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Design and Technical Evaluation of the PTR-TETA20 Macadamia Nut (*macadamia integrifolia*) Sheller

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Abstract: Macadamia (*Macadamia integrifolia*) is a high-value crop not widely known in Indonesia and still processed using conventional shelling methods that are time-consuming and inefficient. This study aimed to design and evaluate the PTR-TETA20 macadamia nut sheller to improve post-harvest efficiency. The research was conducted from May to July 2024 at the Faculty of Agriculture, Sam Ratulangi University. The methodology involved the design, construction, and performance testing of the machine using experimental methods and descriptive data analysis. The PTR-TETA20, measuring 30 × 23 × 113 cm and powered by a 1/4 HP motor with a pulley and V-belt system at 1467 RPM, was tested using 1 kg of macadamia nuts in three repetitions. The average working capacity reached 38.43 kg/hour, with a yield of 92.52%. Nut integrity was recorded as 40.22% whole, 36.10% halved, and 23.66% broken. Moisture content was 2.6% (whole), 2.56% (halved), 2.83% (broken), and 9.52% (shells). The results indicate that PTR-TETA20 offers a practical shelling solution for small-scale producers. However, machine performance can be improved by optimizing roller spacing and ensuring uniform nut drying.

Keywords: Agricultural machinery; Drying methods; Efficiency analysis; Material handling; Mechanical design; Nut processing; Post-harvest technology.

Introduction

Macadamia (*Macadamia integrifolia*) is a perennial plant that is not widely known in Indonesia, even though it has long been cultivated in places like the Cibodas Botanical Garden and the Tlekung Experimental Garden since the Dutch era. Indonesia's climate is quite suitable for macadamia cultivation (Susilowati et al., 2019). For optimal growth, macadamia plants require soil with a light to medium texture, a pH of 5.0 to 5.5, and a soil depth of more than 100 cm. These plants can thrive at altitudes of up to 800 meters above sea level, with ideal growth observed at altitudes between 365 and 457 meters above sea level (Norton, 2017).

Macadamia plants produce seeds with a high fat content (70%) and have been cultivated in Indonesia (Sarwono, 1992; Phatanayindee et al., 2012). Macadamia products serve as raw materials for the food industry and can be processed into various forms, including candy, pastries, ice cream mixtures, or as a coffee-like beverage (Nagao et al., 1992). They are also processed into vegetable oil, which is used as high-quality cooking oil, and chocolate bars (Macadamia bars), which have been marketed in several major cities in Indonesia (Hanum et al., 2019).

In 2019, a macadamia variety from Australia, *Macadamia integrifolia*, gained popularity in Indonesia due to its use in forest and land rehabilitation efforts led by the Ministry of Environment and Forestry. This tree is highly valuable because it produces some of the most expensive nuts in the world, making it a potentially profitable source of income (Ministry of Environment and Forestry, 2019).

Macadamia propagation can be done either generatively through seeds or vegetatively. Generative propagation takes a relatively long time before the plants start producing nuts. The seeds are encased in a

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hard shell (pericarp), about 3 mm thick and brown in color, with the edible white kernel inside (Sarwono, 1992).

PT. Kusuma Satria Dinasasri Wisatajaya is a company operating in the agrotourism sector. They cultivate a variety of seasonal and perennial plants, including tomatoes, apples, strawberries, oranges, and macadamia nuts. Macadamia nuts in the market sell for IDR 400,000 to IDR 500,000 per kilogram.

Post-harvest handling of macadamia nuts, especially breaking the shells, is still done using conventional methods, which require more time and labor, thereby increasing production costs and leading to inefficiencies in the process (Hardner et al., 2012). Based on these challenges, there is a need to design a mechanical tool for efficiently breaking macadamia nut shells.

Materials and Methods

The study was conducted from May to July 2024 at the Agricultural and Biosystems Engineering Workshop, Faculty of Agriculture, Sam Ratulangi University, Manado, Indonesia. The experimental design focused on the development and testing of a macadamia nut shell-breaking machine using the PTR-TETA20 model.

Materials

The materials used in this research included 6 kilograms of macadamia nuts (*Macadamia integrifolia*), a tachometer, and a ¼ HP drive motor. Additional mechanical components comprised 4-inch cutting bits (105 mm) with a thickness of 1.2 mm and a hole diameter of 16 mm, 2.6 mm × 350 mm welding wire, and a dimer (speed controller). Structural components consisted of 4 × 4 angle iron (Type A), pillow block bearings with a 25 mm hole diameter, pulleys (7.5 cm in diameter, with hole diameters of 25 mm and 14 mm), and axle iron measuring 25 mm in diameter and 50 cm in length.

Fastening materials included 10 mm bolts (3 cm long) and ½ inch bolts (1 cm long). The frame and panel structure utilized a 15 mm thick iron plate (15 × 35 cm) and a 2 mm iron plate (60 × 100 cm), supported by a V-belt A65. Additional materials included triplex, transparent plastic, truck inner tube, acrylic glass (20 × 20 cm), hinges, iron paint, and drill bolts. The core equipment in this study was the PTR-TETA20 shell-breaking machine, developed and tested as the primary focus of the research. This study used a design method for developing the macadamia nut shell-breaking tool through trial and error. Data were collected in tabular form and analyzed descriptively to evaluate the machine's efficiency and performance.

Procedure

The work procedures in this research are as follows:

1. Preparation of tools and materials: All necessary tools and materials were prepared to design the macadamia nut shell-breaking tool.
2. Machine testing: The machine was tested with three repetitions. Each test focused on the functionality of the pressing wall and the roller mechanism to ensure proper shell-breaking performance.
3. Testing involved 1 kg of macadamia nuts per repetition to evaluate the shell-breaking efficiency.
4. Every repetition needed 1 kilogram macadamia nuts
5. Evaluation: The results of each repetition were recorded and analyzed to identify the factors that affect the performance, with the goal of reducing damage and ensuring the machine operates efficiently and safely.

Observed Parameters

1. *Working Capacity of the Tool*

The working capacity of the tool can be calculated using the following equation 1.

$$K = \frac{Bb}{t} \times 60 \quad (1)$$

K = Working capacity of the tool (kg/hour)
Bb = Material weight (kg)
t = Time required (minutes)

2. *Engine Speed (RPM)*

The rotational speed of the engine (in RPM) is measured on the driving engine pulley and on the breaking tool pulley using a tachometer. The relationship between the diameters of the pulleys and their respective rotational speeds can be expressed as:

$$\frac{D1}{D2} = \frac{N1}{N2} \quad (2)$$

$D1$ = Diameter of the driving machine pulley
$D2$ = Diameter of the breaking tool pulley
$N1$ = Engine rotational speed (RPM) of the driving engine
$N2$ = Engine rotation speed (RPM) of the breaking tool

3. *Yield of Cracked Macadamia Nuts*

The yield of cracked macadamia nuts is calculated using the following equation:

$$Yield = \frac{A}{B} \times 100\% \quad (3)$$

A = Weight of the resulting material after being broken down (kg)
B = Initial weight of material (kg)

4. *Percentage of Whole and Crushed Nuts*

The percentage of whole macadamia nuts (KU) can be calculated using equation 4, while the percentage of crushed nuts (KH) is calculated using equation 5.

a. Whole nuts

$$KU\ (\%) = \frac{BKU}{BS} \times 100\% \quad (4)$$

b. Crushed nuts

$$KH(\%) = \frac{BKH}{BS} \times 100\% \quad (5)$$

KU = Percentage of whole nuts (%)
KH = Percentage of crushed nuts (%)
BKU = Weight of whole nuts (grams)
BKH = Weight of crushed nuts (grams)
BS = Sample weight (grams)

c. Water content

To measure water content using equation 6.

$$Water\ content\ (\%) = \frac{(A + B) - C}{B} \times 100\% \quad (6)$$

A = Initial weight of the empty cup (grams)
B = Initial weight of sample (grams)
C = Final weight (grams)

Procedure Study

The research procedure that will be carried out is as in the diagram below (Figure 1).

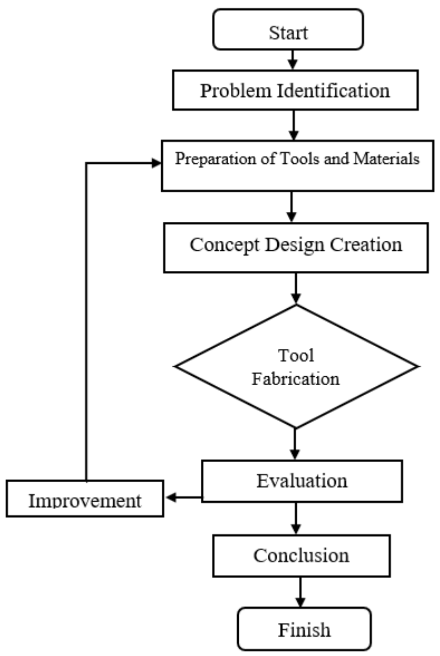

Figure 1. Research Flow Diagram.

Working Principle

The working principle of the PTR-TETA20 macadamia nut shell breaker is based on the utilization of a driving motor (dynamo) as the power source. The power generated by the motor is transmitted through a pulley connected to it. This pulley is linked by a V-belt to the pulley of the breaker roller drive mechanism. Macadamia nuts are inserted through a funnel and enter the space between the pressing wall and the breaking roller, which has a predetermined width. As the nuts pass through this gap, they are effectively cracked open. The broken nuts then fall into a dispensing funnel for collection.

Result and Discussion

Previous Studies and the Design Results of the PTR-TETA20 Macadamia Nut Shelling Tool.

Compared to previous studies, this research titled "Design and technical evaluation of the PTR-TETA20 macadamia nut (Macadamia integrifolia) sheller" offers a clear novelty in both focus and application. While previous studies such as Khan et al. (2023) and Nchoe et al. (2023) concentrated on the utilization of macadamia nutshell waste for material and environmental purposes, this study is centered on the design and performance evaluation of a mechanical shelling device to improve post-harvest processing. Khan et al. (2023) conducted a literature review exploring the potential of macadamia nutshells as raw material for bio-synthetic polymer composites, emphasizing applications in materials engineering. Similarly, Nchoe et al. (2023) investigated the chemical modification of macadamia nutshells for enhancing the adsorption of methylene blue dye from wastewater, with a focus on environmental remediation. In contrast, the current study addresses a practical agricultural problem—namely, the inefficiency and labor-intensiveness of conventional macadamia shelling methods in Indonesia—by introducing and testing the PTR-TETA20 machine. The research provides empirical data on working capacity, yield, nut integrity, and moisture content, contributing a technical solution for small-scale farmers and agro-industry actors. This engineering-based approach to post-harvest technology, particularly for a high-value but underutilized crop, constitutes the main novelty and differentiates this work from previous literature.

The design of the PTR-TETA20 macadamia nut shell breaker features simple dimensions, measuring 30 cm in length, 23 cm in width, and 113 cm in height. This tool is specifically designed to facilitate the cracking of macadamia nut shells, which are typically broken manually. By utilizing the PTR-TETA20, this process becomes easier and faster, significantly enhancing macadamia nut production. The tool is designed for operation by a single person, requiring no special skills, as it is equipped with a user-friendly mechanism.

The PTR-TETA20 tool is constructed with iron-based components that serve as a sturdy foundational structure, capable of withstanding loads and pressure while ensuring stability during operation. It is also equipped with an electric motor as the main driver, providing 1/4 HP of power, along with a speed controller to regulate torque according to operational needs. The transmission system consists of pulleys and V-belts, each designed to effectively transmit power from the motor to the breaking mechanism. This transmission system is engineered to ensure efficient power transfer from the driving motor (dynamo) to the shell-breaking tool. The design of the PTR-TETA20 tool is illustrated in Figure 3 and Figure 4.

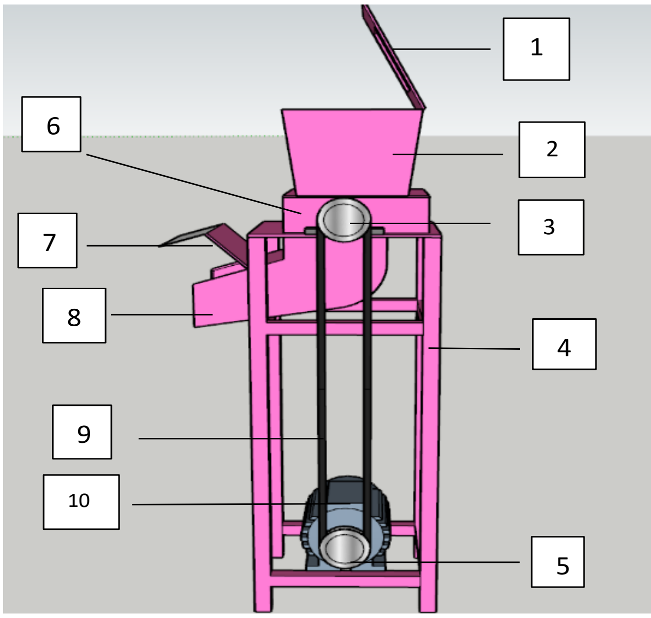

Figure 3. Side View of the PTR-TETA20 Tool
1= Inlet funnel cover; 2= Entrance funnel; 3= Tool pulley; 4= Tool holder; 5= Drive motor pulley; 6= The position of the breaking point; 7= Exit funnel cover; 8= Outlet Funnel; 9= *V-belt*; 10= Drive motor

Figure 4. Isometric View of the PTR-TETA20
11= Pillow blocks
12= Pillow block table
13= Speed Controller

Specifications
1. Tool length: 30 cm
2. Tool width: 23 cm
3. Tool height: 113 cm
4. Pulley diameter for shaft: 25 mm, Upper pulley diameter: 7.5 cm
5. Diameter of the pulley for the shaft of the driving motor: 14 mm, Bottom pulley diameter: 7.5 cm
6. Height of the inlet funnel (top): 20 cm
7. Size of the top of the inlet funnel:
   - Length of inlet funnel: 27.5 cm
   - Width of inlet funnel: 23.5 cm
8. Size of the bottom inlet funnel:
   - Inlet funnel length: 22.5 cm
   - Width of inlet funnel: 18.5 cm
9. Length of exit funnel: 23 cm
10. Exit funnel width: 16 cm
11. Shaft length: 40cm
12. Shaft Diameter: 25mm

Design Structural Exterior of the PTR-TETA20 Tool
1. The inlet funnel cover is constructed from plywood and acrylic glass, measuring 27 cm in length and 23 cm in width. The acrylic glass portion of the inlet funnel cover is 20 cm long and 20 cm wide.
2. The inlet funnel is made from plate iron with a thickness of 2 mm. It has a height of 27 cm, with the upper funnel measuring 27 cm in length and 23 cm in width. The bottom inlet funnel measures 22.5 cm in length and 18.5 cm in width.
3. The upper pulley has a diameter of 7.5 cm, and the circumference for the breaking shaft is 25 mm.
4. The tool holder is made from angle iron, measuring 4 × 4 A, with a height of 65 cm.
5. drive motor pulley has a diameter of 7.5 cm, with a circumference for the drive motor shaft of 14 mm.
6. The position of the breaker eye is constructed from plate iron with a thickness of 2 mm, measuring 8 cm in height, 24 cm in length, and 23.5 cm in width.
7. The exit funnel cover is made from plywood, measuring 23 cm in length and 16.2 cm in width.
8. The exit funnel is constructed from iron plate with a thickness of 2 mm, measuring 10 cm in height, 23 cm in length, and 16 cm in width.
9. The V-Belt is made from rubber, with a thickness of 8 mm, a top width of 12.5 mm, and a belt length of 65 inches (1651 mm).
10. The FLASH -250L type drive motor has a power of ¼ HP, operates at 220 V or 2.4 Amperes, and has a speed of 1400 rpm.
11.
12. Pillow blocks are made from metal materials such as cast iron or steel, measuring 52 mm in width and having an inner circumference of 25 mm. The pillow

block table is constructed from iron, measuring 35 cm in length and 30 cm in width.
13. The speed controller is made from heat-resistant ABS plastic and is equipped with a speed control button or knob.

Design of Functional Outer Parts of the PTR-TETA20 Tool
1. The funnel cover functions to prevent inserted nuts from bouncing out and allows monitoring of the nut breaking process through the acrylic glass on the inlet funnel cover.
2. The inlet funnel serves as the entry and loading area for macadamia nuts during the cracking process.
3. The tool pulley transmits movement from the drive motor to the tool attached to the breaker shaft.
4. The tool holder supports the weight of the tool and maintains the stability of the main frame.
5. The drive motor pulley transmits movement from the drive motor via the V-belt.
6. The position of the breaker eye ensures stability during operation, preventing it from shifting.
7. The exit funnel cover prevents nuts from escaping during uncontrolled cracking and facilitates cleaning inside the tool.
8. The exit funnel directs processed macadamia nuts out of the crushing tool.
9. The V-belt connects components, transmitting power from the drive motor to the breaker mechanism.
10. The drive motor is the main source of power driving the entire tool mechanism.
11. The pillow block or pillow block bearing supports the rotating shaft securely and stably.
12. The pillow block table supports the rotating shaft and positions the pillow block.
13. The speed controller allows users to adjust the drive motor speed according to operational needs.

Internal Components of the PTR – TETA20 Tool

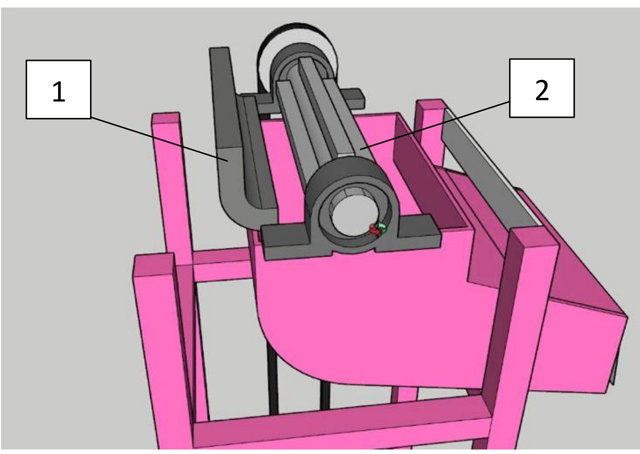

Figure 5. Internal Components of the PTR-TETA20 Tool
1= Pressure Wall
2= Breaker Roll

- *Design Structural Inside the PTR-TETA20 Tool*
  1. Wall suppressor made from iron plate which has thickness 10 mm.
  2. Breaker roll use shaft or iron ass who has 38 cm long and 25 mm in diameter.
- *Design Functional Inside the PTR-TETA20 Tool*
  1. Wall The press functions to provide the pressure needed to crack macadamia nut shells which is supported by crushing rolls that are arranged at optimal distances to maximize breaking efficiency.
  2. Breaker roll works as component rotating breaker.
- *Measure Tool Rotation (RPM)*

To determine the RPM of each pulley, measurements need to be taken using a tachometer. The rotational speed of the drive motor pulley is recorded, and the engine rotational speed (RPM) can be calculated using the (2) equation. Both the upper and lower pulleys have the same diameter of 7.5 cm and the same rotational speed of 1467 RPM, as measured by the tachometer (see Figure 2.3). Since the upper and lower pulleys share the same diameter and rotational speed, they rotate synchronously, ensuring no change in speed or power transmission between the two pulleys.

Figure 6. Rotational Speed Measurement of Upper and Lower Pulleys via Tachometer

Both the upper and lower pulleys in the PTR-TETA20 macadamia nut sheller have identical specifications, with a diameter of 7.5 cm each and a rotational speed of 1467 RPM as measured by a tachometer. The identical diameter and speed ensure synchronous rotation of both pulleys, maintaining consistent power transmission and speed without fluctuation between the two pulleys.

Working Time – TETA20.

The working time of the PTR-TETA20 tool can be seen in Table 1.

Table 1. Average Working Time of PTR-TETA20 Shelling Machine per 1 kg of Macadamia Nuts

Test	Weight of material included (kg)	Time (minutes)
1	1	01.26
2	1	01.39
3	1	01.36
Average	**1**	**1.56**

This table presents the average working time required for the PTR-TETA20 macadamia nut shelling machine across three repetitions, labeled as Repetition 1, Repetition 2, and Repetition 3. Each trial involved shelling a 1 kg batch of macadamia nuts, yielding a consistent average working time of 1.56 minutes per kilogram. The results highlight the machine's efficiency and consistency in processing similar quantities.

Based on the working time of the PTR- TETA20 tool in the three repetitions, different time variations were obtained. Repetition 1 shows a faster time, while repetitions 2 and 3 have times that are almost close. The average working time for these three repetitions is 1.56 seconds. When there are 3 to 4 nuts left, it is difficult to enter the crushing chamber because the holding space that was initially provided for 1 kg of nuts becomes too wide and the nuts easily bounce off. The wider the space that holds the nuts, the more difficult it will be for the nuts to enter the breaker chamber.

Things Observed

1. Capacity PTR Tool Working – TETA20.

The working capacity of the tool can be seen in Table 2.

Table 2. Average Working Capacity of the PTR-TETA20 Shelling Machine

Test	Input Weight (kg)	Time (hour)	Tool working capacity (kg/hour)
1	1	0.0239	41,481
2	1	0.0275	36.36
3	1	0.0267	37.453
Average	1	0.02603	38.4313

This table displays the working capacity of the PTR-TETA20 shelling machine, measured over three repetitions (Repetitions 1, 2, and 3). For each repetition, 1 kg of macadamia nuts was processed. The machine achieved an average working capacity of 38.43 kg per hour across the trials. Variations in working capacity may arise due to factors such as the presence of empty or rotten nuts, which can affect the processing efficiency.

2. Render – TETA20.

The results obtained from the PTR-TETA20 tool can be seen in Table 3.

Table 3. Average Yield of Macadamia Nut Shelling by PTR-TETA20 Machine

Test	Initial weight of material (kg)	Weight of Material After Breaking (kg)	Yield (%)
1	1	0.8929	89.29
2	1	0.9527	95.27
3	1	0.9301	93.01
Average	1	0.92523	92.523

This table presents the yield efficiency of the PTR-TETA20 shelling machine across three repetitions. The machine achieved an average yield of 92.52%, with the highest yield recorded in the second repetition at 95.27% and the lowest in the first repetition at 89.29%. Variations in yield can be attributed to factors such as the presence of empty or rotten nuts and potential accumulation of residue on the machine's components, which may impact performance. These results indicate that machine cleanliness and nut quality can influence shelling efficiency.

3. PTR Tool Performance Test – TETA20.

The performance test of the PTR-TETA20 tool can be seen in Table 4.

Table 4. Average Performance Test Results of the PTR-TETA20 Shelling Machine

U	Time (minutes)	Whole nuts (grams)	Nuts split in 2 (grams)	Crushed nuts (grams)
1	01.26	63.4	56.9	37.3
2	01.39	57.4	62.3	60.0
3	01.36	70.5	51.1	32.0
Average	93.67	63.77	56.77	43.1

This table summarizes the performance of the PTR-TETA20 macadamia nut shelling machine over three test repetitions, each involving 1 kg of macadamia nuts. The average output per trial includes 63.77 grams of whole nuts, 56.77 grams of halved nuts, and 43.1 grams of crushed nuts. Performance variations are noted, particularly when the remaining quantity of nuts is low (2–3 nuts), as they tend to bounce during the shelling process. This suggests that reduced pressure at low nut counts may impact consistency, leading to varied cracking results.

The percentage of whole nuts, halved nuts and crushed nuts can be seen in Table 5.

Table 5. Average Percentages of Whole, Halved, and Crushed Macadamia Nuts

Test	MY	KB	KH	BS	PKU(%)	CLA(%)	PKH(%)
1	63.4	56.9	37.3	157.6	36.10	0.62	23.66
2	57.4	62.3	60.0	179.7	34.66	0.51	33.38
3	70.5	51.1	32.0	153.6	33.26	0.40	20.83
Average	63,766	56,766	43.1	39.35	34.67	0.40	26.01

This table shows the percentage distribution of whole, halved, and crushed macadamia nuts produced by the PTR-TETA20 shelling machine over three replications. Each percentage was calculated by comparing the weight of whole, halved, and crushed nuts to the total sample weight in each replication. Differences in percentages across replications are attributed to material variability, such as the presence of empty, undersized, or rotten nuts, which can influence shelling outcomes and lead to variations in the proportion of whole, split, and crushed nuts.

4. Macadamia Nut Water Content

The water content of macadamia nuts can be seen in Table 6.

Table 6. Average Moisture Content of Whole, Halved, Crushed Macadamia Nuts, and Shells.

Sample	Intact(%)	Halve (%)	Destroyed (%)	Shell (%)
1	2.54	2.27	2.54	8.72
2	1.79	3.60	3.60	8.85
3	3.47	1.82	1.82	11.01
Average	2.6	2.56	2.83	9.52

This table presents the average moisture content of different components processed by the PTR-TETA20 shelling machine, including whole nuts, halved nuts, crushed nuts, and shells. Each sample type shows a unique moisture percentage, which can impact the efficiency of the shell-breaking process. Variations in moisture content between whole, split, and crushed nuts, as well as shells, may influence the force required for effective shelling and the quality of the processed nuts.

From Table 6, the results of the water content in whole nuts, split nuts, crushed nuts and shells, each sample has a different percentage of water content, this difference can affect the shell breaking process. According to Hokmabadi and Sedaghati (2014) freshly fallen nuts may have a moisture content of 25%. Therefore, the husks should be removed immediately to prevent overheating, mold growth and loss of quality. After being shelled, the nuts are dried either naturally or using artificial drying until the moisture content reaches 10% before being sent to the processor. Next, the nuts are stored in a storage area with a moisture content of between 10-15% for long-term storage, so that the shell breakdown becomes more efficient and maximizes the recovery of whole seeds (Yangyuen & Lauhavanich, 2018). The drying process is carried out in stages, to reduce the water content until it reaches a shell moisture content of 15% to avoid reducing the quality of the nuts. According to Wall (2023), gradual drying until the beans have a moisture content of 1.5% is very important to prevent changes in the color of the beans. Even though it is recommended to dry the nuts to 1.5%, the results of the water content contained in table 4.6 nuts that have a water content below 2% still cause the color of the nuts to turn brown, resulting in the nuts becoming too dry, this condition has exceeded the water content making The quality of the beans decreases in terms of taste, nutrients contained, texture and color.

Conclusion

The design and technical testing of the PTR-TETA20 macadamia nut sheller demonstrated its effectiveness in improving macadamia nut processing efficiency. The machine achieved an average working capacity of 38.43 kg/hour with a 92.52% yield, making it a viable option for small- to medium-scale operations. However, roller spacing inconsistencies affected performance, particularly with smaller batches. Nut integrity analysis showed 40.22% whole nuts, 36.10% half nuts, and 23.66% broken nuts, emphasizing the importance of optimizing machine settings for better yield. Moisture content results (2.6% whole nuts, 2.56% half, 2.83% broken, and 9.52% shells) indicate the necessity of proper drying for quality preservation. While the PTR-TETA20 offers an efficient and user-friendly shelling solution, further refinements in roller spacing and feeding mechanisms could enhance its performance and consistency.

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Author Contributions

R.R and P.A executed the research whereas D.T, and L.C.M conceived the idea and supervised the work.

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Conflicts of Interest

The authors declare no conflict of interest.

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