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Development and Performance of Mahua (*Madhuca longifolia*) Seed Decorticator

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Abstract: The manual decortication process of Mahua (*Madhuca longifolia*) is a tedious, costly, low output, time consuming and labour intensive process and injurious to human beings. To overcome this problem, the present investigation was carried out to develop a mahua seed decorticator and evaluate its performance. The performance parameters of developed seed decorticator were tested and evaluated with independent variables, namely four levels of seed moisture content *i.e.* 9, 12, 15 and 18 % (dry weight basis), and four levels of concave clearance *i.e.* 9, 11, 13 and 15 mm. The best performance of mahua seed decorticator was obtained at seed moisture content of 9% and a concave clearance of 11 mm, which resulted in the maximum percentage of whole kernel recovery (67.25%) with decorticating efficiency of 98.18% and overall machine efficiency of 88.63% and a desirability value of 0.932.

Keywords: Concave clearance, Decorticator, Performance, Seed moisture content

Mahua (*Madhuca longifolia*) seed is a tree-borne oilseed that is found in the states of Jharkhand, Chhattisgarh, Odisha, Madhya Pradesh, Maharashtra, and Gujarat in India, with an annual fruit production of nearly 1.81 million metric tonnes. It is one of the most important tree seed oil sources in tribal areas of India (Jha and Vaibhav 2013, Nayak and Sahoo 2020). Mahua is a medium size, deciduous tree, having height up to 16-20 m, usually with a spreading, dense with shady canopy. The tree matures from age of 8-15 years and fruits up to 60 years (Hegde et al 2018). Mahua is mainly cultivated or harvested for three major F's *i.e*. food, fodder, and fuel (Patel et al 2011, Hegde et al 2019). The tree yields several products of daily utilities. The seeds are primarily processed for their oil which is used in various food and non-food industries. Mahua fruits are green at maturity and turn reddish-yellow when ripen. Fruits are 2.5-5.0 cm long, ovoid, fleshy and have 1- 4 elongated seeds (2.0-3.5 cm) of brown colour with shiny appearance (Ramadan and Moersel 2006).

The seed contains two kernels and is highly sensitive to desiccation and freezing, indicating the recalcitrant nature of the seed. Fruits open after 45-60 days of flowering period and seeds get matured by the month of June and are available up to mid-July. The mature fruits fall on the ground on ripening and are tribal people collect the fruits and separate the seed by pressing the fruit wall manually (Patel et al 2011, Gupta et al 2012). However, they are commercially harvested during June and July in rainy season. Harvested matured fruits from the tree can also be kept for ripening and seeds are extracted by depulping the fruit. It is an important tree-based oilseed valued for its high content (33-61%) of pale yellow semi-solid fat (Ghadge and Raheman 2005). Mahua seed oil is the largest source of natural hard fat commercially known as mahua butter or mowrah butter, hence Mahua is also called as an Indian butter nut tree. The oil is edible and consumed in various rural areas and also beneficial for curing of skin diseases and smoothening of skin (Bakhara et al 2016). Because of its many uses, collection of Mahua seeds is an important activity in the annual calendar of tribal families (Yadav et al 2011, Ramadan et al 2016).

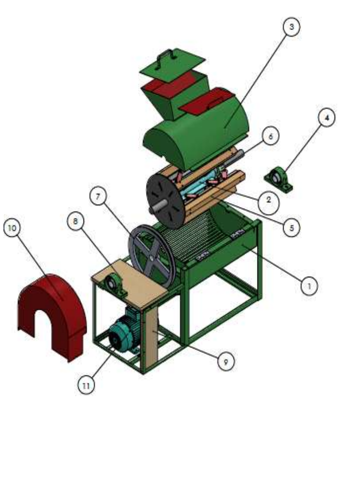
Due to a lack of efficient post harvest management, the seeds are low priced and have less demand in the market, which makes this seed underutilized. One of the important post harvest processing operations for oilseeds is decortication. Traditionally, tribal people and farmers use the manual method of decorticating the seed by applying impact force on the seed with a wooden mallet. The manual decortication process is a tedious, costly, low output, time consuming and labour intensive process and injurious to human beings. Quantity and quality of kernel out-turn fully depends upon the skill of the person. This limits the availability of mahua seed kernel and seed oil in the market. Thus, the quest for a satisfactory, effective, and economical means such as mechanized decortication technique is highly required for small and marginal farmers in the rural and tribal areas of India to reduce the excessive drudgery in mahua seed decortications. To overcome this problem, a mahua seed decorticator was designed and developed and evaluated for its performance.

MATERIAL AND METHODS

The study was conducted in Centre of Excellence on Post Harvest Technology, ASPEE College of Horticulture, Navsari Agricultural University, Navsari, Gujarat- 396450, India.

Moisture content: The moisture content of raw material was determined by following the procedure of AOAC (2000).

Design and development of the machine: Mahua seed decorticator was designed employing SOLIDWORKS software (Version 2020, Dassault Systems) and fabricated at the Centre of excellence of PHT. The machine comprises of the main frame, feed hopper, decorticating casing, a mechanism for adjusting clearance between concave and rotor assembly and a power transmission unit etc (Fig. 1). All fabrication parts were made of mild steel (MS) because it is cheap, durable, and readily available. Standard components such as belts, pulley, bearing, bearing housing *etc*. were purchased from the local market. The capacity of the developed machine was 100 kg/h. The decorticating casing comprised of a rotor assembly with six wooden rasp bars of 500 mm long and 300 mm cylinder diameter mounted on a 30 mm central mild steel shaft that rotates inside a stationary metal concave sieve. The main function of a rotating wooden rasp bar is to apply compression force on the surface of the seeds surface which helps the frangible seed coat to crack. Due to the continuous rotating action of the wooden rasp bar, impact and shearing forces inside the chamber are created, which caused the cracked seed coat to break and detach from the kernel. A feed hopper with dimensions 305 (Length) × 40 (Width) × 120 mm (Height) feeds the bulk mahua seeds into the decorticating casing at the desired feed rate of 1.66 kg/min. The feed hopper and discharge outlets were designed at a 45° angle of inclination to ensure the free flow of the seed during loading and unloading conditions. The concave was made of 26 numbers of Ø 10 mm mild steel bars at an equal spacing of 10 mm to form slotted apertures. The semicircular concave screen was made of mild steel and acted as impacting surface. A single phase 1 HP electric motor with 1440 rpm was used as a drive to rotate the cylinder at 310 rpm. The overall dimensions of the decorticator were 1000 (Length) × 420 (Width) × 850 mm (Height) having a net weight of 101 kg excluding the motor.



Item no.	Part number	Nos.
1	Concave assembly with frame	01
2	Major bush	01
3	Upper concave with	01
4	Bearing P206	02
5	Wooden rasp bar	06
6	Minor bush	01
7	Pulley	01
8	Wood ply 1	01
9	Wood ply 2	01
10	Protection guard	01
11	Motor	01

Fig. 1. Mahua seed decorticator assembly (Left) with Part details (Right)

Performance evaluation of mahua seed decorticator: The performance parameters of the mahua seed decorticator were tested and evaluated with independent variables, namely four levels of seed moisture content, i.e. 9, 12, 15 and 18 %, and four levels of concave clearance, i.e. 9, 11, 13 and 15 mm. Mahua seeds were introduced into the decorticating casing with known quantity (N0) and decortication experiments were carried out. With Factorial Composite Randomized Design (FCRD), 16 combinations were considered as treatments and each treatment had three replications. Sample of 5 kg mahua seeds was taken in each replication of 16 treatments for the decortications in the mahua seed decorticator. The speed (310 rpm) and feed rate (1.67 kg/min) were kept constant for the machine for the entire duration of decortications operation.

After each experiment, the decorticated samples were carefully collected from the outlet and grouped into four categories, namely whole kernel (N1), broken kernel and powder (N2), partially decorticated seed (N3) and un-decorticated seed (N4) and subsequently weighed. The decorticating performance was measured in terms of dependent variables, namely Percent of the whole kernel (η_k), Percent of the broken kernel and powder (η_b), Percentage of partially decorticated seed (η_{pd}), Percentage of un-decorticated seed (η_{ud}), Decorticating efficiency ((η_{de}), Overall machine efficiency (η_{me}) which were determined using (Eq. 1 - 6) using method described by Pradhan et al (2010) and Sobowale et al (2015).

Percent of whole kernel (η_k)

$$\eta_k = \frac{N1}{N0} \times 100 \qquad (1)$$

Percent of broken kernel and powder (η_b)

$$\eta_b = \frac{N2}{N0} \times 100 \qquad (2)$$

Percentage of partially decorticated seed(η_{pd})

$$\eta_{pd} = \frac{N3}{N0} \times 100 \qquad (3)$$

Percentage of un-decorticated seed (η_{ud})

$$\eta_{ud} = \frac{N4}{N0} \times 100 \qquad (4)$$

Where, N0 = amount of seed fed into the hopper, kg

Decorticating efficiency ((η_{de})

$$\eta_{de} = \left[1 - \frac{(N3 + N4)}{N0}\right] \times 100 \qquad (5)$$

Overall machine efficiency (η_{me})

$$\eta_{me} = \left[1 - \frac{(N3 + N4)}{N0}\right] \times \left[\frac{N1}{N1 + N2}\right] \times 100 \quad (6)$$

RESULTS AND DISCUSSION

The fractions (Per cent) and decortications efficiency and overall machine efficiency which were calculated using equations 1-6 (Table 1). Independent parameters like seed moisture content (M) and concave clearance (C) significantly affected the decorticating performance of the mahua seed decorticator.

At any concave clearance from 9 to 11 mm, the per cent of the whole kernel decreased as moisture content increased from 9% to 18% (db). But, at any moisture content from 9 to 18% (db), the per cent of whole kernel recovery increased for concave clearance of 9 to 11 mm but decreased for 11 to 15 mm concave clearance. This may be due to the maximum compression obtained for 11 mm concave clearance with minimum breakage. It is because of the seed was more brittle at low moisture content and it is more susceptible to mechanical damage. The reported results were well supported by the study conducted by Pradhan et al (2010) conducted study on jatropha seeds decortication at different moisture content and concave clearance. At any concave clearance from 9 to 11 mm, the per cent of the broken kernel and powder decreased as moisture content increased from 9 to 18% (db) whereas it decreased with an increase in concave clearance from 9 to 15 mm.

At any concave clearance from 9 to 11 mm, the percentage of partially decorticated seed and per cent un-decorticated seed decreased as moisture content increased from 9 to 18% (db). But, at any moisture content from 9 to 18% (db), the per cent of the partially decorticated seed and per cent of un-decorticated seed increased with an increase in concave clearance from 9 to 15 mm. The results are in line with the observation made by Shashikumar et al (2016) while testing the sal seed decorticator who reported that at higher

Table 1. Effect of the seed moisture content and concave clearance on the performance parameters of the mahua seed decorticator

Treatments	Whole kernel (%)	Broken kernel and powder (%)	Partially decorticated seed (%)	Un-decorticated seed (%)	Decorticating efficiency (%)	Overall machine efficiency (%)	Desirability
T_1 (M_1C_1)	58.87	13.19	0.79	0.56	98.65	80.59	0.312
T_2 (M_1C_2)	67.25	7.26	1.03	0.79	98.18	88.63	0.932
T_3 (M_1C_3)	63.05	7.45	2.31	1.12	96.57	86.36	0.732
T_4 (M_1C_4)	61.26	6.33	2.62	2.13	95.25	86.34	0.615
T_5 (M_2C_1)	58.12	12.83	1.14	0.91	97.95	80.24	0.080
T_6 (M_2C_2)	65.45	7.11	1.33	1.56	97.11	87.60	0.880
T_7 (M_2C_3)	64.13	6.67	2.69	2.27	95.04	86.09	0.679
T_8 (M_2C_4)	60.79	6.15	2.98	2.35	94.67	85.97	0.561
T_9 (M_3C_1)	57.79	12.66	1.56	1.45	96.99	79.56	0.037
T_{10} (M_3C_2)	64.67	6.45	1.81	1.93	96.26	87.53	0.828
T_{11} (M_3C_3)	62.04	6.11	2.87	2.56	94.57	86.10	0.625
T_{12} (M_3C_4)	60.38	6.00	3.12	2.64	94.24	85.72	0.496
T_{13} (M_4C_1)	57.12	12.40	1.65	1.57	96.78	79.52	0.134
T_{14} (M_4C_2)	62.90	6.00	2.15	2.64	95.21	86.92	0.763
T_{15} (M_4C_3)	60.93	5.90	2.70	2.65	94.40	86.07	0.553
T_{16} (M_4C_4)	59.01	5.82	3.33	2.90	94.02	85.59	0.036
S. Em. ±	0.40	0.23	0.10	0.07	0.11	0.29	-
CD at 5%	1.16	NS	0.29	0.19	0.31	NS	-
CV %	1.13	4.89	8.05	6.16	0.20	0.59	-

Where, M= Mahua seed moisture content with M_1 = 9%; M_2 = 12%; M_3 = 15% and M4 = 18%, C = Concave clearance with C_1 = 9 mm; C_2 = 11 mm; C_3 = 13 mm and C_4 = 15 mm

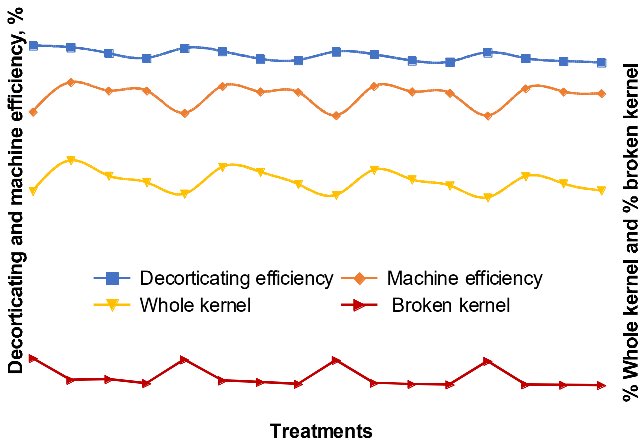


Fig. 2. Evaluation of different parameters for selection of best treatment combination of moisture content and concave clearance

Table 2. Results of optimization mahua seed decorticator with actual and predicted data at 9% (db) moisture content and 11 mm concave clearance [Treatment: T_2 (M_1C_2)]

Response (%)	Actual	Predicted	SE Mean
Whole kernel	67.25±0.74	66.19	0.43
Broken kernel and powder	7.26±0.61	7.24	0.16
Partially decorticated seed	1.03±0.05	1.13	0.11
Un-decorticated seed	0.79±0.07	1.87	0.19
Decorticating efficiency	98.18±0.09	97.85	0.23
Overall machine efficiency	88.63±0.73	88.22	0.18

moisture content and concave clearance, the percentage of un-decorticated seed was highest. The overall machine efficiency (%) decreased with an increase in moisture content from 9% to 18% (db) and moisture content from 9 to 18% (db). The overall machine efficiency (%) did not show any particular trend with respect to concave clearance.

Two factor interactions (2FI) were used for predicating the response. The different runs of experimental data were fitted in the 2FI model and there was 0.932 desirability of response for accrual value at 9% (db) moisture content with 11 mm concave clearance (Treatment–T_2, M_1C_2) (Figure 2). The actual and predicted values for different responses were similar to each other (Table 2). Hence, the two factorial interaction model was the best suitable model for this experiment.

CONCLUSIONS

The best performance of the mahua seed decorticator was obtained at seed moisture content of 9% (db) and concave clearance of 11 mm which resulted in maximum percentage of whole kernel recovery, decorticating efficiency, overall machine efficiency) and desirability value. The installation cost of developed mahua seed decorticator was estimated to be Rs 32,000/- with a throughput capacity of 100 kg/h. The decortication cost per kg of mahua seed was Rs. 0.88 per kg compared to Rs. 7.50 per kg of mahua seeds by manual method. Hence the developed machine was economically feasible to set up a small-scale industry in rural areas.

AUTHORS CONTRIBUTION

This work was carried out collectively by all the authors. The first author F. M. Sahu designed the study, formulated the protocol, methodology, collected the data resources, formal analysis, investigation, visualization and wrote the first draft of manuscript. The third author V. K. Sharma checked design and fabrication of equipment, managed the analysis of the data, figures and the tables. The fourth author H. T. Hegde managed the visualization, literature resources and reviewed the editing. The second author S. H. Suthar supervised the complete experiment and approved the final manuscript. All authors had read and approved the final manuscript.

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