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Design, Construction and Performance Study of a Castor Seed Shelling Machine

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***Abstract* - Castor seed processing in many developing regions remains largely manual, resulting in low productivity, high labour demand, and frequent seed losses. To address these challenges, a motorized shelling machine was developed and evaluated for its performance under different operating conditions. The machine was designed to effectively remove castor seed shells while maintaining seed integrity and improving throughput compared to traditional hand shelling methods. Performance tests were conducted at machine speeds of 600, 800, and 1000 rpm and seed moisture contents of 6, 9, and 12 % (wet basis). The results showed that both speed and moisture content significantly influenced the performance of the machine. The optimum operating condition was obtained at 800 rpm and 9 % moisture content, giving an average shelling efficiency of 91.7 %, seed damage of 2.4 %, and throughput capacity of 50.5 kg/h. The incorporation of a cleaning mechanism further enhances the quality of the output.**

***Keywords* - Castor seed; Winnowing; Performance evaluation; Moisture content; Throughput capacity**

I. INTRODUCTION

Castor (Ricinus communis) is a non-edible oilseed crop valued for its unique oil used in industrial, pharmaceutical, and cosmetic applications. Castor seed produces oil and cake after processing. Castor can be traced to the family of Euphorbiaceae and its oil is highly medicinal and used in several industries since it has a large international market [1]. More than thirty countries across the world grown castor among them are India, Brazil and China are the major producers with sixty-five, twenty- three, and seven percent respectively of the world total production. Analysis on castor plant recorded that 1.36 million metric tonnes out of which about 0.66 million metric tonnes is processed into oil per annum [2].
The castor seed is considered native to tropical Africa and is grown widely in arid and semi-arid regions [3]. It is abundant in the North eastern and South Eastern states of Nigeria [4]. Diverse species are planted in Nigeria, the specie with smaller size gives a higher yield and more volume of oil. The climatic and soil requirements are good for the cultivation of castor in Nigeria and it has only been planted by the local farmers and so have never been planted in commercial quantities in Nigeria [5]. The global application of castor oil presented a yearly rising development [6]. The old method of removing husk from the seeds is labour intensive and more or less fifteen percent is forfeited as a result of breakage and degeneration. Therefore, this research is aimed at design and construction of a castor shelling machine that ensures efficient separation of kernels from the shell, while minimizing damage and maximizing throughput.

II. MATERIALS AND METHODS

Description of The Component Parts

The castor seed shelling cum winnowing machine shown in figure 1 has the following component parts: frame, beaters, hopper, shelling drum, screens, electric motor, pulley, belt, fan, grains outlet and chaff outlet.

Feeding Chamber: The feeding chamber is also known as the hopper; it has a chasm which is located at its base. The sides of the hopper are slanted to allow free flow of the castor beans seed capsules into the shelling chamber.

The Shelling Chamber: It is comprised of the thresh comb. This is made up of a shaft upon which small rods (tongs) are welded to it in a line at intervals. There are two of such lines each welded to opposite sides of the shaft. Each of the tongs is carved to forming an arc of small curvature. The shaft rests on ball bearings of each end. Attached to one of the ends of the shaft is a pulley for drive. The pulley/shaft rotates in the direction of carve of the tongs.

Winnowing Chamber: The blower is located just under the hopper. It is a centrifugal fan and is comprised of four straight impellers attached to the shaft, all in an involute casing. A pulley is attached to the shaft at one of the ends.

Shaking Mechanism: This is a mechanical system that acts to separate the shelled castor seeds from the outer shell. The shaker chamber consists of two vibrating screen and its mechanism, which is mounted on a frame that is supported by ball bearings.

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Power: This is composed of a 5HP electric motor. The 5HP electric motor transmitted power to shelling unit and blower unit both are interconnected by pulleys and belts.

Belt and Pulley: The belts and pulley was selected based on the speed of the driving motor, speed reduction ratio, centre to centre distance between the shafts at the condition under which the shelling action must take place.

The Frame: The frame of the machine is constructed with mild steel angle iron.

Figure 1: The constructed castor seed shelling machine

DESIGN CALCULATIONS

Determination of machine capacity: The machine capacity was determined through shelling drum diameter while the diameter of the shelling drum was determined by using the standard formula given by [2]:

$$vd = {\pi(dc)^2}/{4} \times lc \qquad (1)$$

where vd is the volume (m^3), dc is the diameter (m), and lc is the length (m).

Blower component design: The number of blades for the blower was determined using equations (2 - 3) as obtained from [3]:

$$y_{bf} = {q_{fr}}/{x_v} \qquad (2)$$

$$q_{fr} = b_1 c_1 v_t \qquad (3)$$

where y_{bf} is the number of blades needed for the blower, q_{fr} is the air flow rate for the blower, x_v is the volume of air displaced in the blower component per blade, b_1 is the width over which air is required (m), and c_1 is the chaffs outlet dimensional parameter (m)

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Design of shelling drum weight: The weight of the shelling drum is expressed using equations (4 – 5) as obtained from [2]:

$$z_{sd} = m_1 g \quad (4)$$

$$m_{sd} = \rho b_s \quad (5)$$

where z_{sd} is the weight of shelling drum (N), m_{sd} is the mass of shelling drum (kg), ρ is the density of the drum (kg/m^3), and b_s is the volume of the cylinder (m^3)

Pulley design: The pulleys diameter will be determined using the expression given by [7] as:

$$n_{p1} d_{p1} = n_{p2} d_{p2} \quad (6)$$

where n_{p1} is the speed of driving pulley (rpm), n_{p2} is the speed of driven pulley (rpm), d_{p1} is the diameter of driving pulley (m), and d_{p2} is the diameter of driven pulley (m)

Determination of power required by the fan: The power will be calculated by the expression given by [8] as:

$$p_b = c_c \times \rho_m \times w^3 \times d_d^5 \quad (7)$$

Where p_b is the power required by the fan (kW), d_d is the blade outside diameter (m), ρ_m is the air mass density (kg/m^3), w is the blade velocity (m/sec) and c_c is the power coefficient

Shaft design: The shaft diameter was obtained using equation (8) as given by [7]:

$$d^3 = \frac{16}{\pi \sigma_s} \sqrt{(C_b M_b)^2 + (C_t M_t)^2} \quad (8)$$

where C_b is the shock and fatigue factor applied to bending moment, C_t is the shock and fatigue factor to torsional moment, M_t is the maximum torsional moment, M_b is the maximum bending moment, σ_s is the Allowable design shear stress and d is the shaft diameter (m).

PRINCIPLE OF OPERATION OF THE MACHINE

The machine is first coupled together by bolt and nut fastening. A 5hp electric motor is mounted to the machine and a belt drive arrangement transfers power to the machine. The electric motor is connected to a 240V A.C power source and the switch is put on. The castor is fed into the machine through the feeding hopper from where it comes in contact with the rotary spikes which breaks the pod and allows the kernel out after which it falls by action of gravity through the sieve. The castor kernel and shell then come in contact with the stream of air from the blower which separates the kernel from the shell by the difference in terminal velocity. The shell is blown out via the chaff outlet while the castor drops down and is collected at the seed outlet.

TESTING PROCEDURES

Performance testing of the developed spike-toothed drum shelling machine was carried out to evaluate its functional efficiency, seed quality, and operational capacity for castor seed processing. Clean and conditioned castor pods of uniform maturity were used for the experiment. The pods were categorized into three moisture levels: 6%, 9%, and 12% (wet basis**)**, obtained through controlled air-drying and re-moistening.

Before testing, the machine was inspected for alignment, lubrication, and belt tension to ensure uniform operation. For each trial, 2 kg of castor pods was introduced into the hopper and allowed to pass through the shelling chamber, where the rotating spike-toothed drum struck the pods against the concave surface. The tests were conducted at three different levels of machine speeds of 600 rpm, 800 rpm, and 1000 rpm. After each run, the discharged material was separated manually into three fractions: Shelled seeds, Partially shelled pods, and Unshelled pods. Each fraction was weighed using a digital scale (±0.01 g accuracy). The following performance indices were computed using standard expressions as given by [2]:

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Shelling Efficiency (%)

$$\eta_s = \frac{W_s}{W_t} \times 100 \qquad (1)$$

where

η_s is shelling efficiency (%),
W_s is weight of fully shelled seeds (kg),
W_t is total weight of pods fed into the machine (kg).

Seed Damage (%)

$$D = \frac{W_d}{W_s} \times 100 \qquad (2)$$

Where

D is percentage of damaged seeds (%),
W_d is weight of broken or cracked seeds (kg),
W_s is total weight of shelled seeds (kg).

Throughput Capacity (kg/h)

$$T = \frac{W_t}{t} \times 100 \qquad (3)$$

where

T is throughput capacity (kg/h),
W_t is total mass of pods processed (kg),
t is time taken for shelling operation (s).

III. RESULTS AND DISCUSSION

Results

The results obtained from the experimental tests are summarized in Table 1.

Table 1: Performance of the Castor Shelling Machine at Different Speeds and Moisture Contents

Machine Speed (rpm)	Moisture Content (%)	Shelling Efficiency (%)	Seed Damage (%)	Throughput Capacity (kg/h)
600	6	85.2	2.8	36.4
600	9	83.5	1.6	37.0
600	12	78.9	0.9	35.8
800	6	90.5	4.2	48.2
800	9	91.7	2.4	50.5
800	12	88.1	1.8	47.3
1000	6	89.4	6.2	53.8
1000	9	87.6	5.4	54.1
1000	12	82.3	4.1	52.6

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DISCUSSION

The results of the performance test showed that both machine speed and moisture content had significant effects on the shelling efficiency and quality of the castor seeds.

Effect of Machine Speed on Shelling Efficiency

Figure 2 illustrates the relationship between machine speed and shelling efficiency at different moisture contents. Efficiency improved with an increase in machine speed up to an optimum value of 800 rpm, beyond which a slight reduction occurred. The highest efficiency of 91.7 % was recorded at 9 % moisture. At 600 rpm, the energy imparted by the drum was insufficient to break all pods, leading to lower shelling rates. The slight efficiency decline at 1000 rpm was due to excessive impact that caused seed bounce and loss.

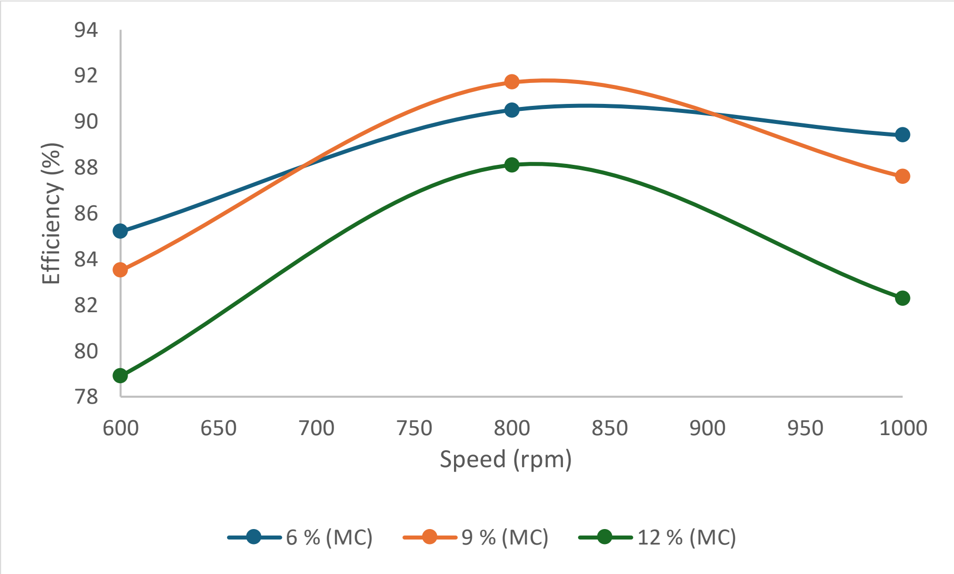

Figure 2: Shelling Efficiency vs Machine Speed at the Three Levels of Moisture Content

EFFECT OF MACHINE SPEED ON SEED DAMAGE

The influence of machine speed on seed damage is shown in Figure 3. The proportion of broken seeds increased steadily with machine speed across all moisture levels. At 600 rpm, minimal seed cracking was observed, whereas at 1000 rpm, damage exceeded 9 %, mainly due to higher collision intensity between the seeds and the drum spikes. Seeds at 9 % moisture experienced moderate damage (2.4 %), indicating a suitable moisture range for efficient shelling without severe cracking. Lower moisture (6 %) resulted in brittle seeds prone to breakage, while higher moisture (12 %) produced tough pods that resisted shelling, increasing unshelled fractions.

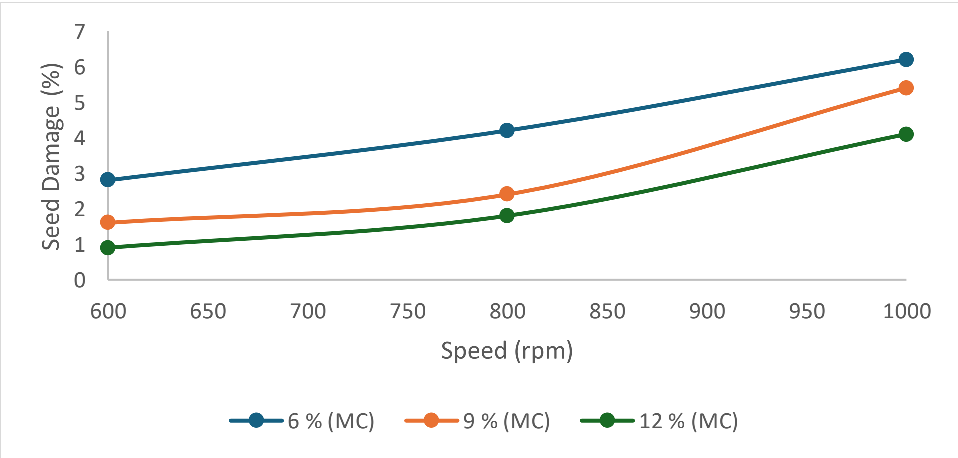

Figure 3: Seed Damage vs Machine Speed at the Three Levels of Moisture Content

EFFECT OF MACHINE SPEED ON THROUGHPUT CAPACITY

The variation of throughput capacity with drum speed is presented in Figure 4. Throughput increased steadily as the speed rose, ranging from 36.4 kg/h at 600 rpm to 54.1 kg/h at 1000 rpm. This linear trend reflects faster material flow and reduced residence time at higher rotational speeds. However, at excessive speeds, the shelling chamber experienced increased vibration and partial seed scattering, which could reduce effective capacity in prolonged operations. The combination of 800 rpm and 9 % moisture content produced both high throughput and acceptable seed quality, confirming it as the most suitable operating condition for efficient shelling.

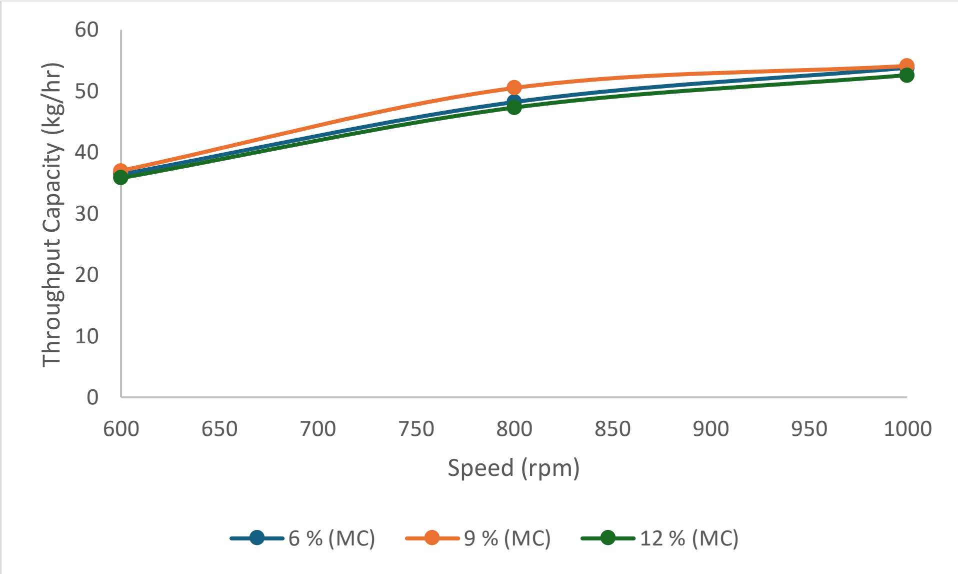

Figure 4: Throughput Capacity vs Machine Speed at the Three Levels of Moisture Content

IV. CONCLUSION AND RECOMMENDATIONS

Conclusion

The machine was developed to overcome the limitations of manual castor shelling, which is often slow, labor-intensive, and causes significant seed loss. Performance evaluation under varying machine speeds and seed moisture contents revealed that both parameters had a direct influence on shelling efficiency and throughput capacity. The study demonstrated that the castor sheller is not only simple in design and operation but also suitable for small- to medium-scale farmers. It offers an efficient, low-cost, and reliable means of shelling castor seeds without compromising seed quality. Compared to traditional hand shelling methods, the developed machine significantly reduces processing time and labor demand, thereby improving overall productivity and promoting mechanization in rural processing systems.

RECOMMENDATIONS

The developed castor seed shelling machine demonstrated good efficiency and operational stability, yet there remains room for improvement. Future research work should focus on scaling the machine to accommodate higher processing capacities while maintaining its functional efficiency. Also, experimental investigations are recommended to assess the performance of the sheller under different castor varieties, moisture conditions, and different machine parameters. Such studies will provide deeper insights into the influence of these variables and aid in the development of performance models for optimization.

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