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Development of a castor oil extraction machine

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Abstract
A variety of processes, drawbacks, and wastes associated with existing techniques of castor seed oil extraction, specifically the traditional method, lower the quantity, quality, and pace of castor oil production. This paper built an efficient and high-quality castor seed oil extraction machine and contrasted its performance with common manufacturing method. A castor oil extractor was designed, fabricated, and performance assessed using the continuous screw method and revolving screens, powered by 4 horsepower pumps. Within the designed apparatus of 10 kg capacity, a range of 0.78–2.58 kg of castor beans was heated for 8 and 15 minutes and then crushed for 10 minutes in separate sessions. The initial run produced an average of 0.072 kg of unclean and moist cake. After 15 minutes of device preheating, an average of 1.16 kg and 0.9 kg of virgin oil and baked cake came out, respectively. Preheating the machine improved its oil extraction output by 61%. Relative to the lengthy, dirty old typical, the newly created technology results in better extraction operations, less castor seed oil waste, and a faster production period. The developed machine results in more castor oil produced, fewer toxicity hazards, time savings, and environmental hygiene maintenance.

Keywords: Castor seed, Oil extractor, Pre-heat, Oil waste, High quality

1. Introduction

Castor oil is a valuable, economical, non-edible raw material in terms of price and quality. Presently, the use of vegetable oil has gained attraction for commercial production of biodiesel as a result of its high content of ricinoleic fatty acid and the possibility to esterify with only methanol (Osorio-Gonzalez *et al.*, 2020). Vegetable oils are crucial to the food, pharmaceutical, medical, and industrial sectors. More oil from natural plants is urgently needed. Among its many benefits are renewable energy, environmental friendliness, ease of production in rural areas, and the economic value of its oil for industrial and medicinal purposes. Castor seed (Ricinus communis) is a non-edible oil seed that is widely cultivated, as shown in Figure 1 (Salau *et al.*, 2021). The plant's seed, the castor bean, is primarily used for body ointments, lamps, lighting, and enhancing the growth and texture of hair. Its oil is also utilized in medicine to treat parasitic worm infections and arthritis. The oil found in the seed's ranges from 40% to 60% and is rich in triglycerides, primarily ricinolein, which is a water-soluble toxin that is absent from the plant's structure (Adeodu *et al.*,2022).

As substitutes for oil, a number of feed stocks derived from vegetable sources, including soybean, rapeseed, canola, palm, corn, japtropha, and castor seeds, have been investigated. Among these sources, castor seeds have the potential to be a very promising feedstock since castor oil stands out from other vegetable oils due to its high ricinoleic acid content (over 85%). Castor oil has the most constant viscosity of any vegetable oil, and it has the highest percentage of fatty hydroxyacids of any vegetable oil (Patel, 2016). Vegetable oils play a crucial role in the industrial economies of developing nations since seed oils are widely used in daily life. The hydraulic press, continuous screw press, expeller process, and solvent extraction are the most commonly utilized design techniques for extracting castor oil from castor seed (Navaneethan *et al.,* 2020). In order to prepare castor seeds for extraction upon harvesting, the following procedures must be followed: (a) hull can be removed mechanically with a castor bean dehuller or manually by drying the seed to allow for open splitting, (b) using a rotating screen or reels, remove any foreign objects from the seed, such as sticks, stems, leaves, sand, or dirt, (c) using a steam-jacketed press to heat the kernels to a specific temperature and dry them out to facilitate extraction, (d) allowing the cooked seeds to dry out before extraction.

About 20% of the oil may be extracted from the kernel using the conventional methods of castor oil extraction, which are incredibly laborious, time-consuming, and ineffective. There is a low proportion of oil recovery (Isa *et al.,* 2022; Pajic *et al.,* 2020). The conventional methods are the well-known and widely practiced methods of oil extraction, namely solvent extraction, hydraulic press, and continuous screw press (Busari *et al.,* 2022). Many seed oils are extracted by either a continuous screw press, a hydraulic press, or a combination of the two. The primary use of castor oils is as a basic ingredient in the production of nylon, sebacic acid, plasticizers, and engine jet lubricants. Castor oil's high lubricity reduces friction, which is superior to other vegetable oils and petroleum-based lubricants. It really clings to metal, especially hot metal, heavy-duty automotive greases, coatings and inks, surfactants, polyurethanes, soaps, polishes, synthetic resins, fibers, paints, varnishes, dyes, leather treatments, hydraulic fluids, and sealants. Regardless of the extraction method, extracted and refined oil must be evaluated for its physiochemical properties to determine its application**.** Castor oil is applicable in most areas of human life, such as fuel and biodiesel, soaps, waxes, and greases, lubricants, hydraulic and brake fluids, fertilizers, and pharmacological and medicinal usage (Mkhize, 2023; Kamalakar *et al.,* 2015).

Traditional castor seed extraction is linked to multiple safety hazards, inefficiencies, waste generation, and time dedication, as shown in Figure 2. If consumed by human beings, the poisonous material identified as ricin found in castor seeds can be extremely harmful. The amount, production, and potency of castor oil are all impacted by oil residues and losses throughout production. The main downside of the current castor seed oil extraction apparatus is its relatively low productivity and electricity-powered operation configuration. It is therefore challenging to use in agricultural and energy-poor areas. Consequently, the purpose of this research is to develop and construct a lightweight castor seed oil extractor that minimizes adverse health effects, results in minimal to no oil loss, and enhances the amount and grade of castor oil that is extracted. Some of the human health, environmental, business, and economic advantages are: cleaning the air and drinking and recreational water; increasing safety for industrial workers; reducing harm to plants and animals from toxic chemicals being released into the environment; lowering the potential of global warming, ozone depletion, and smog formation; reducing chemical disruptions of the ecosystem; increasing plant capacity; saving energy and water; and so on (EPA, 2020; Mkhize *et al.,* 2023).

Several problems are associated with the existing castor oil extraction methods, specifically the traditional techniques, quantity, quality, and time of production. This study designed and built an energy-efficient and high-quality castor seed oil extraction machine using the continuous screw method and revolving screens for enhancing quantity and virgin oil.

Figure 1: Castor seeds

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Figure 2: Traditional Castor Oil Production

2.0 Material and methods

Availability of materials, appropriateness, economic feasibility, and serviceability were among the factors considered when selecting the machine-building components. The frame, discharge chute, motor gear, shaft, nuts, and bolts are the components, with mild steel making up the majority of the materials employed. It was fixed to the machine frame and linked to the apparatus by the shaft, which revolves within the extraction chamber. Bolts and nuts are fasteners that are utilized to securely bind the machine's components to the frame. Figures 3 and 4 show simplified and exploded views of the developed extractor.

The hopper allows the shell that is fastened to the chassis to be delivered into the extraction chamber. The built metallic stainless steel has a trapezoid design 270 mm in length, 220 mm in width, and 180 mm in height with a capacity of 10.69 kg. The equipment is secured to the structure by bolts and nuts, and it conceals the rotating shaft. Power transmission from the motor to the machine is accomplished by the motor gear. Collections of 17.8 kg castor seeds were prepared and introduced through the hopper into the device at varying masses for ten times ranging 0.78 – 2.58 kg. The fat is extracted by squeezing and compressing the seeds to extract the oil where the shaft spins ahead. After turning on, the machine was left to operate for eight minutes until the castor was crushed. For a repeat, the machine was preheated for fifteen minutes before breaking to allow it to finish dehydrating the cake and producing clean castor oil. The data and machine evaluation were determined and recorded for discussion. The following step-by-step procedures were taken for effective performance and evaluation of the developed machine.

The required power for shelling a castor seed is calculated by equations 1 and 2.

$$P = M_t X \omega \tag{1}$$

$$P = \frac{2\pi N M_t}{60} \tag{2}$$

The utilized torque in de-hulling a castor seed is found by equation 3.

$$M_t = Fr \tag{3}$$

The angular speed and extraction shaft diameter for rotating the shaft per minute of operation are contained in equations 4 and 5.

$$\omega = \frac{2\pi N}{60} \tag{4}$$

$$d^3 = \frac{16}{\pi \tau_a} \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \tag{5}$$

The shaft operation is evaluated by twisting moment and torsional equation 6.

$$\frac{T}{I} = \frac{\tau}{r} \tag{6}$$

The polar moment of inertia of the shaft about the axis of rotation is found by equation 7.

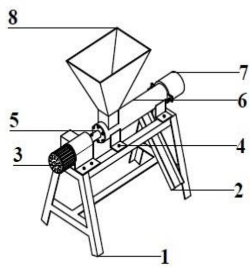
$$I = \frac{\pi}{32} d^4 \tag{7}$$

The volume of castor seeds put into the hopper is calculated by equation 8.

$$V = \frac{1}{2}\pi(R^2 H - r^2 h) \tag{8}$$

Where, K_b is combined shock and fatigue factor applied to bending moment, K_t is combined shock factor applied to torsional moment, M_b is maximum bending moment, M_t is maximum torsional moment, d is diameter of the shaft, P is power consumed by the shaft (Nm), M_t is torque on the shaft, ω is angular velocity (rad/s), T is the twisting moment, I is the polar moment of inertia of the shaft about the axis of rotation, τ is torsional shear stress and r is distance from neutral axis.

Where: R and r are outer and inner radii; H and h are outer and inner heights; and V is the volume of the hopper.



8	HOPPER	STAINLESS	270*220*180	1
7	CHAFF COVER	STAINLESS	80*80	1
6	EXTRACTION CHAMBER	STAINLESS	320*65	1
5	EXTRACTION SHAFT	STAINLESS	300*25	1
4	BOLT & NUT	HSS	29*8	16
3	MOTOR GEAR	AS BOUGHT	140*173*89	1
2	DISCHARGE CHUTT	STAINLESS	255*119	1
1	FRAME	MILD STEEL	495*289*140	1
S/N	COMPONENT	MATERIAL	DIMENSION	QUANTITY
LEGEND				

Figure 3: Designed extraction machine

Figure 4: Exploded view of extraction machine

3.0 Results and Discussions

The performance outcomes of the castor oil extractor at the first and second runs are presented in Tables 1 and 2. Realizing that the dirty and moist nature of the fat and cake generated necessitated a longer heat-up period (10 to 15 minutes) prior to the castor bean crushing process, Table 2 presents the outcomes that were achieved. Prior to adding the castor seeds, the oil was tainted with wet cake after eight minutes of extraction. However, the oil production and cake leftover purity were both enhanced by extending the machine's preheating period to 15 minutes. This means that before extracting, the equipment needs to be pre-heated. Preheating the device improved the amount of oil obtained, pursuant to the effectiveness assessment. Table 1 displays the operational outcome for the device's initial execution after development

Table 1: Results of Castor Oil and Cake I

Characteristics	Test result
Quantity of castor seed	0.78kg
Time allowed for heating	8 minutes
Time of crushing and extraction	10 minutes
Quantity of oil	0.019kg
Quality of oil produced	Impure
Quality of cake produced	Not dry

Table 2: Result of Castor Oil and Cake II

Characteristics Examined	Test result
Quantity of castor seed	0.78kg
Time allowed for heating	15 minutes
Time of crushing and extraction	10minutes
Quantity of oil	0.23kg
Quality of oil produced	Pure
Quality of cake produced	Dry

Table 3 presents the results of vegetable oil and cake produced at varying masses of castor seeds. The mass of oil extracted without and with pre-heating the device, the volume of pure and impure oil extraction, and the density of treated oil extract were shown. It is observed from the table that an average of impure castor oil of 0.072 kg yielded 4%, while a production of 1.16 kg amounted to 65%. The amount of vegetable oil produced is a function of its quantity, as there are increases as observed. Oil produced from the pre-heated machine is purer and outweighed by those without pre-heated samples.

Table 3: Amount of castor oil and Cake obtained after extraction

Trials	Mass of seed (kg)	Mass of oil extracted oil without pre-heating the machine (kg)	Mass of oil extracted after pre-heating the machine (kg)	Volume of oil extracted after pre-heating device (ml)	Density of oil extracted (kg/m^3)	Mass of cake after oil extraction (pre-heating) (kg)
1	0.78	0.019	0.23	240	0.96	0.35
2	0.98	0.031	0.43	439	0.98	0.47
3	1.18	0.043	0.64	660	0.97	0.60
4	1.38	0.054	0.86	896	0.96	0.72
5	1.58	0.066	1.06	1093	0.97	0.85
6	1.78	0.077	1.28	1306	0.98	0.96
7	1.98	0.089	1.48	1510	0.98	1.08
8	2.18	0.100	1.67	1722	0.97	1.19
9	2.38	0.113	1.88	1958	0.96	1.32
10	2.58	0.125	2.08	2144	0.97	1.43
Total	17.8	0.717	11.61	11968	9.70	8.97
Average	1.78	0.072	1.16	1197	0.97	0.90

The pure yield of castor oil obtained from seeds is a function of pre-heating the machine to a high temperature before dehulling. Unlike the traditional technique of extracting castor oil that required production processes via collection of seed pods, shelling pods, dehulling, boiling the seeds, drying of seeds to reduce moisture, grinding of seeds to form paste, mixing the paste with water, and boiling to extract oil that took almost the whole day, the developed extractor takes less than an hour to produce a virgin vegetable oil from the seeds and its cake after pre-heating by the machine.

4.0. Conclusion

A low-cost, compact castor oil extractor was designed, constructed, and successfully put to use utilizing locally sourced materials. The development addresses an affordable and robust solution that boosts both manufacturing and quality. The results produced a refined and virgin oil devoid of waste but enhanced the oil from castor seeds for economic use. The outcome of the comparative outcome test demonstrates that, in comparison to traditional methods, which were time-consuming and unsanitary, the machine upheld an elevated level of extraction of oil qualities in terms of cake excellent (50.6%) and oil quality (65%) at a higher pre-heated temperature in a short period of time (ten minutes). The apparatus is inexpensive and could be readily integrated into moderate- and large-sized businesses for the industrial manufacturing of castor oil. The appliance uses relatively little power, is secure and simple to run, and is not harmful to the ecosystem.

5.0 Recommendation

The study recommended that alternative power sources to drive the machine, such as solar energy, should be researched for application in energy-limited communities.

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