FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 8 No. 5, October, 2024, pp 374 - 378
DOI: https://doi.org/10.33003/fjs-2024-0805-2756

DESIGN OF AN AUTOMATED COCONUT DEHUSKING MACHINE WITH RADIO FREQUENCY CONTROL AND LEAD SCREW MECHANISM

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ABSTRACT

Coconut is a good source of minerals like manganese, copper, iron and selenium, all of which are important for various bodily functions including bone health and red blood cell formation. Manual dehusking of coconut is labour-intensive, hence, this work focuses on development of an efficient coconut dehusking machine adaptable to Nigerian coconuts for small-scale coconut processors using the lead screw technology that facilitates automatic operation. The machine uses electric motors to drive lead screws, which translate rotational action into linear movement. Effective husk removal is made possible by a tearing force mechanism attached to the lead screws and the machine's operations are coordinated by an Arduino with a "C" programming. Radio Frequency (RF) module was used to automate the dehusking process. Control action of the RF module activates the rotation of the upper motor while the motion of the lower motor lifts the coconut placed in the coconut holder to the dehusking knife where a tearing force would be exerted on the husk of the coconut. The average time taken to dehusk a coconut was 114 seconds. Compared to the manual method with dehusking time of 513 seconds per coconut, the designed machine has a notable reduction in dehusking time. The success recorded during testing clearly demonstrates its efficacy and would translate to improved productivity and enhanced safety for small-scale farmers and the coconut industry.

Keywords: Lead screw, Coconut, de-husk, Arduino Nano, Radio Frequency module, Electric motor

INTRODUCTION

Coconut, with a multitude of applications, has been a useful and significant perennial plant for thousands of years. Nowadays, people all over the world are realizing the numerous health advantages and practical applications of it as a daily staple diet (Ovat & Odey, 2019; Beveridge *et al*., 2022; Arumugam & Asyraf Md Hatta, 2022). In Nigeria, coconut is very important economically since it generates money and job opportunities in rural areas where it is grown and processed (Olorunfemi *et al*., 2022). The coconut is a large, oval-shaped, dry drupe with three unique layers: the endocarp, a hard inner layer that surrounds a large seed, the mesocarp, a thick and fibrous middle layer and the exocarp, a thin outside layer (Schmier *et al*., 2020). The sprouting coconut palm makes use of one of the three germination pores present in the endocarp. The endosperm tissue, which envelops a tiny, cylindrical embryo, is the portion of the seed that can be eaten. The testa or outer coat of the seed, is brown in color (Ramadurai *et al*., 2019). In general, coconut can measure up to 381 mm in length and 305 mm in width. It is surrounded by a fibrous husk that is 25–50 mm thick and has a smooth, greenish or yellowish exterior shell which can be a reliable alternative to fuelwood when converted into solid fuels called briquettes. (Danlami *et al*., 2023; Konan *et al*., 2023).

Dehusking involves the removal of the outer fibrous layer of a coconut. (Prajwal *et al*., 2021). According to Venkataramanan *et al*. 2014, Rajamani *et al*. (2020), the labour-intensive, time-consuming procedure of manually dehusking coconuts is generally done by hand using sharp equipment, which increases the risk of accidents and injuries. Manual dehusking typically takes about 513 seconds per coconut, with an average processing time of $1\frac{1}{2}$ hours per ten coconuts for small-scale processors. Available machines, costing approximately 312,000 NGN (Patil *et al*., 2015) are beyond the financial reach of many Nigerian farmers. Dehusking equipment for coconuts have been developed in response to these problems; however, because Nigerian coconuts come in diverse sizes and the developed machines are too expensive for small-scale farmers and processors, many of these machines are not suitable for Nigerian coconuts. Consequently, a low-cost, effective and user-friendly coconut dehusking system that is appropriate for small-scale coconut growers and processors is required. Few dehusking machines have been able to effectively replace the time-consuming and labour-intensive manual procedure of removing the entire coconut husk in a short amount of time, despite the fact that there are numerous devices available worldwide (Pascua *et al*., 218; Navaneethan *et al*., 2020). For a variety of reasons, including insufficient and inefficient dehusking, frequent shattering of coconut shells during the process (Kadam *et al*., 2023), labour-intensive operations, high costs, inefficiency, complicated operation, expensive maintenance requirements and unavailability in local markets, many of these technologies have proven to be ineffective. In order to overcome some of these limitations, lead screw technology and radio frequency control are used in this work. The lead screw process converts rotational motion into precise linear movement, which ensures consistent dehusking pressure, minimizing damage to the coconut shell while improving efficiency. Other advantages of the lead screw technology are; low cost, compact size and high efficiency in vertical applications. Unlike other machines that rely on manual adjustments or expensive automation systems, this design incorporates radio frequency control for seamless automation, significantly reducing the cost and operational complexity. Since many existing dehusking machines are unsuitable for small-scale farmers due to their high cost, complexity and incompatibility with the diverse sizes of Nigerian coconuts, this work focuses on design and construction of a localized coconut dehusking machine that uses leadscrew technology and is both economical and effective.

A coconut dehusking machine was invented by Anu (2012) and Azmi *et al*. (2015) for small-scale production in rural areas. Two spike-equipped rollers, chain drives, a presser, clearers, shafts, and a belting framework make up the machine. Using a pulley and belt combination, a 2 horse power electric motor operating at 1500 rpm was utilized to drive two shafts. The turn speed of the motor was decreased from 1500 rpm to 21 rpm (70:1) by means of a box of worm gears. The coconut fruits affixed to the revolving shaft had their husks removed using two metal cylinders fitted with a set of spikes. The performance test analysis shows that, despite its poor efficiency, this machine successfully dehusks the edible portions of coconuts without breaking the nuts or bending the length of the extracted fiber.

A coconut dehusking machine was built by Wadile & Kolhe (2017) and Amal *et al*, (2018). It consists of a dehusking unit fixed on a frame with an electric motor as a power source and a speed-reducing device. In order to rip the husk away from the shell, two cylindrical rollers with cutting pins on each surface spin in opposing directions and at various speeds. The cutting pin profile and the depth at which the nut is inserted into the rollers determine how well the husk separates from the shell. Since the shapes of coconuts differ greatly, the distance between the two rollers must be adjusted to achieve the appropriate depth of insertion. The main disadvantage of this method is that frequent replacement of the cutting pins, which are fastened to a chamber by latches, is necessary for efficient dehusking. Meanwhile, some of the technologies used in the development of the existing coconut dehusking machines requires the operator moving close to the machine during operation. This exposes the operator to the accident that may occur as a result of the malfunction of the machine. Radio frequency control that allows the machine user to keep a distance from the machine during operation is used in this work to enhance safety of the operator.

This work advances knowledge through the development of a cost-effective and efficient coconut dehusking machine adaptable to Nigerian coconuts for small-scale coconut farmers and processors using the lead screw technology that facilitates automatic and efficient operation.

MATERIALS AND METHODS

The coconut dehusking machine is powered by a 12V switched-mode power supply that stabilizes voltage and ensures a consistent current flow, so reducing voltage fluctuations that may damage the motor or lead to erratic performance. The main function of the 10mm industrial lead screw with buttress thread is to provide a controlled linear movement in the machine. As the lead screw rotates, the nut attached to it moves along the threads, resulting in the desired linear motion. A high-torque electric motor connected to the top of the frame exerts a large amount of pressure while the second motor attached to the base lifts the coconut holder. The system's circuit diagram is shown in Figure 1.

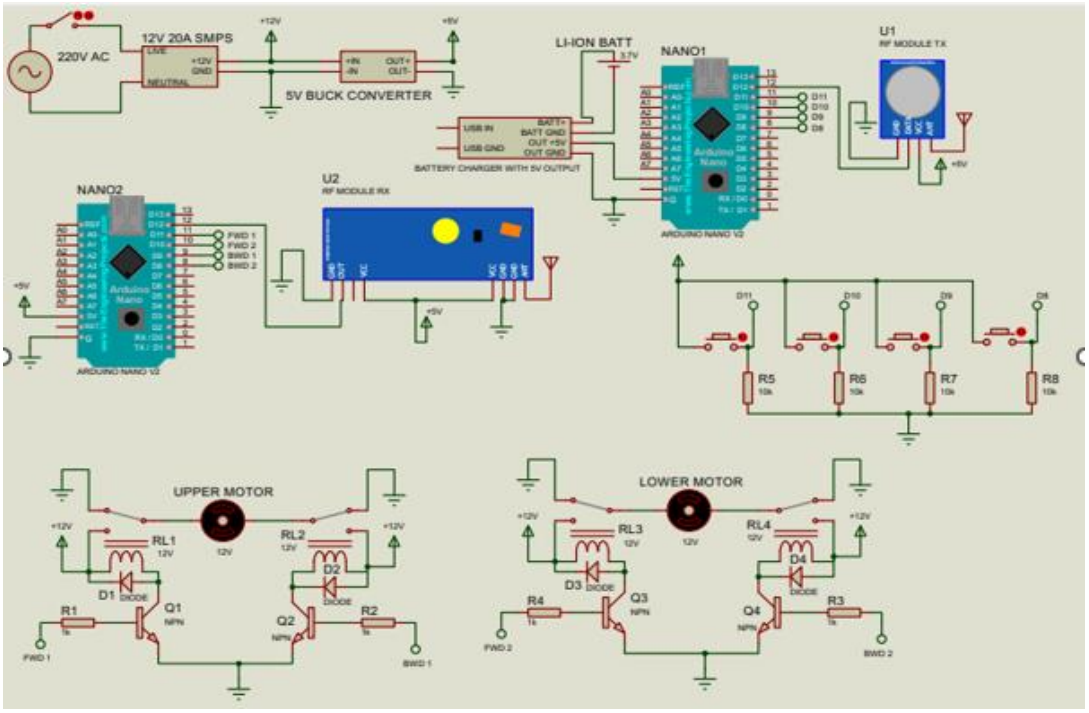

Figure 1: System circuit diagram

A Li-ion battery serves as the system's portable power source. As illustrated in the circuit diagram of Figure 1, the Arduino Nano microcontroller functions as the central control unit, enabling sensor integration, motor control, data processing, and connectivity with other devices. The design and choice of materials for the fork and the coconut holder were based on the average sizes of coconuts obtained in Ikole-Ekiti and the neighbouring villages. The sampled coconuts are ovoid in shape having an average length of 100mm-150mm, average diameter of 120mm-200mm, average weight of 0.61kg-1.33kg and average shell diameter that ranges from 75mm to 122mm. The dimension of the constructed prototype is shown in Table 1.

Table 1: Dimension of the constructed coconut dehusking machine

Component Part	Dimension
Length of frame	939.0 mm
Breadth of frame	447.0 mm
Dehusking knife length	187.0 mm
Knife sharp edge	38.0 mm
Top Lead Screw	17.5 mm

The constructed dehusking machine is shown in Figure 2.

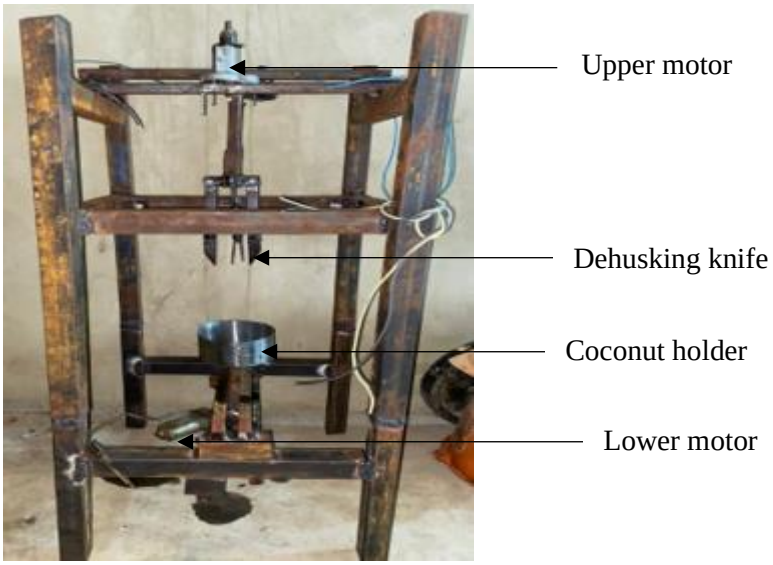

Figure 2: Constructed prototype

Two independent 12V power supplies convert 220V AC to 12V DC to power the system, one for motor 1 and another for motor 2. Motor 1 has a current and power rating of 12A and 144W, respectively. This corresponds to 0.193 horse power in mechanical power. Motor 2 has current and power ratings of 4A and 48W, respectively, which correspond to 0.064 horse power. A radio frequency (RF) transmitter and receiver were used to automate the dehusking process. Digital pins 12 and 11 on the Arduino were used for the connections of the RF transmitter and receiver, respectively. Four pushbuttons on the transmitter are linked to the Arduino Nano's digital pins 8, 9, 10, and 11. Digital pin 11 was allocated to button 1 (B1), digital pin 10 to button 2 (B2), digital pin 9 to button 3 (B3), and digital pin 8 to button 4 (B4). To bring the digital pins of the Arduino Nano low when these buttons are pressed, 10kΩ resistors were used to pull each of these pins up to 5V. Four relays were connected on the receiver side such that two relays formed an H-bridge that could operate a motor. In order to enable each motor attached to a certain H-bridge to revolve in both clockwise and counterclockwise directions, two H-bridges were designed within the receiver. Thus, "11" is sent and relay 1 is turned on when the B1 button on the transmitter is pressed, causing motor 1 to move in a clockwise manner. When B2 is pressed, relay 2 turns on and motor 1 starts to rotate counterclockwise, transmitting the number 10. The process is the same for the lower motor (motor 2); motor 2 rotates in a clockwise direction when B3 on the transmitter is pressed, transmitting "9" and turning on relay 3. Pressing B4 on the transmitter causes the number "8" to be transmitted, relay 4 to activate and motor 2 to revolve counterclockwise. The circuit connection is displayed In Figure 3.

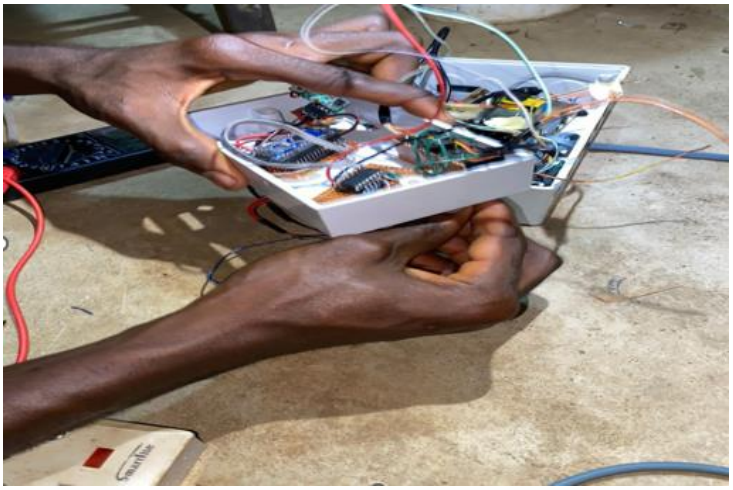

Figure 3: System automation circuit connection

The Arduino, which plays an important role in coordinating the processes of the machine was programmed using C programming language.

RESULTS AND DISCUSSION

The machine was tested using a sample of ten coconuts under the same operating conditions. The sizes of the test samples varied slightly. Nine coconuts were efficiently dehusked while the shell of the tenth broke in the process of dehusking. The smallest sample would have been broken as a result excess pressure exerted on it by the knife. The developed coconut dehusking machine completes the entire dehusking operation in a number of steps shown in the flow chart of Figure 4. As shown in Figure 4, when button B1 was pressed, "11" was transmitted and relay 1 was activated for the clockwise rotation of the upper motor. Depressing of button B4 caused "8" to be transmitted thereby energising the relay 4 for the counterclockwise rotation of the lower motor. The motion of the lower motor lifted the coconut placed in the cup or coconut holder to the dehusking knife where a tearing force was exerted on the husk of the coconut. The average time taken to dehusk a coconut was 114 seconds.

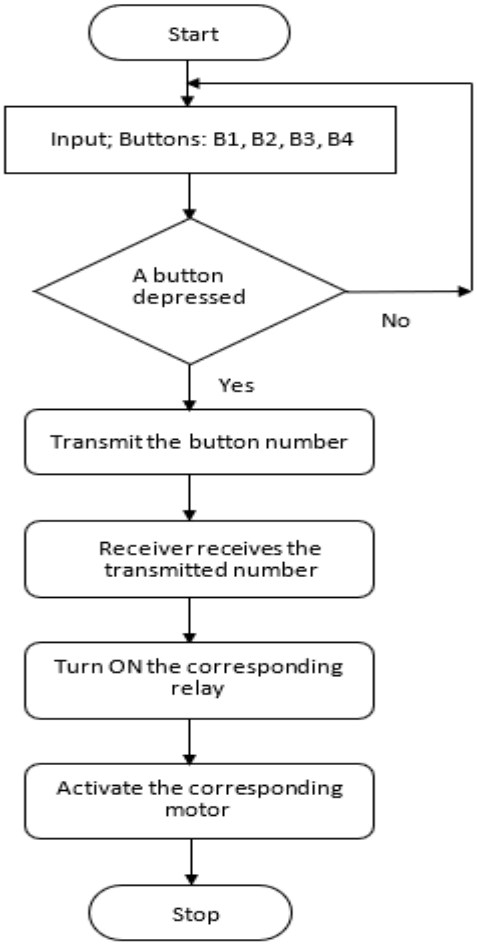

Figure 4: System operation flowchart

The machine's success during testing clearly demonstrates its efficacy. Compared to manual methods, it has a notable reduction in dehusking time, demonstrating its efficiency. The dehusking process was made quick and accurate by the lead screw and radio frequency control technique, which made it a feasible alternative for optimizing coconut processing task and boosting production in the coconut processing sectors. Safety of the operator of the developed machine is guaranteed because the radio frequency control gives room for a considerable distance between the operator and the machine. Moreover, the dehusking machine would be affordable to the local farmers due to low cost of production of 143,000 NGN per unit. A small worry was noted in those situations when the sizes or forms of the coconuts varied, resulting in cases of insufficient dehusking. Future research may look into making minor modifications to the pressure application apparatus to overcome this and guarantee consistent performance across different coconut kinds. The modifications to improve this design may be incorporation of an adjustable knife that automatically adjust to various sizes of coconut to forestall breakage and partial dehusking.

CONCLUSION

In order to solve the problem of labour-intensive characteristics of traditional dehusking and to localize coconut dehusking process, this research work was geared towards the construction of an effective and semi-automated coconut dehusking machine employing the lead screw process. Lead screws are driven by electric motors in the machine, converting rotating action into linear movement. A ripping force mechanism fastened to the lead screws allows for efficient husk removal and an Arduino with "C" programming controls the machine's functions. To automate the dehusking procedure, a radio frequency (RF) module was utilized. The Arduino's digital pins 12 and 11 were utilized to connect the RF transmitter and receiver, respectively. Four pushbuttons on the transmitter are connected to digital pins 8, 9, 10, and 11 on the Arduino Nano. Button 1 (B1) was

assigned digital pin 11, button 2 (B2) was assigned digital pin 10, button 3 (B3) was assigned digital pin 9, and button 4 (B4) was assigned digital pin 8. The lower motor raises the coconut from its position in the cup or coconut holder to the dehusking knife, where a ripping force is applied to the coconut's husk, when the control action of the RF module initiates the counterclockwise rotation of the upper motor. Dehusking a coconut took an average of 114 seconds. The machine's effectiveness was well demonstrated by its performance during testing. Its efficiency is demonstrated by the significant reduction in dehusking time when compared to manual approaches. The lead screw and radio frequency control approach made the dehusking process fast and precise, making it a viable substitute for streamlining the coconut processing work and increasing output in the coconut processing industries.

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