Design and Development of Automated Walnut Cracking Equipment using DC Motor

B.S. Lalith Krishna[1], R. Sai Ackshara[1], S. Shobana[1], P. Vimal Kumar[1], Dr. A. Allwyn Sundarraj[2]

[1]Department of Food Technology, Sri Shakthi Institute of Engineering and Technology, Coimbatore.
[2]Assistant Professor, Department of Food Technology, Sri Shakthi Institute of Engineering and Technology, Coimbatore.

ABSTRACT

Walnuts are one of the most widely consumed tree nuts in the world. Walnut is a good source of many nutrients such as proteins fat, vitamins, amino acids, carbohydrates and minerals. Walnut is a source of many by products as well such as walnut shells and green husk which are used for various purposes. Walnut shells show good antioxidant activity because of the presence of polyphenols and also have ample amount of oil. The conventional method of cracking walnuts with a hammer or stone is time-consuming, difficult, and wasteful. The "Walnut Cracker Using DC Motor" project aims to design and build an automated walnut cracking machine using a DC (Direct Current) motor as its core component. The system comprises a DC motor, a power supply, a control unit, a mechanical structure, and safety features. The mechanical structure consists of metal frame, hopper and shell removal. The DC motor is employed to exert controlled force on the walnuts, cracking their shells without damaging the edible part. The control unit manages motor speed, direction, and duration to ensure precise cracking. The Capacity and speed of this walnut cracker is 1 to 2kg and 85rpm respectively. The cracking of walnut increases with decrease in speed as the torque increases. The main advantages of this equipment include high efficiency, low energy consumption, Compact in structure, Easy maintenance, low cost and Small occupation space. This project presents an efficient and user-friendly solution to automate the walnut cracking process.

KEYWORDS: *Walnut shells, cracking walnuts, time consuming, Dc motor, precise cracking, user friendly*

INTRODUCTION

Walnuts (Juglans regia) are a type of tree nut in the walnut family. They originated in the Mediterranean and Central Asia and have been consumed by humans for thousands of years. Walnut thrives throughout the north western Himalayan area of India, reaching as far as Darjeeling and Sikkim. The extraction of the kernel from the shell is the most significant post-harvest procedure in walnut. In India, particularly in Jammu and Kashmir, this operation is still done manually, which increases the cost and processing time for kernel extraction. The market value of a walnut is determined by its quality, which includes colour, shell and kernel quality, and is heavily impacted by harvest and postharvest techniques. The price of kernels is determined on the basis of whole kernels/broken kernel.

Manual walnut cracking requires a lot of skill and patience for safe recovery of nuts from the shell which is too slow and risky. The average capacity of walnut cracking manually has been reported as 14-18 kg/day, depending upon the efficiency and the skill of the worker. Since the walnut cracking is the most critical operation for getting high quality kernels, so efficient methods and devices used to crack walnut shell are urgent to be designed and developed based on the physical characteristics and mechanical properties of walnut. In India, cracking walnut manually using hammer is still prevalent even at walnut processing industries. Keeping in view, the aforementioned facts the present study on development of automated walnut cracking machine was undertaken with an aim to increase the cracking of walnuts and to reduce time, manpower and other constraints attributed with existing practice of walnut cracking.

LITERATURE REVIEW

Persian walnut (Juglans regia L.) is a type of edible tree nut in the Juglandaceae family. It is widely farmed in the United States, Asia, and Europe as a major temperate nut crop. According to USDA 2017, China is the leading walnut producing country in the world and India ranks seventh in the world walnut production. The Agricultural and Processed Food Products Export Development Authority (APEDA) has designated Jammu & Kashmir as India's largest walnut export zone (Hussain et al., 2018a). In 2011, the global production of whole walnuts (with shell) was approximately 3415000 metric tons. China, Iran, the United States, and Turkey were the largest producers, accounting for almost 48.4, 14.2, 12.2, and 5.4 percent of total generation, respectively, in 2011(Rabhi, n.d.). In India, walnut harvesting and cracking are still done by hand. Because of the hard shell and intricate form of the inside nutmeat, breaking the walnut shell is a challenging task. The price of walnut nearly doubles after shelling. So, if harvesters start extracting the nutmeat from the walnuts themselves using technology, they can increase their revenues. Traditionally, shattering the shell is done by hand using stones or hammers (Opobiyi et al., n.d.). walnut cracking and harvesting is carried out manually which increases the cost and processing time for kernel extraction (Ghafari et al., 2011). Since the cracking process is the most crucial and delicate phase in producing high-quality kernels, mechanical qualities of walnut cultivars must be considered while designing and developing a cracking machine (Guzel at. al., 1999).

Many researches stated that the kernel extraction efficiency depends on the shell moisture, nut size, shell thickness and loading position of nuts. Similarly, Braga et al., (1999) and Ayd2n (2002) discovered that the maximum force required to crack nuts occurred when nuts were placed at right angles to the longitudinal axis, whereas the minimum force required to crack nuts occurred when the force was applied along the physical longitudinal axis. In recent years, a number of nut cracking machines with various designs and features such as cracking and nut from kernel separation have been produced; these various designs can be examined as a reference to construct our own nut breaking solution (Ghafari et al., 2011).

The cracker, which is made up of a hopper with a flow rate control device, a cracking unit, a sorter, and a power system, works on the attrition principle by employing crushing force from a cylinder and helix. The efficiency and productivity of this walnut cracker is the Rolek nutcracker cracks palm nuts to produce a cracked mixture consisting of more than 35 wt % whole kernel, less than 12 wt % broken kernel, less than 1 wt % uncracked nuts and less than 2 wt % half-cracked nut (Dasso, n.d.).

The walnuts are placed inside the clamp of a hand-operated walnut cracker. The force required for cracking walnuts is provided by pressing the handle. The spring's excessive force absorbs aids to reduce kernel damage during walnut cracking. the walnut cracker has a cracking efficiency of 87% and a full kernel recovery of 87% when tested with palm kernel, the toughest nut in its class, the machine works satisfactorily. The machine can be modified to meet the nut-cracking needs of a variety of nuts; its potential throughput capacity is 73.7 kg/min. Similar to 1.76 kW and 94.2 kg/min, the power needed to break palm kernel nuts is 1.82 kW, with a theoretical throughput capacity of 73.7 kg/min (Ghafari et al., 2011).

The walnut cracker works based on the working principle of cracking unit is based on the compression of the walnut between two rollers rotating in opposite direction. Sphericity coefficient for soft shelled, medium shelled and hardshelled walnut were 0.850, 0.845 and 0.857, respectively. The machine has the cracking efficiency which was found highest (82.1 %) at 43 rpm and 15-20% shell moisture content, while it was lowest (70.9 %) at 63 rpm and 8-12% (d.b) shell moisture content. The kernel damage increased linearly with the rotational speed of roller and found highest (21.8 %) at 69 rpm and 8-12 % (d.b) shell moisture content, while it was lowest (11.7 %) at 25 rpm and 15-20 % (d.b) shell moisture content. At standardized speed of operation (43 rpm) and shell moisture content (15-20%), the throughput capacity of the machine was recorded as 56.1kg/h with cracking efficiency of 82.1% and kernel damage of 13.8%. While throughput capacity observed with traditional method was 2.5 kg/h with cracking efficiency of 85.9%, and kernel damage of 8-9 % (Dixit et al., 2022).

OBJECTIVES

The main aim of this project is to develop an automated walnut cracking machine that will be able to reliably accomplish cracking of walnuts using DC motor and achieve high cracking efficiency comparing to the manual cracking method. To accomplish low energy consumption, easy maintenance and to develop an equipment that occupies less space and utilizes less time for cracking.

MATERIALS AND METHODS

DESIGN AND CONSIDERATION

A conceptual design of the machine was created using the Solid works software while taking into consideration the functional requirements and design concerns of the prototype. During the development of the automated walnut cracker high efficiency, low energy consumption, easy maintenance, compact in structure, small occupation space and minimal kernel damage were considered.

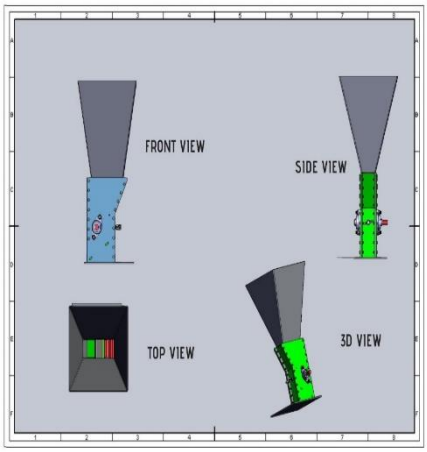

Figure 1. 3D Model of Equipment

COMPONENTS OF MACHINE

The developed system consists of a DC motor, a power supply, a control unit, a mechanical construction, and safety measures. The DC motor is used to provide regulated force to the walnuts, breaking their shells without damaging the edible part. To achieve exact cracking, the control unit regulates motor speed, direction, and duration. The environmental elements of product are Operator, Break the walnuts, the size of the walnuts, Electric energy, Cost and Control.

METAL FRAME:

The metal frame forms the main structure of the cracker. It provides the necessary strength and support for cracking the walnut shells. The Frame is projected to give strength to prevent toppling or excessive vibration of the prototype while supporting the weight of the several systems.

HOPPER:

A trapezoidal-shaped hopper is mounted on the stand and held in place by a hopper support structure. The nut feed flow channel, which is inclined from the hopper base to the top of the cracking unit at the nut's angle of repose, connects it to the cracking unit. It holds the nuts in place and feeds them into the cracking mechanism. The hopper of length 225mm, top width 310mm, bottom width 150 mm and height 250mm was fabricated for holding the walnuts during the operation of the machine. The volume of the hopper is to hold 1 to 2kg of walnut. To manage the feed rate, a nut flow rate control mechanism is installed between the hopper and the cracking unit.

CRACKING MECHANISM:

The cracking mechanism uses a stainless steel roller blade that is attached to a DC motor and rotates at a speed of 85 rpm to break the walnut shells by rotational force without harming the walnut's edible portion.

DC MOTOR:

The DC motor provides the power necessary to drive the cracking mechanism. It can be a simple, low-speed (85rpm) DC motor suitable for this walnut cracker. The principle of motor is “An electric motor is a machine which converts electrical energy to mechanical energy”. The specifications of the DC motor used are 12 Volts DC is the operating voltage for the motor and is standard for most automotive electrical systems. The rotational speed of the motor is 85 Rpm when it's in operation. It determines how fast the window can be raised or lowered. The Current Rating is 3 Ampere-hours (3Ah) which specifies the capacity of the motor's power source, typically a battery. It indicates how long the motor can operate at its rated current before the battery is depleted Some motors may have noise ratings, measured in decibels (dB), to indicate how quiet they are during operation. The motor is mounted within the window mechanism, including details about the mounting holes or brackets. The motor is compatible with, such as manual switches, electronic control modules, or central locking systems. Motors might have built-in protection mechanisms, such as overcurrent protection, thermal protection, or anti-pinch features for safety. Any safety certifications or standards that the motor complies with, such as CE, UL, or RoHS, ensuring it meets safety and environmental requirements.

BALL BEARING:

A 15mm x 35mm x 11mm ball bearing is typically described by its inner diameter (15mm), outer diameter (35mm), and width (11mm). The material used for the bearing components, such as the balls and races. Common materials include chrome steel, stainless steel, or ceramic. The bearing has seals or shields for protection against contaminants. Common designations include RS (rubber seal), ZZ (metal shield), or 2RS (both sides sealed). The Precision Rating measures the bearing's accuracy and smoothness of operation. Common precision ratings include ABEC (Annular Bearing Engineers' Committee) ratings, with ABEC 1 being the lowest and ABEC 9 being the highest precision.

SPUR GEAR:

The torque ratio can be calculated by considering the force exerted by one gear's tooth on another gear's tooth. Consider two teeth in contact at a location on the line connecting the two gears' shaft axes. The force will have a radial as well as a circular component. The most typical scenario is a gear meshing with another gear, however a gear can mesh with any device that has appropriate teeth, such as linear moving racks.

SMPS:

A 12V 10Ah SMPS (Switched-Mode Power Supply) specification would describe the characteristics and parameters of a power supply unit that provides 12 volts of output voltage and is capable of delivering a maximum current of 10 amperes.

ADJUSTMENTS CONTROL:

Adjustment controls in a walnut cracker are used for customizing the cracking process to suit the size, variety, and condition of the walnuts being processed. These controls enable the operator to fine-tune various aspects of the machine's operation. It can adjust the feed rate to control how quickly walnuts are moved into the cracking mechanism. This adjustment ensures a consistent supply of walnuts for cracking.

CONVEYOR CHUTE:

Conveyor chute in a walnut cracker is used to separate the cracked walnut shells from the edible nut. After the walnuts have been cracked by the machine's cracking mechanism, the walnut kernels and its shells will discharge through the conveyor chute.

WORKING MECHANISM:

Walnuts are typically fed to the machine by a feeding mechanism (hopper), which enters the cracking mechanism, which is powered by a DC motor and a carbon steel roller that rotates at an 85rpm speed. The DC motor is activated by the user via a switch attached to the switch mode power supply. When the DC motor is turned on, the roller begins to rotate. The roller presses down on the walnut shell. The roller revolves and applies regulated pressure to the walnut shell. The grooved or textured surface of the roller aids in gripping and cracking open the shell. The walnut shell breaks without damaging the edible portion of the walnut. The user can monitor the cracking process and stop the DC motor when they believe the shell has cracked sufficiently to access the nut inside.

RESULT AND DISCUSSION

The kernel damage increased linearly with the speed of roller. The kernel damage was found highest at higher rpm values and while it was lowest at lower rpm values Increasing speed of the cracking roller results in an increase in kernel damage. Higher the speed, the higher the kernel breakage ratio due to increase in impact velocity which also increases the impact energy. The breakage of kernel is a result of absorption of excess energy generated by the system.

Table 1. Comparison between Mechanical and Manual Walnut Cracking

CHARACTERIZATION	MANUAL CRACKING	WALNUT CRACKER
Throughput capacity	Less	More
Cracking efficiency	Less	More
Kernel damage	Less	More
Time taken for cracking	More	Less
Labor requirement	More	Less

STANDARDIZATION OF SPEED OF OPERATION:

The speed of operation was standardized keeping in view of higher cracking efficiency, low kernel damage and higher throughput capacity. The cracking efficiency was highest at lower rpm of rollers and while the throughput capacity was highest at higher rpm of rollers. The kernel damage was lowest at lower speed. Hence, taking into consideration, the maximum cracking efficiency, minimal kernel damage and higher throughput capacity, the speed of operation was recommended as 85 rpm as standardized operating parameters for the efficient operation of developed walnut cracker.

Figure 2. Walnut Cracker Equipment

COST ESTIMATION

Table 2. Cost of the Components for the Cracking Machine

S.No	COMPONENT NAME	TYPE	COST
1	Power window motor	-	950
2	SMPS (AC to DC convertor)	12v-10AH	1350
3	Power supply	-	70
4	Spur gear	-	250
5	Ball bearing	02*100	200
6	Ball bearing cup	02*70	140
7	High tension cutting blade	-	400
8	Steel Rod	15mm	120
9	MS pipe with sheet	-	1200
10	Welding and Machine work	-	2000
		Total	6680

CONCLUSION

During this project we have started by studying existing nut cracking solutions and comparing them, in that phase we managed to find many cracking types and different ways to separate nuts from kernel, from among these solutions we had the idea of a simpler design based on rotating rollers. After the choice of solution, we developed an automated walnut cracking machine and evaluated with different levels of roller speed. Roller speed had significant effect on throughput capacity, cracking efficiency and kernel damage. With increasing roller speed, the throughput capacity of the machine increased but kernel damage also increased whereas the cracking efficiency decreased. The cost of the machine was worked out to be Rs. 6,680. In addition, the voltage of DC motor is 12 volts, rotational speed of motor when it is in operation is 85 RPM, the current rating is 3Ah, and the dimensions of ball bearings are 15mm inner diameter,35mm outer diameter and 11mm width. By use of this machine, the farmers will be relieved with arduous job of walnut cracking and accomplishes better cracking of walnuts.

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