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Design and Development of a Low Cost Chironji Nut Decorticator

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ABSTRACT

The chironji nut (Buchanania lanzan) is currently shelled by hand since there isn't a suitable machine. Since chironji nuts are similar to gorgon and cashew nuts, their shelling can also be done through the methods followed in gorgon and cashew nuts. Chironji nuts are challenging to decorate because of their small size and hard-shelled grains, which cut in much more strongly to the kernels. It takes a lot of repeated impact and shear stresses on the shell to shell the nuts. In order to maximize decorticating efficiency and recovery and minimize broken kernel, a 3 horsepower electric motor-driven sheller with a capacity of 140–150 kg/h was conceived and constructed. The factors, which include feed rate, moisture content, concave clearance, and impeller speed, were tuned. The impeller, concave, cleaner/grader, and hopper are the four main parts of the sheller were mathematically designed. AutoCAD software was used to model the designed components before they were manufactured in the Indian Institute of Technology Kharagpur, India's machine shop. The machine measures 1140 mm in length, 1107 mm in width, and 2120 mm in height. The machine can process 157 kg of nuts per hour with a 69% decortication efficiency. The machine's overall weight was determined to be 168, and the estimated cost of fabrication was around 65,000 Indian rupees.

Keywords: *Chironji nut, decortication efficiency, impeller, concave, cleaner/grader, AutoCAD and hopper.*

INTRODUCTION

The Anacardiaceae family includes the commercially valuable tree species *Buchanania lanzan* (chironji). Nepal, Burma, and India all have this [1]. Commonly found in the dry forests of Jharkhand, Madhya Pradesh, Chhattisgarh, Varanasi, and Mirzapur districts of Uttar Pradesh, the plant thrives on yellow sandy-loam soil [9]. Chironji is a moderately sized, nearly evergreen tree with tomentose branches and a straight, cylindrical trunk that can grow up to 10 to 15 meters in height. The hard, dark grey or black bark is reddish on the inside and cracked into noticeable squares that are 1.25 to 1.75 cm thick. Its widely rectangular, densely coriaceous leaves have a rounded base. November is when the tiny, greenish-white flowers begin to bloom.

Chironji fruits are collected by hand in April and May after maturing for 4 to 5 months. Harvested chironji fruits must have their green skins removed before shelling since they turn black when stored. Fruits are typically soaked in plain water for an entire night and then massaged between palms or with a jute sack to remove the skin. To get clean nuts, the water with the fine skins is decanted and rinsed with fresh water. After being washed, the nuts are sun-dried and kept for subsequent processing, such as shelling.

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A stone slab is used to rub the dried nuts on a rough surface to shell them, and then the kernels are manually separated.

While the entire kernel is used as sweetmeats or in place of almond kernels, the chironji kernels, which contain roughly 52% oil [14], are used as an alternative to almond and olive oils. In India, chironji oil—also referred to as "char"—is derived from the fruits of Buchanania lanzan. It has a lot of medical uses; the kernels in particular are used as a tonic and expectorant. Skin conditions are treated with the oil that is derived from kernels. Despite their widespread use, there is very little information on the physical and engineering characteristics of chironji nuts and kernels.

Due to its high demand in international markets, the chironji nut has emerged as a significant crop for generating foreign cash. Both public and commercial organizations have shown a strong interest in growing this sector as an industry by expanding its capacity for both production and processing. Only 30 to 40% of the chironji nuts that are manually shelled are recovered as entire kernels, and the remainder are in broken forms that are sold for a significantly cheaper price, according to the information that is currently available. Chironji are shelled by hand, which is a laborious and time-consuming process. In order to increase decorticating efficiency and produce higher-quality chironji kernels, a chironji nut decorticator that saves time and minimizes drudgery must be developed.

It is crucial to research the engineering and physical characteristics of chironji nuts and kernels in order to create a better decorticator. Nevertheless, there aren't many studies on these topics. In order to create a cashew nut decorticator, several researchers have thoroughly examined the physical and

engineering characteristics of cashew nuts, such as their sphericity, bulk density, porosity, angle of repose, hardness, etc. Some researchers have also tried to investigate the chemical and nutritional makeup of chironji nuts. The dried chironji kernel's total lipid content was around 65.6%. Neutral lipids make up 90.4% of it, followed by glycolipids at 3.4% and phospholipids at 6.2%. Free fatty acids (7.8%) and triacylglycerols (82.2%) make up the majority of neutral lipids with small amount of diacylglycerols, monoacylglycerols, and sterols [1].
The shelling techniques used for gorgon and cashew nuts can also be used for chironji nuts because they are similar to these nuts. Several techniques for shelling roasted nuts were proposed by [8]. Roasted cashew nuts are tossed onto a metal plate for shelling using centrifugal force in the Sturtevant technique. Poor shelling efficiency is the outcome. A nut-shaped blade holds premium nuts in place while cutting them along a natural line in the Oltmare method. Because each nut must be positioned for cutting, shelling has a very limited capacity. Despite these advancements, shelling is still done by hand by striking the nut along its longitudinal axis with a wooden hammer. According to reports, each worker's average shelling capability was 8 kg per day, with 36% of the kernels being whole, 30% half-split, and 34% broken [3]. With a 70% shelling efficiency and an 18 kg/hr shelling capacity, the cashew nut sheller produces 50% entire kernels, 22% partially split kernels, and 28% broken kernels [2]. As a result, there is an urgent need to build a mechanical chironji nut sheller that can streamline the process, lessen laborious tasks, and enhance product quality.

MATERIALS AND METHODS

Raw Material

In Jharkhand, India, chironji nuts (*Buchanania lanzan*) were harvested from a forested area. A suitable set of sieves was used to clean and grade the purchased batch of chironji in order to get rid of small, immature nuts and extraneous objects. Low shelling efficiency may result from nut size variations [4]. Fig. 1 depicts shelled kernels and green chironji nuts. The decorticator requires a 3 HP electric power supply to function. The recently created decorticator had a dehulling capacity of 140 to 150 kg/h.

Fig. 1, Chironji nut

The different components of the sheller viz., impeller assembly, decorticator chamber, cleaner/ grade assembly and hopper were designed mathematically. The details of component designing have been given in following sub sections.

Decorticating impeller assembly: The diameter of impeller was calculated using equation.

$$D = \frac{60 \times u}{\pi \times N} \quad (1)$$

The diameter of the shaft was calculated using the equation 2 to 5.

$$T_e = \sqrt{(K_m \times M_b)^2 + (K_t \times T)^2} \quad (2)$$

$$T_e = \frac{\pi \times d_{ip}^3 \times \tau}{16} \quad (3)$$

Tangential load working on pulley = $F_{it} = \frac{2T}{d_{ip}}$ (4)

$$T = \frac{P_s \times 60000}{2 \times N} = 76.38 \text{ Nm}$$

Bending moment on strip, $M_{bm} = F_{it} \times x_i$ (5)

Cleaner assembly

The cleaning unit consists of a set of two sieves. The top sieve has 6 mm rectangular holes and is provided to separate un-hulled chironji nut from hulled and broken kernels. The second sieve 3 mm diameter holes provided to separate the whole kernels from broken kernels and foreign materials. The volume flow rate of the material coming to sieve was calculated using equation 6 to 8 [12].

$$\text{Volume flow rate} = \frac{\text{feed rate}}{\text{bulk density}} \quad (6)$$

Volume flow rate of material coming to sieve, Q_s can also be given as $Q_s = W_s \times t_s \times V_s \, m^3/\text{min}$ (7) Seedbed thickness was assumed to be equal to the size of single chironji nut i.e. ts = 7 mm Oscillating velocity of sieve shaker

$$V_s = \frac{l_s \times n_s}{60} \quad (8)$$

The length and width of the sieving unit can be calculated using equation 7 to 9. The inclination angle of the two sieves has been kept 10 degrees with horizontal. The direction of the slope for the top sieve was opposite to the other sieve. Both sieves were accommodated in a main sieve frame which could be oscillated at a frequency of 300 stroke/min through an eccentric drive having an eccentricity of 20 mm.

Hopper

The hopper of the decorticator has been made in a trapezoidal shape using 1 mm MS sheet. The length and width of the hopper top is 570 mm and 410 mm respectively. The capacity of the hopper, for chironji nut, is 20 kg. The height of the trapezoidal hopper, h can be calculated using the equations 9 and 10 [13].

$$Volume = \frac{1}{2}\left[(L_t - L_b) \times B_t \times h + (B_t - B_b) \times L_b \times h + L_b \times B_b \times h\right] \quad (9)$$

Side slope of the hopper can be found from equation 14

$$\beta = Cot^{-1} \frac{Top\ width - Bottom\ width}{Height\ of\ the\ box} \quad (10)$$

An adjustable opening of hopper, for controlling the feed rate, has also been made for controlling the feed rate of the Chironji nut.

Power transmission

The power transmission to the shelling impeller and cleaning unit was provided through V–a belt and pulley arrangement. B groove pulleys and V–V-belt of size B–78 were used to transmit the power from the motor to the impeller and cleaner assembly. The diameter of motor, impeller and cleaner pulleys was 3 inch 76.2 mm, 12 inch 304.8 mm, and 8 inch 203.2 mm respectively. The main shaft on which the impeller is mounted is subjected to torsion loading and bending moment in combination.

Testing of decorticator

The developed decorticator was tested for shelling efficiency (%), kernel recovery (%) and broken yield (%). The decorticating efficiency was calculated using equation 11.

$$D_E = (1 - \frac{w_h}{w_t}) \times 100 \quad (11)$$

Similarly, broken yield B_G in terms of broken and powder was calculated using the equation 12 [15].

$$B_G = (\frac{w_r + w_o}{w_t}) \times 100 \quad (12)$$

Experimental design

In preliminary trials, four independent variables viz., moisture content, impeller speed, concave clearance, and feed rate greatly affecting the shelling efficiency chironjinut decorticator as compared to other independent parameters. A central composite Rotatable Experimental Design (CCRD) [6,10] was carried out with four selected independent variables. The responses (dependent variable) were kept decortications efficiency, recovery of chironji nut kernel and broken yield of kernel.

RESULTS AND DISCUSSIONS

Design and Development of Chironjinut decorticator.

A 150–160 kg/h chironji nut decorticator was created. Important information regarding the fundamental decorticating operation, which is necessary to design commercial scale-shelling machines, was obtained through the development and testing of a tiny decorticating unit prototype [11]. Fig. 2 shows a schematic representation of the developed decorticator. The following sections highlight key aspects of component design, manufacture, and assembly.

Design of main components of the decorticator

The mathematical designing of decorticating impeller (for its length and diameter), impeller shafts (for its diameters), concave (area of concave, spacing, and number of rounds needed for fabrication of concave), cleaner grader assembly (for its length and width) and feeding hopper (for its top length, top width, side slope and height) were carried out.

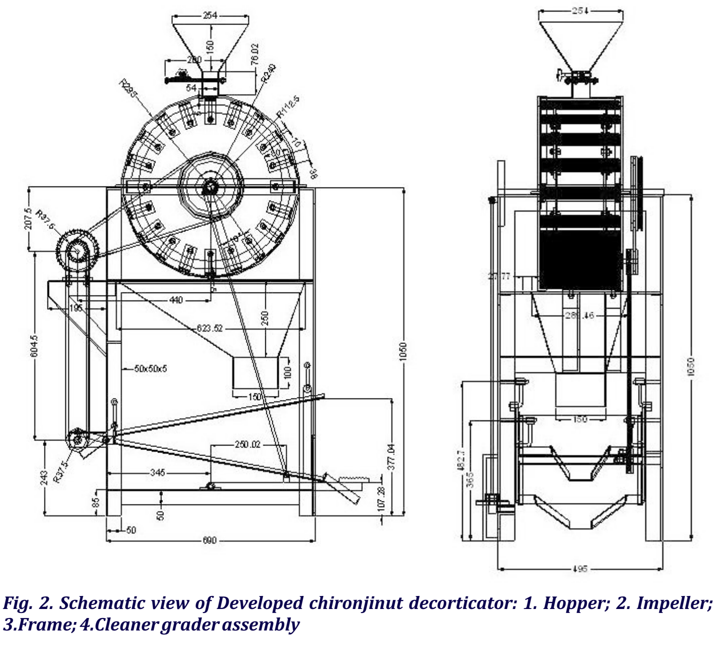

Fig. 2. Schematic view of Developed chironjinut decorticator: 1. Hopper; 2. Impeller; 3.Frame; 4.Cleaner grader assembly

Decorticating impeller

The recommended peripheral speed of the shelling cylinder (Fig. 3) for barnyard millet crops is 13 m/s. Based on the cylinder speed variation between 150 to 300 rpm, the average design speed was adopted as 200 rpm. The diameter of the shelling impeller was calculated at 590 mm using Equation 1. The length of the impeller (590 mm) was calculated assuming the aspect ratio of the impeller 1.2.

Fig. 3. Shelling Impeller

Impeller shafts

Both bending moment and torsion loading are applied to the shaft that the impeller is placed on. Therefore, equations 2 through 5 were used to determine the shaft's equivalent twisting moment in accordance with the maximum shear stress theory. It has been assumed that the impeller shaft has 80% of the power available, with the remaining 2% going to the blower and 20% going to the cleaning assembly. [16] proposed a similar supposition for the design of thresher impeller shafts. The torque transmitted by the main shaft was 76.38 Nm, and the total power available for shelling was 2.984 W. The Impeller pulley has been mounted on one impeller shaft at a distance of x_i = 55 mm from the center of the bearing. The diameter of the impeller shaft pulley was kept 80 mm. Torque (76.38 N) and bending moment (88.19 Nm) working on impeller pulley were calculated using equation 5. The diameter of the shaft (30 mm) was calculated using equations 2 and 3.

Concave

The same circular fixed concave covering 160 degrees of the cylinder circumference, formed from a square bar (10 mm), was used to create the concave length, which was maintained at the same length as the impeller (172 mm). The concave's radius of curvature is 295 mm, which is the same as the cylinder's radius. The concave measured 824 mm in length and 235 mm in width. Using equation 6, the concave surface's area (193640 mm2) was determined. The MS flats were spaced 8 mm apart. Equation 7 was utilized to determine the total number of flats utilized in the concave's construction.

Cleaning and grading sieve

The size of the whole and decorticated chironji nuts, which ranged from 1 mm to 1.7 mm, was taken into consideration when designing the cleaning and grading apparatus.

The first and second sieves were maintained at 3.1 and 1.4 mm in size, respectively. A total of 65 percent of the feeding material was intended to be handled by the sieves. The kernels entered the sieve at a rate of 160 kg per hour. The chironji nut kernel had a mass density of 516.4. Equation 6 was used to determine the volume flow rate (0.0043 m^3/min) of the material entering the sieve. It was discovered that the sieve shaker's oscillating velocity was 3 m/min. Equations 7 and 8 were used to get the sieve's breadth (340 mm). The sieve's length and width, assuming a 1:9:1 aspect ratio, are 650 and 340 mm, respectively. A 15-degree slope was applied to two sieves. because the shaker's speed is half that of the sieving unit's required speed (150 strokes per minute).

Hopper

The seed box's dimensions were intended to hold 20 kg. given that the chironji nut kernel's bulk density is 578.3. Consequently, 20 kg of grain will have a volume of 0.0376 m3. The hopper's top length and width were determined to be 570 mm and 410 mm, respectively, based on the machine's requirements. Using equation 9, the trapezoidal hopper's height (323 mm) was determined. Using equation 10, the hopper's side slope was determined. At a moisture content of 0.0893 kg/kg dry matter, the chironji nut and kernels had respective angles of repose of 30° and 35°. It was determined that the calculated side slope of 51° was appropriate for chironji nut. For easy flow of material inside the hopper the side slope should be higher than angle of repose.

Fig. 4. Chironji Nut Decorticator

Technical Specification of developed machine decorticator

- Length of the machine: 1140 mm
- Width of the machine: 1107 mm
- Height of machine: 2120 mm
- Weight of the machine: 168 kg
- Power source: 3-phase, Electric motor 3 HP
- Decortication efficiency: 69 %
- Machine capacity: 156.67 kg nut/h
- Approximate cost of the machine: Rs 65,000/-

CONCLUSION

The design, construction, and performance evaluation of a chironji nut decorticator were completed. The outcomes of the parameter optimization process demonstrate that the decorticator's performance is not much impacted by the chironji's experimental independent factors. With a 157 kg/h machine capacity, the designed decorticator has a 69% decortication efficiency.

REFERENCES

1. Hemavathy, J. and Prabhakar, J. V. (1988), Lipid Composition of chironji (*Buchanania lanzan*) Kernel, *Journal of food composition and analysis*. 1: 366-370.

2. Jain, M. L. (1982), Some aspects of improved post-harvest technology of cashew nuts. *Unpublished M. Tech. thesis*, Post-Harvest Technology Centre, Department of Agricultural and Food Engineering, Indian Institute of Technology, Kharagpur, India.

3. Jain, R. K. and Kumar, S. (1997), Development of a Cashew nut Sheller, *Journal of Food Engineering*, 32: 339-345.

4. Joshi D C (1993). Mechanical shelling and oil expression of pumpkin seed. Ph. D. thesis. Department of Agricultural and Food Engineering, Indian Institute of Technology, Kharagpur, India.

5. Kumar, A. (1989), Studies on cashew nut processing and development of related equipment, Unpublished PhD. Thesis, PHTC, AgFE, IIT, Kharagpur.

6. Lorezen J T; Anderson V L (1993). Design of Experiments. A No–name Approach, Marcel Dekker, Inc, New Yark, pp 53–123.

7. Montgomery D C (2001). Design and analysis of experiments (5th edition). New York: John Wiley., pp. 455–492.

8. Oloso, A. O. and Clarke, B. (1993). Some aspects of strength properties of cashewnuts, *Journal of Agricultural Engineering Rex,* 55: 27-43.

9. Pandey, G. P. (1985), Effects of Gaseous Hydrogen Fluoride on the leaves of *Terminalia tomentosa* and *Buchanania lanzan* Trees, *Journal of Environmental Pollution (Series A)* 37: 323- 334.

10. Rastogi N K Rajesh G and Shamala T R (1998). Optimization of enzymatic degradation of coconut residue. *Journal of Science and Food Agriculture*, 76: 129–134.

11. Sanders K F (1996). Development of the shelling principle for serradella sheller. Journal of Agricultural Engineering Research, 63: 1–8.

12. Sarma A (2007). Studies on design and performance of maize dehusker –cum-sheller. Unpublished Ph.D. Thesis, Department of Agricultural and Food Engineering, IIT, Kharagpur, India -721302.

13. Singh K P; Chandra S; Bhattacharyya R; Srivastava A K; Gupta HS (2008). Design, development and evaluation of manual-cum-bullock operated zero till seed-cum- fertilizer drill for hills. AMA, Japan, 39(3): 50-56.

14. Wealth of India (1948), A dictionary of Indian Raw materials and Industrial Products, Delhi, Vol. I, pp. 233.

15. Goyal, R. K., Vishwakarma, R. K., & Wanjari, O. D. (2008). Optimisation of the pigeon pea dehulling process. *Biosystems Engineering*, 99: 56–61.

16. Varshney, A. C. (2004). Data book for agricultural machinery design.