Development of a Small Capacity Coconut Charcoal-Fired Peanut Roasting Machine and Performance Evaluation Using a Smartphone-Based Colorimeter Application

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Abstract

This study aimed to design and develop a compact coconut charcoal-fired peanut roasting machine with a 2-kg capacity, investigating the correlation between the roasting chamber temperature and peanut product output through linear regression analysis and correlation. The main components of the designed and developed peanut roasting machine include the frame, heating chamber, roasting chamber, furnace, and driving mechanism. The machine's dimensions are 480 mm x 330 mm x 380 mm, with a furnace capacity of at least 1 kilogram of coconut charcoal. A low-speed motor was employed to drive the roasting chamber.

To assess the Maillard browning reaction resulting from the roasting process, a smartphone-based colorimeter application was utilized to measure the CIE L* ideal roasting color. The analysis indicated that as roasting time increased, the roasting chamber temperature also increased at a rate of 1.320, while the CIE L* decreased at a rate of 1.170. Pearson's correlation analysis demonstrated a strong negative correlation between chamber temperature and CIE L*, with an r-value of 94.71% and statistical significance at $p = 0.0073$. Additionally, when plotting the trends of chamber temperature and CIE L*, the intersection point was observed at 21.8 minutes, indicating that the optimal roasting chamber temperature for the highest rate of temperature increase and CIE L* decrease is 134°C. The developed peanut roaster can roast 2 kg of skinless peanut using 1 kg of coco-shell charcoal and achieve the best roasting color in 22 minutes at 134°C.

Keywords: colorimeter application, heating chamber, Maillard browning reaction, peanut roaster, roasting chamber

Introduction

This study addresses the challenges faced by small-scale agricultural processors (Dhillon R, & Moncur Q, 2023), particularly in the Romblon province. It aims to contribute to developing the MIMAROPA region by designing and providing a cost-effective peanut roasting machine suitable for micro and small enterprises (International Labour Organization, 2019).

One of the most common year-round legumes grown in the Philippines is the peanut (Arachis hypogaea). Approximately 24,000 hectares are used to harvest this crop. The Philippines Statistics Authority (PSA, 2022) reported the production of peanuts. The average increment in peanut production in the country was 2.2 percent from 2019 to 2021. It rose to 30.57 thousand metric tons in 2021 from 29.30 thousand tons in 2019. Among the top major peanut-producing regions in 2021 are Region 1 with 12 209.7 MT, Region II with 2 842.99 MT, Region VI with 2 678.11 MT, Region X with 2 650.24 MT, Region II with 2 352.64 MT, and Region IX with 1 187.42 MT. MIMAROPA is the last region to reach thousands of metric tons of production with 1,552.79 MT.

Peanuts, locally known as "mani," is a nutritious food, a good source of protein, and a relatively cheap energy food (Launio et al., 2018). It can be eaten raw, used as ingredients in Filipino dishes, and processed into peanut butter, solvents, oils, and medicines (DA, 2021). Peanut farming also provides income to many Filipinos, especially in the large producing regions (DA, 2021).

Conceptual Framework of the Study

The conceptual framework in this study was used as bases in the development of a small capacity peanut roasting machine using coconut charcoal as fuel. It has three main components that include input, process, and output. The input and processes determined the desired output based on the objectives of developing of a small capacity peanut roasting machine (MacCuspie et al., 2014).

The input section has three subcomponents: knowledge requirement, fabrication tools and equipment and testing material and equipment. The knowledge requirements covered the understanding of the concept of small capacity peanut roasting technologies. It included relevant information from the related literature on the design of small capacity peanut roasting machine. It also included relevant information about some characteristics of peanut, peanut roasting and coconut charcoal as fuel. Moreover, similar concepts of the project were drawn from perceptions and existing principles. The fabrication tools, testing material, and equipment were also important inputs in this study. Locally available materials were used in the fabrication. The consultation was likewise sought for the design and assembly of the mechanical components and systems.

The process explained how the inputs were integrated to come up with the desired machine. The process was the actual conduct of designing, developing and evaluating the machine. Lastly, the desired output was the evaluated and perceived economically viable small capacity peanut roasting machine using coconut charcoal as fuel that was fabricated utilizing and integrating the necessary inputs and processes.

Peanut Roasting

Roasting is one of the primary processes in producing peanut butter (McDaniel et al, 2012. Roasting is defined by Bagheri (2020) as a temperature - time dependent process with temperatures higher than 150ºC. This process forms a yellow - brown pigments called "non-enzymatic reactions" (Shi et al., 2016). By roasting the peanuts, the sensory and nutritional properties were improved, but the texture, color, and flavor of products were excluded (Jiao et al., 2016). Generally, roasting improves the chemical, sensory, and physical attributes of peanuts as well as the storage properties (Shi et al., 2016). Roasting process is tedious and time-consuming, and food is subjected to structural changes through thermal processes, reducing moisture content (Unguwanrami et al., 2021).

There are different ways of roasting. Shi et al. (2016) conducted a study to characterize roasted peanuts as products of dry, oil, and blister roasting. In the study, the researchers used a constant temperature of 117ºC throughout all the different ways of roasting. The roasting time varies as oil roasting is faster than dry roasting. Two (2) kilograms of peanut were used for batch deep frying and blister frying in 16 liters of pure peanut oil.

Blister frying is a roasting method that initially involves immersing the shelled peanuts in water. This roasting method has yet to be scientifically defined. However, instructions involve soaking blanched peanuts in water at 95ºC for a particular time, cooling them, air drying them, and then deep frying them (Miyagi, 2013). Shi et al. (2016) argued that this initial step, before deep frying, results in a loss of soluble sugars and protein, affecting the texture and flavor of the roasted product. The study found that blistered peanuts are the most damaged, and most of the free sugars are lost, affecting the flavor of the roasted product.

The use of hot air or microwave heating without the use of oil or water is dry roasting (Raigar, 2017). Chang et al. (2019) defined dry roasting as being performed at a temperature range of 150 C to 250 C on a small quantity of oil base to induce aromas associated with roasting. Microwave roasting is among the most energy-intensive roasting techniques (Bagheri, 2018). Raigar (2017) argued that dry roasting produces a uniform heat distribution, hence a faster heating rate and short processing time. Dry roasting profoundly affects the peanut's physical and chemical characteristics (Jittrepotch et al., 2010). This technology's roasting efficiency primarily depends on the roasting power and time (Degon, 2021; Raigar, 2017). Bagheri (2020) reported that one of the limitations of microwave roasting is that the surface temperature is higher than the inner parts of the food, resulting in under- or over-roasting of food. However, a combination of infrared and microwave roosting methods could be considered. Increased time and power levels decrease moisture content, pH levels, browning index, and overall acceptability of the roasted peanut (Shi et al., 2016; Bagheri, 2020). Furthermore, low production rates, subpar product quality, and high energy costs are drawbacks of traditional roasting methods using hot air ovens (Jiao et al., 2016).

Deep frying is a roasting method by completely immersing the shelled peanut into hot oils at a temperature of 150^{o}C to 190^{o}C to "trigger a simultaneous heat and mass transfer among oil, food, and air to result in food dehydration" (Chang et al., 2019 and Miyagi, 2013). Oil or fat is a suitable heat transfer medium that induces desirable sensory qualities such as oily and nutty flavors (Shibli et al., 2015). Some factors affecting deep frying are frying time and temperature, oxygen concentration, pH, and food components such as moisture content rather than the frying oil (Chang et al., 2019). Moreover, Oil, blister, and dry roasting are common methods used for small-scale production. Other technologies in roasting processes include batch operations and continuous or industrial applications. Batch roasting is assisted by simple technology using drum and ball roasters or semi-fluidized systems (Khan, 2021).

Industrial roasters operate at a continuous feed rate of peanuts, moving them into an oven by gravity or through a conveyor (Khan, 2021). Some advantages of continuous rosters are uniform peanut roasting through hot air, reduced labor costs, and increased process efficiency by constant feed rate (Khan, 2021). Industrial roasting was found to have different types based on roasting methods by oil, infrared, hot air or microwave, and infrared-hot air roasting (Bagheri, 2018; Bagheri et al., 2016 and Raigar et al., 2017).

Peanut Color Development

It is to be noted that roasting is a critical processing step and vital to the development of color, flavor and texture through chemical reaction, heat transfer and drying that occurs during roasting. Through chemical and heat reaction during roasting, peanut changes its color, flavor and texture. Color attracts customers. The color of is an important indicator of taste and quality (Philipps, 2018). It is one of the aspects for consumers to purchase the product that looks more appealing.

The rate at which reactions occur during roasting is affected by the roasting temperature as well as airflow through the roasting bed (Sarkar, Ahiduzzaman, & Akhtaruzzaman, 2012). These conditions in turn effect the reaction kinetics of roasting which are important to understanding the overall roasting process. Further, the development of color is mainly a function of nonenzymatic browning, and more specifically the Maillard Browning Reaction (MBR) (Schulze, 2019).. In order for the MBR to occur in peanuts, roasting temperatures need to be at least approximately 160^{o}C with continues stirring for 40-60 minutes (Woodroof, 1983). Color development depends on the initial composition of sugars and amino acids, as well as roasting time and temperature.

There are two kinds of color measurements, the Hunter Lab and the CIE L*a*b*. (Hunter Associates Laboratory, Inc). The color scales are designated as: L scale for light (a low number from 0 - 50) or dark (high number from 51 - 100); a scale for red (positive number) or green (negative number); and b scale for yellow (positive number) or blue (negative number) (Ly, Dyer, Feig, & Chien, 2020). The L, a and b values are required to completely describe the color of an object. To obtain the best roast quality, the ideal color for roasted peanuts has CIE L* values in the range of 52–65 (Shi, Sandeep, Davis, & Sanders, 2016).

Smartphone-based Colorimeter Application

A colorimeter is an instrument used to measure the intensity of the color of an object (Choudhury, AKR, 2014). It assesses the absorbance of light waves, specifically focusing on alterations in the intensity of electromagnetic radiation within the visible spectrum as it interacts with an object or solution through transmission or reflection. This measurement aids in determining substance concentration, as the absorption or transmission of light is contingent upon the solution's properties, including particle concentration, (Choudhury, AKR, 2014).

Rani, Saptami (2019) developed a smartphone-based colorimeter. The colorimeter is engineered for smartphones leverages the device's internal sensors, including the CMOS camera, flash LED, and high-power processor, for practical implementation. This self-contained colorimeter, designed to be affordable, lightweight, sturdy, and portable for field use, integrates intelligent sensing capabilities without the need for supplementary optics or external power sources. Its versatility extends to real-time, on-site analysis of various analytes in environmental research, biomedical contexts, and agriculture, the areas that are not covered by traditional bench-top colorimetric instruments.

In India, Sella, N et al (n.d.) developed an application that transforms smartphones into colorimeters, facilitating simple colorimetry experiments in educational settings that lacks extensive infrastructure, such as schools and colleges. Leveraging smartphones in classrooms offers a significant advantage, enabling effective teaching and learning without the need for specialized instruments like colorimeters, thus promoting flexibility and accessibility in educational practices across various locations and times.

Prototype Roasting Machine

In 2018, Ariyanti et al. analyzed the parameters of an existing peanut roasting machine designed for small and medium enterprises. To determine the optimal roasting time, temperatures, and tube operation speed to produce a product with a good color and taste. The machine's components include the roasting chamber, feed hopper, primary driver, speed reduction mechanism, drain outlet, and a 2 HP electric motor. Moreover, Ariyanti et al., 2018, mentioned in their experimental study that testing was conducted for 80 experimental combinations using the three factors with five variable temperatures: 80ºC, 85ºC, 90ºC, 95ºC, and 100ºC. The motor speed was varied at 30, 35, 40, and 45 rotations per minute (rpm). Roasting time includes 10, 15, 20, and 25 minutes. However, the capacity of the roasting chamber still needs to be identified (Ariyanti et al., 2018).

The study found that the correlation between temperatures of 95ºC to 100ºC is very strong. It was concluded that the optimal parameters of the machine are at 95 C, 40 rpm, and 25-minute roasting periods. These optimal values produced an adequate dry moisture content, which resulted in good taste and color, (Ariyanti et al., 2018).

Small and Medium Enterprises

Government agencies promote technology-based entrepreneurship programs in many regions with abundant traditional crops (Department of Agriculture, 2021). These programs often focus on leveraging the availability of low-cost agricultural raw materials to encourage value-added processing by local micro and small-scale processors (Department of Trade and Industry, 2020). However, a significant barrier to the success of such programs is the limited access to affordable processing equipment in these regions (Sims B, & Kienzle J, 2017). While some equipment exists in the market, it is often prohibitively expensive (Francisco, JP, 2018).

Investing in expensive processing machines can be daunting for small processors and budding entrepreneurs (Department of Trade and Industry, 2020). While labor-intensive and time-consuming, manual processing is the only viable option (Wang, Shangci (2015)). This project seeks to address this problem by offering an affordable peanut roasting machine to provide an alternative to manual processing.

Notably, the Romblon province, like many parts of the Philippines, has transitioned from viewing peanuts solely as a household food source to recognizing their potential as a commercial crop with high-value products (Department of Agriculture, 2021). The Department of Trade and Industry reports a growing number of registered food processors in Romblon, with a significant portion engaged in peanut butter production (Department of Trade and Industry, 2020). However, most of these processors still rely on manual roasting, which presents challenges such as burns, low capacity, and inefficiency (Kabri et al, 2010).

While peanut roasting machines are available in the market, they are often imported and designed for large-scale operations, making them unsuitable for micro and small enterprises in the region (Francisco, JP, 2018). This project, initiated by

RSU, seeks to bridge this gap by designing and providing a low-cost peanut roasting machine tailored to the needs of rural entrepreneurs (Ghimire, Nimesh et al, 2017) in Romblon and the broader MIMAROPA region.

The economic impact of this initiative could be substantial if village-level processing plants can achieve commercial production with sustained volume (Department of Agriculture, 2021). As demand for these products grows, the project envisions the proliferation of such processing plants in various production areas (Department of Trade and Industry, 2020). Additionally, ongoing research and development efforts are crucial, ensuring a seamless integration of activities from crop production to product development (Sumberg, J, et al, 2013).

In summary, this project aims to empower rural entrepreneurs in Romblon and the MIMAROPA region by offering an affordable peanut roasting solution, potentially boosting economic growth, and fostering innovation in the agricultural processing sector (Food and Agriculture Organization, n.d).

Objectives of the Study

The main objective of this study is to design, develop, and evaluate the performance of the small-capacity batch-type peanut roaster machine using coconut charcoal as fuel.

Specifically, the study aims to:

1) Design and fabricate the body and frame, the roasting and heating chamber, the furnace, and the driving mechanism of a small capacity peanut roaster;
2) Evaluate and analyze the performance of a small capacity peanut roaster using linear regression analysis and correlate the roasting chamber temperature to the output peanut product.

Materials and Methods

1) Materials

Most of the materials used in the fabrication of the peanut roasting machine were sourced out locally. However, the materials that are unavailable were sourced from online stores. Galvanized angle bars and flat bars were used for the body and frame of the machine, while food-grade stainless materials were used for parts that are directly in contact with the peanuts to ensure compliance in food safety protocols. Additionally, pillow blocks were used to aid the rotation of the roasting chamber, while bolts and nuts were used to securely fasten detachable parts to ensure the stability of the machine.

2) Fabrication and Testing tools and equipment

A variety of workshop tools and equipment were used in the development of the machine. A welding machine was used in joining the angle bars and flat bars for the framework of the roaster. In boring holes, drill and drill bits were utilized ensuring precise alignment and assembly. For cutting, shaping and polishing the materials, a grinding machine with attached grinding and polishing disks were used to refine both the inner and outer components.

In the testing phase, a 1000 – gram capacity weighing scale was used to accurately measure a total of 50 kilograms shelled and skinned peanut samples. These samples were roasted using a total of 25 kilograms of coconut charcoal.

To determine the browning color of the roasted peanuts, a Smartphone Colorimeter App was obtained from a Google Play platform. This widely adopted application allowed CIE Lab* color space measurement, a crucial parameter in evaluating roasted peanut quality. Its reliability has been validated in numerous recent and published studies, further supporting its use in this research.

3) Methods

The small-capacity peanut roasting machine was designed based on the two (2) kilogram roasting capacity. The design was based on previous and existing studies, considering other design alternatives. A careful study was considered in designing the different components and their functions, including the material specifications and sizes. Calculations of the dimensions of components were carried out using different formulas from the books and results of previous studies. Since the data and literature on peanut roaster machines are limited, the proponents have adapted the 18-rpm velocity of the rotating shaft based on the related literature (Owen, 2017). In order that the machine comes into reality the conceptualized small-capacity peanut roasting machine and its components, the following parameters were considered in the computation:

Sprocket

Sprockets transmit rotary motion from the motor shaft to the shaft roasting cylinder shaft. When the sprocket rotates, the teeth hold the chain and move the other parts.

- Number of teeth

To find the number of teeth for the large sprocket, the researchers applied the formula presented below:

$$T_1N_1=T_2N_2 \tag{1}$$

- Speed Ratio

$$\frac{\text{Big Sprocket}}{\text{Small Sprocket}} = \frac{N_2}{N_1} \tag{2}$$

- Diametral Pitch

The pitch was based on the standard pitch for the selected chain type.

For smaller sprocket

$$D_1 = \frac{\text{pitch}}{\sin(\frac{180}{no. of\ teeth})} \tag{3}$$

For larger sprocket

$$D_2 = \frac{\text{pitch}}{\sin(\frac{180}{no. of\ teeth})} \tag{4}$$

Chain

A chain transmits power from the motor to the rotating roasting cylinder and must be designed appropriately to achieve the required rotation.

- Chain center-to-center distance

The center-to-center distance of the chain must not be less than 1 ½ times the diameter of the larger sprocket (PSME, 1993)

- Length of chain

$$L = (2)(C) + \frac{T_1 + T_2}{2} = \frac{(T_1 - T_2)^2}{40(C)} \tag{5}$$

C = center-to-center distance

T = no. of teeth

Other design parameters

- Total weight of cylindrical mixer

Total weight = weight of mixer + weight of load (6)

- The force required to rotate the mixer weight

$$F = ma \tag{7}$$

m = mass, kg

a = acceleration, kg/m^2

- Centrifugal Force of Revolving Mixer

$$F_c = \frac{mv^2}{r} \quad (8)$$

M = Total mass of the cylindrical mixer; kg

V = velocity of cylindrical mixer; m/s

$$V = \pi DN \quad (9)$$

D = diameter of the mixer; m

N = mixer's speed; rpm

r = radius of the cylindrical mixer; m

- Total Force to Rotate the Mixer

$$F_T = F + F_C \quad (10)$$

- Total torque required to rotate the mixer

$$T = F_T\,(r) \quad (11)$$

F_T = Total Force

r = radius of the cylindrical mixer; m

- Power required to rotate the mixer (Transmitted HP)

$$P = 2\,\pi TN \quad (12)$$

T = torque required to rotate the drum; KN

N = speed of the shaft; rps

- Design Horsepower

Design hp = Transmitted hp (factor of safety) (13)

The factor of safety use of 1.4 was based on the machine elements book by Mores and Faires; Table 17.7, pg. 460.

- Cylindrical Mixer Shaft Size

To determine the Shaft Size, we applied the formula presented below:

From PSME CODE, Article 3.5, pg. 18

$$P = \frac{D^3 N}{53.5} \quad (14)$$

P = transmitted hp

N = shaft speed

- Heat Value for Coconut Charcoal, QC

q_c = GCV x Efficiency of fuel x Efficiency of stone (15)

q_c = heat value

GCV = Gross Calorific Value of charcoal

- The heat needed to roast 2 kg of peanuts, Qp

The peanuts are assumed to be roasted in 25 minutes per batch.

$$Q_p = m_p \times C_p \times (T_2 - T_1) \quad (16)$$

Where:

Q_p = heat needed to roast peanut

m_p = mass of peanut to be roasted in 25 minutes = 2 kg/25 min = 0.08 kg/min

C_p = Specific heat of peanut = 2.291 to 2.404 kJ/kg. °K (Radwan, May 2007)

- Mass of Fuel needed to Roast 2 kg of peanuts

It is assumed that the heat needed to roast peanuts is the heat developed by the charcoal in the heating chamber.

$Q_p = Q_c$

- Air Fuel Ratio of Charcoal

$$\text{Theoretical A/F} = 11.5C + 3.45\left(H - \frac{O}{8}\right) + 4.35S \quad (17)$$

Actual air needed.

Actual A/F = Theoretical A/F (1+e)

e = 60%

Peanut Color Measurement - *Maillard Browning Reaction*

The color analysis of the roasted peanuts was conducted using the CIE Lab* color space measurement method, facilitated by a SmartApp colorimeter. This application, available for a nominal fee, had been widely employed in numerous recent and published studies, attesting to its credibility and suitability for this research.

In measuring the color, the crosshair on the cellular phone's screen must be on the color target, and then the button to capture must be pressed. Moment 1 will show the color on picker mode, and Moment 2 will show the last color measured to compare. The scan mode identified the colors in real-time, and the color list was seen with all measured colors. The MBR was categorized into light, brown, and dark.

The roasted peanut sample with 100-gram peanuts was evenly filled into the sample cup to a depth of approximately 10 mm (Muego-Gnanasekharan et al., and A.V.A. Resurrection, 1993). The sample cup was entirely covered with peanuts, and no light could pass through the cup. The data collected was analyzed and interpreted.

The color scales are designated as L scale for light (a low number from 0 - 50) or dark (high number from 51 - 100); a scale for red (positive number) or green (negative number); and b scale for yellow (positive number) or blue (negative number) (Ly, Dyer, Feig, & Chien, 2020). The L, a, and b values are required to describe the color of an object completely. The ideal color for peanut paste prepared from roasted peanuts has Hunter L values of 51–52(Shi et al., 2017), and for blanched peanut kernels, it is 47.5–49.5 (McDaniel, White, Dean, Sanders, & Davis, 2012). Moreover, Hunter L values of 52–54 and 42–44 were considered light and dark roasts for blanched peanut kernels (McDaniel, White, Dean, Sanders, & Davis, 2012).

To obtain the best roast quality, the ideal color for roasted peanuts has CIE L* values of 52–65 (Shi, Sandeep, Davis, & Sanders, 2016).

***Figure 1**. The installed SmartApp Colorimeter icon in a Smartphone*

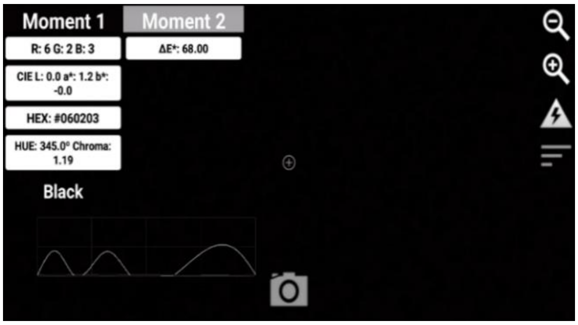


***Figure 2.** A capture of a black color using the Smart App Colorimeter*

Fabrication

To minimize costs in materials and ensure the quality of workmanship, the fabrication of the peanut roasting machine was contracted out. The materials used and the parts fabricated were thoroughly discussed with the experienced fabricator. Close monitoring and supervision were also carried out to guide the fabricator in attending to other details of the machines.

After the body, frame and furnace were fabricated, other components such as the motor, fans, temperature and speed control systems were installed. Initial testing was conducted to make further improvements and adjustments before proceeding with actual testing and evaluation.

Performance Testing and Evaluation Procedure

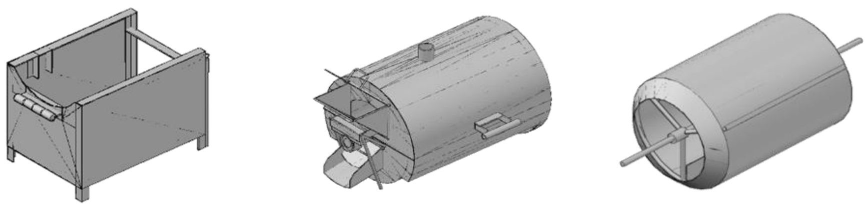
Performance testing and evaluations of the developed peanut roasting machine utilized a total of 25 batches of shelled peanuts, and each batch weighs 2 kilograms. The performance of the machine was evaluated using the different parameters such as roasting time and chamber temperature that allows for a comprehensive assessment of the machine. All tests were conducted from a cold start, with five tests conducted daily, at 8:00 and 10:00 in the morning, 1:00, 3:00, and 5:00 in the afternoon, for five consecutive days.

The roasting process includes start-up time and roasting time. Start – up time is the time required to ignite the coconut charcoal until such time that majority of the charcoal at the top of the furnace is burning. Roasting time on the other hand, starts from placing the peanut in the machine until the peanut is perceived roasted based on the parameters of the study.

Statistical Method

Pearson r correlation (Abun, Damianus, et al. 2021) was used to determine the relationship between the variables, while linear regression was used to determine the Optimal CIE L*, roasting time, and roasting chamber temperature.

The Working Drawing



(a) (b) (c)

Figure 3. *The frame (a), the insulated heating chamber (b) and the roasting chamber (c) of the Machine*

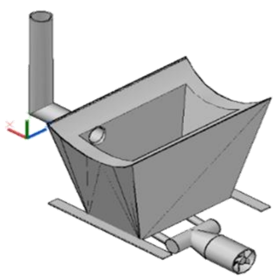


Figure 4. *The Coconut Charcoal Furnace*

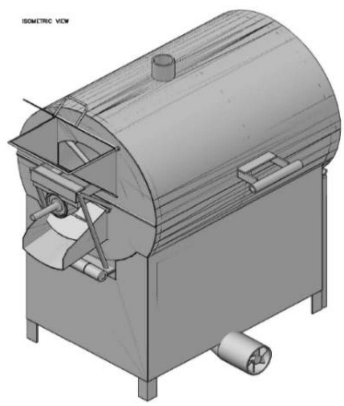


Figure 5. *The isometric View of the Machine*

Results and Discussion

A. The Peanut Roaster

The machine is composed of 5 components: the frame, the cylindrical chamber, the cylindrical mixer, the furnace, and the driving mechanism.

1. Frame

The machine's frame serves as a support for the machine's components. It is made of an angle bar. It has a dimension of 480 mm x 330 mm x 380 mm.

2. Heating Chamber

The heating chamber comprises a stainless sheet on the inner side and a galvanized Iron sheet on the outer part. In between the sheets is a fiber mat that serves as an insulator to prevent heating of the outer part. A flat bar serves as the frame of the chamber housed in the cylindrical chamber is the cylindrical mixer.

3. Roasting Chamber

The roasting chamber is made of a stainless sheet. It is welded to a stainless rod that serves as the frame. The frame is bolted to a 0stainless shaft and driven by the driving mechanism.

4. Furnace

The trapezoidal furnace has a base dimension of 150 mm x 200 mm, an opening dimension of 410 mm x 26 mm, and a height of 300 mm. It is made of cement 1.5 inches thick with a galvanized iron sheet on the outer side that serves as the frame. Class A mixture is used in cement.

A fan is installed to provide the air needed to aid in the complete combustion of charcoal. At the bottom part is the discharge for ash. The furnace can accommodate a maximum amount of 1,250 grams of coconut charcoal.

5. Driving Mechanism

The driving mechanism comprises a power supply converter, a low-speed motor, and a set of sprockets and roller chains.

The slow-speed motor was used since it can quickly drive the desired rpm of the mixer. The motor has a rating of just enough for the power requirement to drive the mixer.

Total Cost of the Project

The total cost of the completed Peanut Roaster Machine was based on the accounting of the expenditures for supplies and materials, labor, and other expenses. The total project cost is P 22,000.00.

Result of Test and Evaluation

The purpose of testing and evaluating the developed peanut roasting machine is to assess its performance, functionality, and overall quality.

Table 1. *Start-up time for firing the 1000 grams of coconut charcoal on a daily average.*

Parameters	Day 1	Day 2	Day 3	Day 4	Day 5
Daily average Start-up time (',") (minutes, seconds)	8’ 30”	8’ 25”	8’40	8’50”	9’0”

Table 1 shows the average daily start-up time of firing the coconut shell until all the charcoal inside the furnace is burning. Roasting in the developed machine can be accomplished with an average of 8 minutes and 40 seconds. All tests were conducted from a cold start.

Figure 6. *The CIE L* capture of 100-gram peanut from one of the samples roasted in 15 minutes.*

Table 2. *The temperature inside the roasting chamber and the CIE L* result obtained during the 15-minute roasting.*

Parameters	Test 1	Test 2	Test 3	Test 4	Test 5
The temperature inside the roasting chamber (OC)	125	123	127	124	128
CIE L*	75	79.5	74.6	62.3	68.2

Table 2 shows the results of tests obtained during the 15-minute roasting of peanuts that recorded the temperature inside the roasting chamber ranging from 123ºC to 128ºC with an average temperature of 125.4ºC.

Meanwhile, the CIE L* result ranges from 62.3 to 79.5, which was higher than the ideal CIE L* (52-65) values, except for the 62.3 results of test 4. However, since the average CIE L* value for the 16-minute roasting was 71.92, the results were still considered not ideal quality color.

Figure 7. *The CIE L* capture of 100-gram peanut from one of the samples roasted in 18 minutes.*

Table 3. *The temperature inside the roasting chamber and the CIE L* result obtained during the 18-minute roasting.*

Parameters	Test 1	Test 2	Test 3	Test 4	Test 5
The temperature inside the roasting chamber (° C)	126	125	129	130	128
CIE L*	72.6	76.1	69.6	72.6	72.7

Table 3 shows the results of tests obtained during the 18-minute roasting of peanuts that recorded the temperature inside the roasting chamber ranging from 125ºC to 130ºC with an average temperature of 127.6ºC.

Meanwhile, the CIE L* result ranges from 69.6 to 76.1, which was higher than the ideal CIE L* values. The average CIE L* (52-65) value for the 18-minute roasting was 72.72; the results were considered the unideal quality color of roasted peanuts.

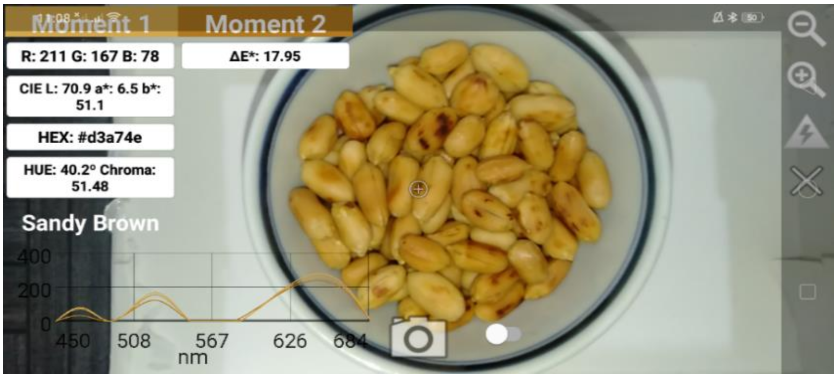


Figure 8. *The CIE L* capture of 100-gram peanut from one of the samples roasted in 21 minutes.*

Table 4. *The temperature inside the roasting chamber and the CIE L* result obtained during the 21-minute roasting.*

Parameters	Test 1	Test 2	Test 3	Test 4	Test 5
The temperature inside the roasting chamber (°C)	136	134	133	134.33	136
CIE L*	59.7	68	70.9	66.1	68

In Table 4 were the results of tests obtained during the 21-minute roasting of peanuts that recorded the temperature inside the roasting chamber ranging from 133°C to 136°C with an average temperature of 135°C.

For now, the CIE L* result ranges from 59.7 to 70.9, which was higher than the ideal CIE L* (52-65) values, except for the 59.7 result of test 1. However, since the average CIE L* value for the 21-minute roasting was 66.54, the results were still considered not ideal quality color.

Figure 9. *The CIE L* capture of 100-gram peanut from one of the samples roasted in 24 minutes.*

Table 5. *The temperature inside the roasting chamber and the CIE L* result obtained during the 24-minute roasting.*

Parameters	Test 1	Test 2	Test 3	Test 4	Test 5
The temperature inside the roasting chamber (°C)	135	136	139	138	138
CIE L*	69.9	68	70.9	59.7	57.6

Table 5 shows the results of tests obtained during the 24-minute roasting of peanuts that recorded the temperature inside the roasting chamber ranging from 135°C to 139°C with an average temperature of 136.75°C.

Moreover, the CIE L* result for the 24-minute roasting ranges from 57.6 to 70.9, which have values within the ideal CIE L* (52-65) values, except for the result of tests 1, 2, and 3, with 69.9, 68, and 70.9, respectively. The average CIE L* value was 65.22, which may be considered to be under the ideal quality color of roasted peanuts.

Table 6. *The temperature inside the roasting chamber and the CIE L* result obtained during the 27-minute roasting.*

Parameters	Test 1	Test 2	Test 3	Test 4	Test 5	Ave
The temperature inside the roasting chamber (° C)	138	143	139	142	140	140
CIE L*	63	57.6	56.7	52.2	61.1	58.12

Table 6 shows the results of tests obtained during the 24-minute roasting of peanuts that recorded the temperature inside the roasting chamber ranging from 138°C to 143°C with an average temperature of 140°C.

Figure 10. *The CIE L* capture of 100-gram peanut from one of the samples roasted in 27 minutes.*

Furthermore, the CIE L* result for the 24-minute roasting ranges from 52.2 to 63, with all the values within the ideal CIE L* (52-65) values.

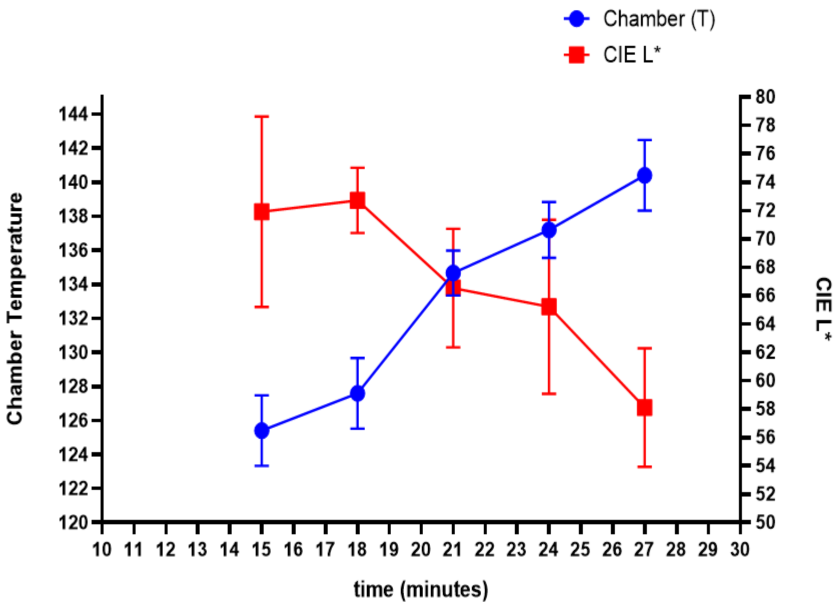


Figure 11. *Graph showing the relationship between the roasting chamber temperature, time, and the CIE L*.*

As shown in the graph above, the results indicate a notable relationship between the roasting chamber temperature and the CIE L* value, a measure of lightness, with a negative correlation. Specifically, as the temperature in the chamber increases, the CIE L* value decreases. This relationship is supported by a strong Pearson correlation coefficient ($r = -94.71\%$), indicating a high degree of association between the two variables. The analysis further demonstrates that this correlation is statistically significant ($p = 0.0073$), suggesting that it is not due to random chance.

Moreover, the liner regression line shows a challenging result. The study revealed a negative or inverse correlation between two variables which means that as one variable increases, the other variable decreases. In this study, a negative correlation was observed such that as the chamber temperature increases, the CIE L* of the roasted peanut decreases. It can be noted that the intersection of the trend line where the temperature of the chamber increases as the value of CIE L* decrease was observed at 21.8 minutes. The intersection of the trend is at the optimum with the chamber of temperature of 134°C signifying that this temperature assumes the most effective balance between the two variables, an indication that accurate temperature control is needed to attain the desired roasting outcomes.

Conclusions

The main components of the designed and developed peanut roasting machine with the capacity of 2 kg include the frame, heating chamber, roasting chamber, furnace, and driving mechanism. The machine's dimensions are 480 mm x 330 mm x 380 mm, with a furnace capacity of at least 1 kilogram of coconut charcoal. A low-speed motor was employed to drive the roasting chamber.

To assess the Maillard browning reaction resulting from the roasting process, a smartphone-based colorimeter application was utilized to measure the CIE L* ideal roasting color.

Recommendations

1) Endorse the use of the machine to small and medium enterprises engaged in selling roasted peanuts and peanut butter processing.
2) Conduct evaluation on the acceptability of the machine.
3) Conduct simulations using computational fluid dynamics to determine the optimum parameters of the machine.
4) Assess the properties of the roasted peanuts produced under optimized conditions, focusing on sensory evaluation, moisture content and surface color.

Acknowledgment

The authors would like to extend their heartfelt gratitude to the many individuals who played important roles in realizing their research project. This endeavor would not have been possible without them.

First and foremost, they offer the highest praises, glory and honor to the Almighty God for the guidance and blessings bestowed to the authors.

To their families, colleagues and friends for the unconditional love, endless support and inspiration to hurdle odds and trials. The unwavering support of the Fadriquel and Fos-Fetalver families has been a source of strength and motivation.

They sincerely thank the RSU Management team, led by the esteemed President, Dr. Merian P. Catajay-Mani. Her visionary leadership and commitment to academic excellence have set the stage for their research endeavors. They also want to acknowledge the vital contributions of the Vice President for Research, Development, and Innovation, Dr. Eddie G. Fetalvero, the Vice President for Academic Affairs, Dr. Emelyn F. Montoya, the Vice President for Administration and Finance, Dr. Tomas T. Faminial, and the Chief Administrative Officer, Atty. Glenn Sartillo. The top management's support and guidance have been instrumental in their success.

They want to thank the entire CET Family. The CET's dedication to fostering academic growth and innovation has been a cornerstone of their achievements—special thanks to the Mechanical Engineering Chairperson, Engr. Christian M. Mortel, for the encouragement.

They express gratitude to all for being a part of this important chapter in their academic and research journey.

OGF

CFF

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Appendix A

Itemized Cost of Materials Used in the Construction of the Charcoal Fired Roasting Machine			
Qty	**Unit**	**Description**	**Cost Php**
1	pc	3/16x1 in. angle bar	288.75
3	pc	1/4x5/8 in. flat bar	337.00
2	pc	Pillow block (1/2 in. inside diameter)	400.00
2 1/2	ft	½ in. shafting (stainless steel)	373.75
8	ft	Stainless shaft (1/4 in.)	336.00
1	pc	Drill bit (1/4 in.)	126.00
12	ft	¼ in. stainless round bar	590.00
1	pc	Stainless sheet (0.9 mm)	2,310.00
1	pc	G.I Sheet (0.5 mm)	1,071.00
30	pc	Bolts and Nuts (3/8 in.)	315.00
20	pc	Bolts and Nuts (Philips head 3/8 in.)	105.00
4	pc	Bolts and Nuts (8 mm)	63.00
13	pcs	Bolts and Nuts (Stainless 3/8)	136.50
5	kg	Cement	78.75
1	pc	Axle (motor cycle)	89.25
6	pcs	bushing	378.00
1	pc	Motor (Wiper of Car Dash Board)	682.50
40	pcs	Stainless Electrode (gauge #10)	420.00
2	kg	Electrode (gauge #12)	168.00
2	ft	G.I. pipe (1.5 in. inside diameter)	105.00

2	ft	G.I. pipe (1/2 in. inside diameter)	100.00
2	kg	Fiber mat	420.00
1	pc	Industrial thermometer	252.00
2	m	Level hose	21.00
2	ft	Aluminum (tubular 1 3/4x4 in.)	210.00
6	pcs	Cable tie	31.50
1	pc	Carbon brush	105.00
5	pcs	Sand paper (no. 120)	52.50
2	pcs	Toggle switch	42.00
4	ft	Automotive wire	63.00
2	375 ml	Paint thinner	253.50
1	375 ml	Epoxy primer (gray)	94.50
2	pc	Alligator clip (small)	31.00
1	unit	Lathe turning	840.00
1	pc	Power supply (220 ac to 12 dc)	513.00
1	set	Chain and sprocket	472.50
1	unit	Colorimeter Application (online)	175.00
TOTAL			**12,050.00**