40.425
10	Sieve hanger	M.S. Round	6 mm ϕ	1	18	18
11	Connecting rod	M.S. Round	16 mm ϕ	0.5	18	9
12	Pinion	Cast iron	200/50 mm ϕ	2.5	65	162.5
13	Bearing (pillow)	High Carbon steel	2 Nos.	1	45	45
14	Nuts, Bolts and Washers		14 no.s each	0.5	65	32.5
15	Primer		500 gm	0.5	75	37.5
16	Paint		500 gm	0.5	102	51
Total material cost						1895.52
Labour charges @ 25 % of material cost						473.88
Miscellaneous @ 10 % of material cost						189.552
Total cost of stamen remover						2558.952
Rounded off to						2560

Annexure V

Calculation of cost of operation of stamen remover

Assumptions:

- i. Average annual use = 250 hours
- ii. Life of machine = 10 years
- iii. Salvage value = 10 % of initial cost

A. Fixed cost

Cost of remover with all accessories = Rs. 2560.00

Depreciation/h = _____
= Rs. 0.92

Interest on investment/h = $2560 \times \text{---}$
(@ 15% per annum) = Rs. 384

Let he repays in 4 year, So total interest
will be $384 \times 4 = 1536$

Total investment on interest/h =
 $1536/2500 = 0.61$

Repair and maintenance cost/h = $\text{---} \times \text{---}$
(@ 1% of initial cost per annum) = Rs. 0.10

Total cost/h = $0.92 + 0.61 + 0.10$
= Rs. 1.63

Fixed cost of remover/h = Rs. 1.63

B. Operating cost

Assumptions:

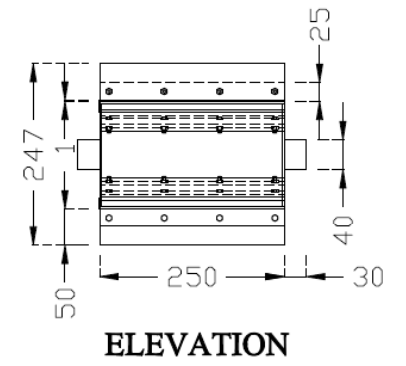
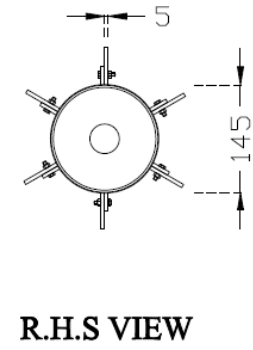
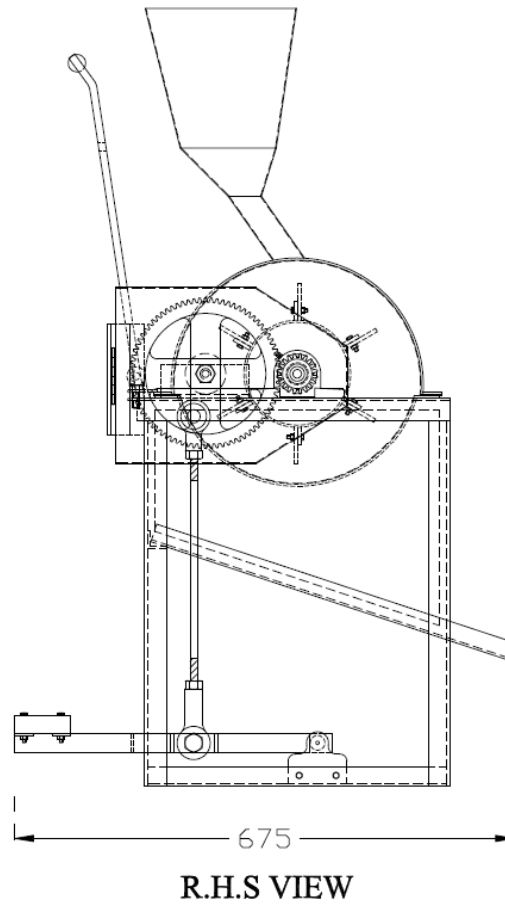
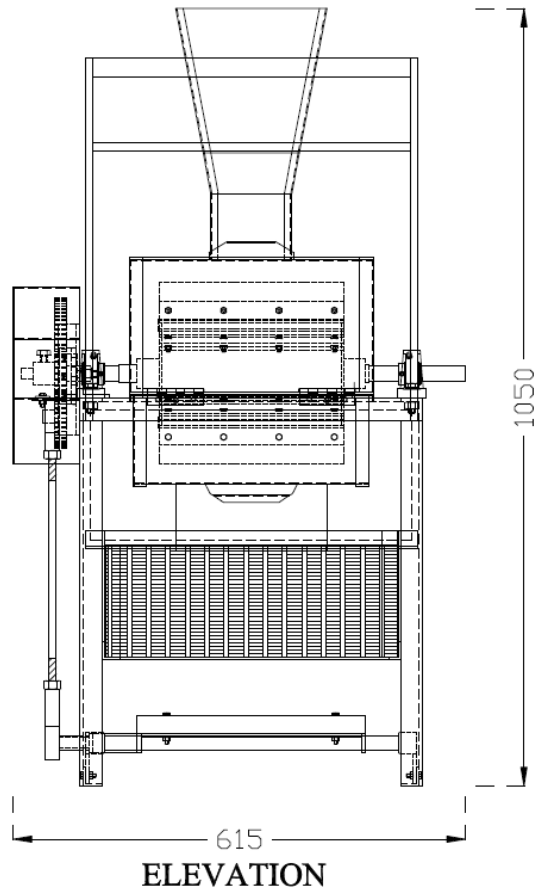
- i. One labour is required to utilise the full capacity of the machine
- ii. Wage rate of Rs. 300 per man per day of 8 hours

$$\text{Labour cost of one person/h} = \frac{300}{8} = \text{Rs. } 37.5$$

$$\text{Total operating cost/h} = \text{Rs. } 37.5$$

$$\begin{aligned}\text{Total cost of operation of remover/h} &= \text{Rs. } 1.63 + 37.5 \\ &= 39.13\end{aligned}$$

$$\begin{aligned}\text{Total operating cost per 1 kg mahua} &= \frac{\quad}{\quad} \\ &= \text{Rs. } 2.17\end{aligned}$$



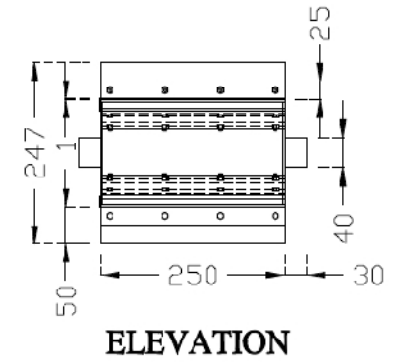
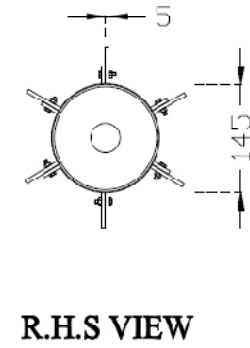
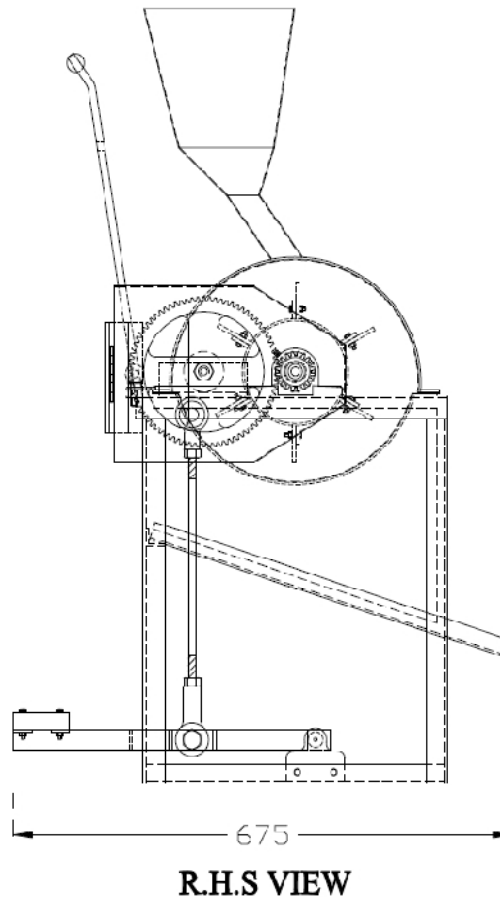
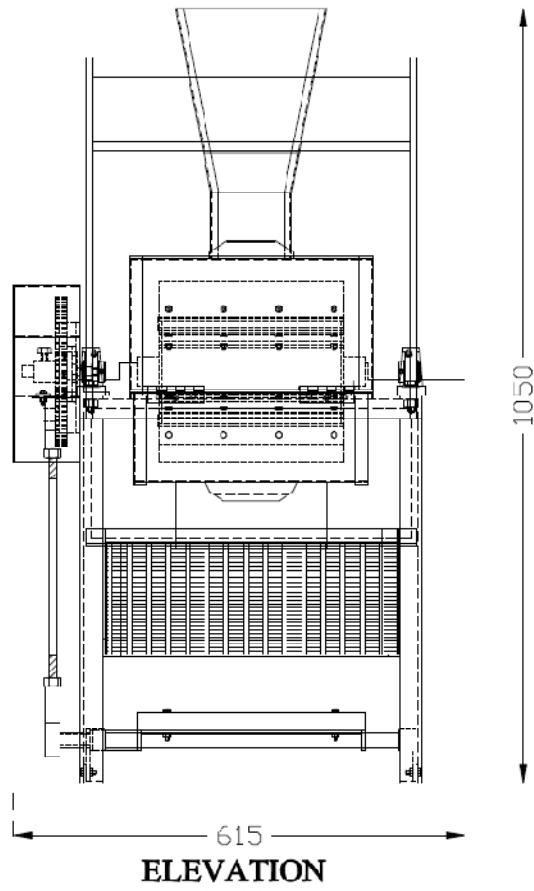




Plate 4.1 Tray drying of mahua flower



Plate 4.2 Measurement of coefficient of friction



Plate 4.3 Measurement of angle of repose



Plate 4.4 Measurement of terminal velocity



Plate 4.5 Anemometer



Plate 4.6 Weighing machine



Plate 4.7 Canvas



Plate 4.8 Cylinder



Plate 4.9 Hopper



Plate 4.10 Sieve



Plate 4.11 Fresh mahua flower



Plate 4.12 Dried mahua flower



Plate 4.13 Testing of machine



Plate 4.14 Testing of machine



Plate 4.15 Manual stamen removal



Plate 4.16 Manual aspiration of stamen



Plate 4.13 Developed stamen remover



Plate 4.14 stamen removed mahua flowers



Plate 4.15 Stamens