

Development of a Coconut De-Shelling Machine

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ABSTRACT. *The traditional method used in India, for the separation of copra and shell from partially-dried split coconuts, is labor intensive. To overcome this problem, a power-operated coconut de-shelling machine was designed and developed. The capacity of the machine is 200 nuts or 400 cups per batch. The loading and unloading is done manually. The optimum average moisture content for the maximum de-shelling efficiency (92%) was 35% (d.b.). The optimum rotating speed of the de-shelling machine was 10 rpm and the time taken for de-shelling was four minutes. The cost of the machine is US\$ 590 and the cost of de-shelling 1000 nuts is US\$ 1.15. The comparative time saved by using the de-shelling machine was four times as compared to the manual method.*

INTRODUCTION

Coconut is commercially cultivated in 93 countries especially on the small and marginal holdings over an area of 11.8 million hectares and about 10.26 million tons of copra equivalent were produced in the year 2002 (Rethinam, 2003). India contributes to 15.28% of the global area and 19.44% of global production, and is the largest single market for coconut, consuming almost its entire production of 12.6 billion nuts. Indonesia is the next largest market for coconut, consuming nearly 11.2 billion nuts accounting for about 74% of its production. As much as 50.8% of the total coconut area in India is concentrated in Kerala and the state accounts for 43.6% of the total production of the country. Kerala is a small state along the west coast of India, which accounts for only 1.18 % of the total land area of the country.

Coconut serves as the basic raw material for a series of agro-processing activities and sustains the livelihood of over 10 million people in the country. The main unit operations in copra processing are de-husking, splitting, de-shelling and drying. During the drying process as the moisture content gets reduced, the meat shrinks and is scooped out from the shell. After partial drying and when the moisture content of copra is reduced to about 25-30% (w.b.), the shell and copra are separated using a traditional wooden knife. This was done by taking individual half cups in hand and scooping out the kernel (Thampan, 1981).

Rey (1955) reported a knife-shaped shallow spoon, which moved back and forth upon the rotation of a cam, and in the process, the coconut meat was scooped in fragments. Mix (1957) designed a shelling machine for removing the shell from the fresh coconut meat,

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while Blandis and Glaser (1973) used water under pressure to separate the coconut meat from the shell.

Even in large processing units, about 15-20 labourers are used for de-shelling 20,000 to 30,000 nuts (Singh, 2004). This is a labor-intensive operation and takes several hours to separate shell and copra. However, no attempt has been made so far to develop a mechanical de-shelling machine. With this objective, an attempt has been made in the present study to develop a de-shelling machine.

MATERIALS AND METHODS

The maximum capacity of the proposed de-shelling machine was considered to be 200 split coconuts at a time. Efforts were made to design and fabricate a batch-type de-shelling machine, which included the primary components such as the de-shelling chamber, main frame, motor and reduction gear box.

De-shelling chamber

De-shelling takes place due to the impact force caused by the fall of split and partially dried coconuts one over the other. Twenty five percent free space was provided in the chamber for the impact of the nuts with each other. By assuming the length of the de-shelling chamber and that the maximum capacity of the chamber is 200 split nuts, the radius of the cylindrical chamber was determined by using the Equation 1 (Singh, 2004).

$$r = \sqrt{\frac{4M}{3 \times p_b \times \pi \times L}} \quad (1)$$

Where,

r = Radius of de-shelling chamber (m).

L = Length of the de-shelling machine (m).

M = Weight of 200 split nuts at a moisture content of 34% (d.b.), (kg).

p_b = Bulk density of split nuts at moisture content of 34% (d.b.), (kg/m^3).

Flights

Straight flights were incorporated in the design, as the coconuts have to be carried from bottom to top of the de-shelling chamber.

Motor

The following formula was used to calculate the power of the motor, which was necessary to rotate the de-shelling chamber.

$$P = \frac{2\pi NT}{4500\eta_m} \times 746 \quad (2)$$

Where,

P = Power of motor required (W).

N = Number of revolutions per minute.

T = Torque (kg-m).

η_m = Motor efficiency (%).

Reduction gear box

A reduction gear box having a speed ratio of 144:1 (Make: Cyclo, Bangalore, India) was used in conjunction with a motor and a set of pulleys to rotate the de-shelling chamber at different speeds.

Main axle

The main axle was fabricated using a 60 mm Outer Diameter (OD) mild steel shaft of 1.75 m length (L) by suitably reducing the ends to accommodate two bearings and a pulley. Provision was also made on the shaft to insert a key to secure the pulley in position tightly. The bush used was of the size of 50 mm Internal Diameter (ID) \times 90 mm (OD) \times 75 mm (L). The circular de-shelling chamber was fabricated using a seamless pipe of 283 cm L and 25 mm ID. The diameter of the de-shelling chamber was 90 cm. Two numbers of identical circular pipes were used. These two circular pipes were connected using 40 numbers of 25 mm \times 25 mm \times 6 mm 'T' angles with a gap of 25 mm in between them. The 'T' angles were welded in such a way that the projected 'T' was facing inside. A door was provided with the facility to open for easy loading and unloading. The sides of the chamber were connected to the main axle with the help of 6 numbers 100 mm \times 10 mm \times 320 mm mild steel plate. The sides of the chamber were closed using 25 mm \times 25 mm \times 10 mm gauge welded mesh.

Main supporting frame

The rectangular supporting frame on which the main axle along with the de-shelling chamber rests was fabricated using 75 mm \times 75 mm \times 8 mm size mild steel angle iron as main supporting frame which was connected with 50 mm \times 50 mm \times 6 mm mild steel angles along all the sides. The height of the supporting frame was 110 cm and width was 144 cm. The bearing housing was fixed on the supporting frame and the entire unit was fixed as shown in Figure 1 and Plate 1. The motor and reduction gearbox were mounted separately using suitable a framework. Both the frames were fixed on the ground using suitable foundation bolts and nuts to avoid vibration.

Experimental procedure

Fully-matured (12 months old and above) West Coast Tall (WCT) variety of coconut (*Cocos nucifera* L.), a local variety available abundantly in Kerala was harvested from the high density multi-species cropping system plot of the Central Plantation Crops Research Institute, Kerala, India and used for all the experiments. Hereafter, the term fruit refers to the un-husked coconuts, and coconuts or nuts refer to the de-husked and split (two halves) coconuts. The fruits were de-husked manually and split into halves using a splitting device developed at CPCRI, Kasaragod, Kerala (Singh, 2004). The average moisture content of the freshly harvested nuts was in the range of 81-94% (d.b.) and it was dried up to 25-66% (d.b.) for de-shelling. The moisture content of the sample for drying tests was determined using the copra moisture meter developed by Madhavan (1985). The accuracy of the moisture meter was compared with AOAC (1995) and the moisture readings were found to have an accuracy of $\pm 0.5\%$. The hot air electric oven (BAGSVIG) with 3 kW heaters with the maximum temperature of 150°C was used to dry the coconut. The experiment was conducted to optimize the number of rotations of the de-shelling chamber

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Method of operation

Partially-dried copra was loaded into the de-shelling chamber manually. The capacity of the de-shelling chamber was 400 partially dried cups. During the drying tests, the de-shelling machine was kept close to the oven. When the average moisture content of the copra reached 35% (d.b.) the door of the oven and de-shelling chamber were opened and copra was loaded directly from the oven. The de-shelling chamber was allowed to rotate at a speed of 10 rpm for different periods and the de-shelling efficiency was calculated.

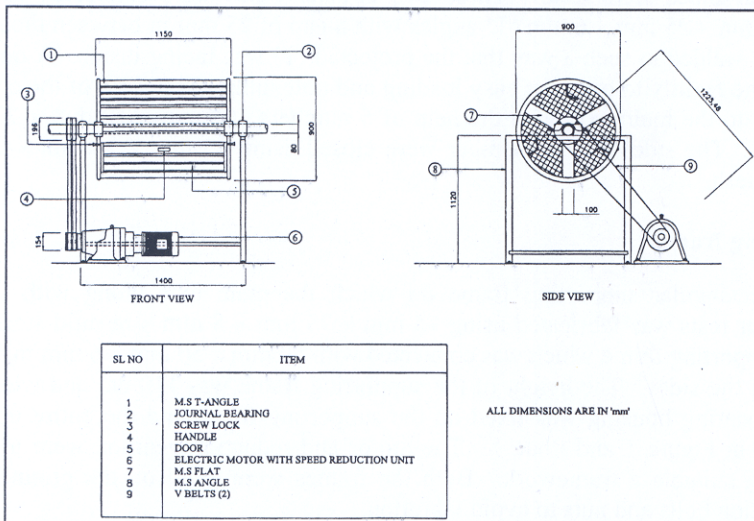


Fig. 1. Design drawing of the de-shelling machine.

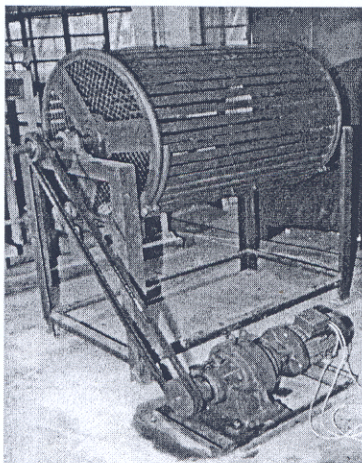


Plate 1. View of the de-shelling machine.

RESULTS AND DISCUSSION

The dimensions of the cylindrical de-shelling chamber were calculated as 90 cm diameter and 115 cm length to hold 200 split coconuts at average moisture content of 35% (d.b.) based on the bulk density and porosity already calculated and reported (Singh and Udhayakumar, 2004). Loading and unloading of partially dried copra was done manually. The design drawing of the de-shelling machine is depicted in Figure 1. Three flights having $29 \times 22 \text{ cm}^2$ cross section running throughout the length of the drying chamber were fixed inside the de-shelling chamber at a distance separated by 120° . The lip angle of the flight was fixed at 70° based on preliminary tests conducted, so that the nuts can fall freely from the flight uniformly into the de-shelling chamber. The power required to rotate the cylindrical de-shelling chamber at 10 rpm was calculated as 2,238 W. To achieve the required low speed, a reduction gear box with a set of pulleys was fixed. A 3.0 phase 2,238 W (3 hp) electric motor was coupled to rotate the de-shelling chamber at the desired rpm (Figure 1 and Plate 1).

Effect of moisture content on de-shelling efficiency

The de-shelling machine was tested for its performance evaluation with partially dried copra having moisture contents in the range from 25 to 66% (d.b.). The optimum average moisture content for de-shelling was found to be 35% (d.b.). At 35% (d.b.) moisture content, the de-shelling efficiency was 82%. Five replicated tests were conducted for each moisture content and the average values were used for calculations. The increase in de-shelling efficiency with respect to decrease in moisture content is illustrated in Figure 2. The relationship existing between moisture content M (% d.b.) and de-shelling efficiency D_e (%) is non-linear and can be represented by the following regression Equation 3.

$$D_e = 215.46 \exp^{-0.0338M} \quad (R^2 = 0.96) \quad (3)$$

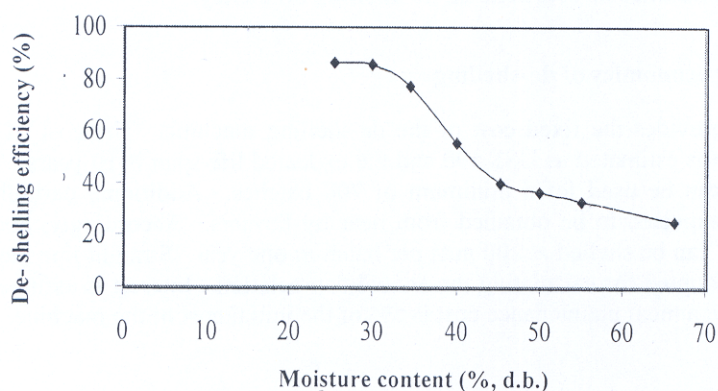


Fig. 2. Effect of moisture content on de-shelling efficiency at 10 rpm.

Effect of number of rotations on de-shelling efficiency

The effect of number of rotations on the de-shelling efficiency was calculated by keeping the moisture content constant at 35% (d.b.) when the partially dried nuts (400 cups) were loaded manually and the machine was operated. However, there was no further significant increase in the efficiency of de-shelling after 40 rotations (Fig. 3). On careful examination, it was also observed that unless the coconuts are of the same maturity, the efficiency will not increase due to the uneven moisture content in the partially dried copra. Therefore, the optimum number of rotations was fixed as 40 and the de-shelling time based on the speed of the reduction gear output was 4 min. The increase in de-shelling efficiency with respect to number of rotations is given in Figure 3. The relationship between number of rotations R (rpm) and de-shelling efficiency D_e (%) is non-linear and represented by the following regression Equation 4.

$$D_e = 45.479 \ln(R) - 78.044 \quad (R^2 = 0.94) \quad (4)$$

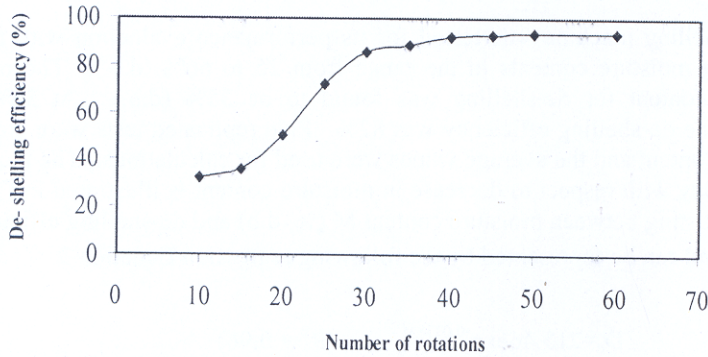


Fig. 3. Effect of number of rotations on de-shelling efficiency.

Comparative cost economics of de-shelling

Table 1 provides the fixed cost of the de-shelling machine. The cost of the de-shelling machine was estimated as US\$ 590 and the expected life span is 10 years. The de-shelling machine can be used for a minimum of 700 batches. Additional partially dried copra required is expected to be obtained from near by farmers. Accordingly, about 700 batches of coconut can be shelled at 200 nuts per batch in one year. Straight line method of depreciation was adopted for calculating the annual depreciation. Interest is assumed to be 10% per annum and annual maintenance cost is 5% of the initial cost of the machine.

Variable cost

For 35 minutes, the labor will be diverted from copra dryer or employed for de-shelling of copra. Approximate time for loading, unloading and operating the machine will be 7 minutes per batch as loading and unloading will be done adjacent to the hot air oven.

Considering the average de-shelling efficiency of labor as 439 nuts/h and wages for laborer under Kerala conditions as US\$ 2.7/8 h, labor cost to de-shell 1000 nuts will be US\$ 0.78. Considering the electrical consumption for the machine as 537.5 W/batch at US\$ 0.04/kW.h, the electricity cost to de-shell 1000 nuts will be US\$ 0.10. Comparative cost analysis between de-shelling by machine and manual method is given in Table 2.

Table 1. Fixed cost of the de-shelling machine.

Cost item	Cost (US\$)
Interest (at 10 % per annum)	59
Annual depreciation	59
Maintenance cost (at 5 % of the initial cost)	30
The total fixed cost	148
Fixed cost per batch per year (assuming that the de-shelling machine will be operated for 700 batches in a year).	0.21
Fixed cost for 5 batches (1000 nuts)	1.05

Table 2. Comparative analysis of variable cost between de-shelling by machine and manual methods.*

Cost item	De-shelling machine	Manual method
Labor for 35 minutes for five batches	US\$ 0.20	2.27 h = US\$ 0.78
Electricity for five batches at; <ul style="list-style-type: none"> • 537.5 W/batch • US\$ 0.04/kW.h** 	US\$ 0.10	Nil
Total cost for de-shelling 1000 nuts	US\$ 1.15	US\$ 0.78

Note: * Under conditions in Kerala, India; ** Subsidized rates for farmers.

Thus, the cost of de-shelling 1000 nuts using the de-shelling machine works out to be US\$ 1.15 if the labor is diverted from copra dryer. If hired separately, it works out to be US\$ 1.35 where as the cost of de-shelling using human labor will be US\$ 0.78. The comparative time saved by using the de-shelling machine was 1.8 h/1000 nuts, but still the use of manual labor is cheaper. As de-shelling is a skilled job, it is felt that the machine will be useful in the long run.

CONCLUSIONS

A power-operated coconut de-shelling machine was designed and developed. The capacity of the machine was 400 half cups per batch. The optimum average moisture content for the maximum de-shelling efficiency (92%) was 35% (d.b.). The optimum speed of the de-shelling machine was 10 rpm and the time taken for de-shelling was 4 min./batch. The time saved by using the de-shelling machine was four times as compared to the manual method.

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