Open Global Scientific Journal 02 (01): 25-36 2023

Contents lists available at openscie.com

Open Global Scientific Journal

Journal homepage: https://openglobalsci.com

Physical and Chemical Properties of Robusta Coffee Beans at Different Temperatures and Roasting Times

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ARTICLE INFO

Article History:
Received 05 May 2023
Revised 10 May 2023
Accepted 15 May 2023
Published 22 May 2023

Keywords:
Chemical properties
Physical properties,
Roast Time,
Robusta Coffee,
Temperature.

ABSTRACT

Robusta coffee in the Rejosari Mojokerto Village is undertaken by the local community. However, to ensure the production of high-quality coffee and avoid the production of low-priced products, it is imperative for the community to possess a comprehensive understanding and knowledge of coffee post-harvest processing methods. This study aims to investigate the physicochemical properties of Robusta coffee under varying roasting temperatures and times. Several key variables were observed, including the number of beans per 100 grams of coffee, geometric diameter (GM), and average weight of coffee beans, which were employed to assess the physical properties of the coffee. Furthermore, the chemical composition of coffee was analyzed in terms of extract weight, ash content, caffeine, glucose, and coffee protein levels. The results indicate that 100 grams of Robusta coffee contain an average of 368 individual coffee beans, each weighing approximately 0.27 grams, with a geometric dimension (GM) of 10.3 mm. Moreover, the extract weight, caffeine, glucose, and protein content exhibit a decreasing trend during the roasting process. As the roasting time increases and the temperature rises, the percentage of coffee extract and caffeine content decreases. Notably, coffee roasted at 200°C for 20 minutes exhibits the highest ash percentage, reaching 4.16%. It was observed that higher roasting temperatures and longer roasting periods result in increased ash content. This study highlights the significant influence of varying roasting temperatures and times on the quality of the resulting coffee beverage.

1. Introduction

Generally, coffee cultivation on the slopes of the Anjasmoro Mountains is characterized by the planting of two types of coffee: Robusta and Excelsa (Sutrisno & Sholichah, 2020). Among these, the residents of Rejosari Village predominantly cultivate Robusta coffee, known for its strong and pungent taste and aroma, attributed to its higher caffeine content compared to Arabica coffee (Aditya et al., 2015; Hastuti, 2018; Hasbullah et al., 2021). Caffeine, a prominent compound found in coffee, exerts an addictive effect on enthusiasts, providing a sense of calmness and warding off drowsiness (Farida et al., 2013; Babova et al., 2016). Additionally, research has highlighted the various health benefits of coffee, such as its antioxidant properties, ability to enhance cognitive performance, and potential for cancer prevention (Farida et al., 2013; Babova et al., 2016). The chemical composition of coffee beans encompasses caffeine, carbohydrates, fats, amino acids, organic acids, chlorogenic acid, trigonelline, minerals, and volatile aromas (Apriyanto et al., 2022; Higdon & Frei, 2006). In Robusta coffee, caffeine content typically ranges from 1.7% to 4%, while Arabica coffee contains approximately 1% to 1.5% caffeine content (Apriyanto et al., 2022; Higdon & Frei, 2006; Edowai, 2019; Suwiyarsa et al., 2018).

The coffee industry in Rejosari Mojokerto Village is predominantly driven by smallholder plantations, constituting a significant majority of coffee production (99.33%) as compared to large plantations managed by the state and private sector (BPS, 2021). However, the post-harvest processing practices employed by the village residents remain relatively simple. During periods of high coffee prices, harvesting is often conducted without meticulous cherry selection, resulting in suboptimal quality. Conversely, during periods of low prices, farmers tend to harvest coffee beans with red skin, which can be stored or consumed for personal use. Moreover, the drying process relies on traditional sun-drying methods, with limited utilization of advanced drying technologies such as forced convection systems (Sary, 2016), gasification (Hamni, 2014), or varying airflow speeds in solar dryers (Yani & Fajrin, 2013; Hasbullah et al., 2021).

While some studies have explored the physical characteristics of Robusta coffee from Rejosari, such as surface volume, ground coffee pH, and moisture content (Isnianto, 2021), these studies lack information on bean quantity and weight. Therefore, there is a need to comprehensively investigate the physical and chemical properties of Robusta coffee beans cultivated by the residents of Rejosari Mojokerto Village, particularly concerning the influence of roasting time and temperature.

This study aims to determine the physical and chemical characteristics of Robusta coffee beans from Rejosari Mojokerto Village by examining the effects of roasting time and temperature. By enhancing the understanding of coffee's chemical composition and the quality of Robusta coffee, this research seeks to promote informed decision-making during post-harvest processing, thus mitigating arbitrary practices.

Food quality and preservation are vital concerns, with water content and cooking processes playing pivotal roles in food deterioration (Palupi et al., 2007). Protein is an essential component of food; however, exposure to high temperatures during cooking can lead to protein degradation (Lamid et al., 2015). Therefore, by investigating the chemical content and quality of Robusta coffee, this study aims to enhance public knowledge and promote improved cultivation and post-harvest handling practices among the community.

2. Methods

Robusta coffee beans were collected from coffee plantations owned by Rejosari villagers, specifically selecting beans with red-colored skins indicating their readiness for harvest. The study focused on evaluating both the physical and chemical properties of the coffee beans. For the physical properties, the number of seeds was determined following the methodology of Yusianto and Widyotomo (2013), while the geometric diameter was measured based on the approach outlined by Sutrisno and Sholichah (2020). Seed weight was assessed using the procedure described by Winarno and Perangin-angina (2020). In terms of the chemical characteristics, pH measurement, determination of total dissolved solids, assessment of water content, and analysis of glucose, protein, and caffeine levels were conducted. Statistical analysis was performed to explore any significant differences or correlations among the parameters.

2.1 Physical properties of coffee beans

2.1.1 Number of Seeds Per 100 g

The number of beans is determined by weighing coffee beans as much as 100 g and then calculating the number of beans.

2.1.2 Diameter geometric (GM)

GM (m) = $\sqrt[3]{LWT}$ Where: L = *Length* W = *Width* T = *Thickness*

2.1.3 Seed weight

The following formula calculates the determination of weight per coffee bean:

$$Seed\ weight = \frac{100\ g\ coffee}{Total\ amount\ of\ coffee}$$

2.2 Physical and Chemical characteristics of ground coffee

2.2.1 Coffee powder preparation process

Coffee beans were made of nine samples weighing 100 g each (Isnianto, 2021), as the following table shows:

Table 1. Research sample treatment

Treatment	B 1	B 2	B 3
A 1	A1B1	A1B2	A1B3
A 2	A2B1	A2B2	A2B3
A 3	A3B1	A3B2	A3B3

Description:
A = temperature at roasting
B = length of roasting Time
A1 = 180 ^{0}C B1 = 10 minute
A2 = 190 ^{0}C B2 = 15 minute
A3 =200 ^{0}C B3 = 20 minute

2.2.2 Cider Content

A sample of coffee grounds weighing up to 2 grams is initially measured, followed by the measurement of 500 ml of liquid in a cup. To prepare the filtered solution, a measuring cup is filled with 200 ml of hot water and left to sit for one hour. The filtered water is then rinsed completely, and the process of filtering the sample solution is repeated using a funnel and filter paper. After the filtered solution has cooled to room temperature, it is gradually poured into a measuring cup until it reaches the desired volume of 500 ml. Using a pipette, 50 ml of the filtered water is transferred into a porcelain dish with a known weight. The dish is then subjected to heating at a specific temperature until the water evaporates. Subsequently, the dish containing the dried coffee grounds is placed in an oven at

105 °C for a duration of 2 hours. After cooling in a desiccator, the weight of the ground coffee is measured again. The computation of results is performed using the following formula (Budiyanto et al., 2021; Lestari & Rohmatulaili, 2022):

$$\% \, coffee \; extract \; = \frac{W_1 \; x \; 500}{W_2 \; x \; 50} \; x \; 100\%$$

Ket: W_1 : Extract weights
W_2: Sample weight

2.2.3 Ash content

In this method, a coffee sample weighing 3 grams is placed into a pre-weighed petri dish. The dish, along with the coffee sample, is then weighed. Next, the cup containing the coffee sample is heated to a temperature of 550 °C, and the cup is opened to allow the coffee grounds to burn and turn into ash. This heating and ashing process is repeated until the coffee grounds have completely transformed into ash. Once the ashing process is completed, the petri dish with the resulting ash is allowed to cool inside a desiccator to reach ambient temperature. The dish, along with the ash, is then repeatedly weighed until a consistent weight is obtained. To determine the ash percentage, calculations can be applied based on the weight of the ash compared to the initial weight of the coffee sample (Budiyanto et al., 2021)

Ash content = $\frac{W1-W2}{W} \; x \; 100\%$

Explanation:
W: The weight of the example before it is not in g.
W_1: sample weight + cup after deep feeding g
W_2: inner empty cup weights g

2.2.4 Caffeine levels

Both the coffee grounds, which weighed 2 grams, and the magnesia powder or magnesium oxide (MgO) were placed into the Erlenmeyer. Both materials were combined. Erlenmeyer, which already has a sample of coffee grounds inside, is given water that has been distilled, and then MgO is heated to a boil. After the solution is allowed to cool, the next steps are to weigh and filter it. A volume of the solution equal to 50 ml is transferred to a measuring flask, and then 25 ml of sulfuric acid is added (H_2SO_4). A sample of the solution was placed in the measuring flask, and 10 ml of $CHCl_2$ was used to extract it five times. Shaking vigorously for a full minute is required to complete the extraction process. The Kjeldahl procedure was then performed after adding 10 ml of a solution containing 10 percent potassium hydroxide to the Kjeldahl flask. The formula below can be used to calculate the amount of caffeine.

Caffeine levels (%) = $\frac{c}{w} \; x$ V x $fp \; x \; 100\%$

Ket: C: caffeine concentration of the calibration curve (micrograms/milliliter)
W: sample weight (g)
V: volume of the final solution (ml)
Fp: dilution factor

2.2.5 Glucose

The Nelson-Somogyi method of uv-visible spectrophotometry was utilized to ascertain the coffee's glucose concentration. The sample of coffee powder was filtered into a size 60 mash, after which it was weighed up to 2 grams and placed into a hydrolysis beaker. Next, 3 percent HCl was added up to 200 ml, anti-foam was added between 3 and 4 drops, and the mixture was covered with a condenser. The hydrolysis process lasts three hours, with the clock starting to tick after the water reaches a rolling boil. The sample is taken out and put in the refrigerator. After being allowed to cool, the sample solution is then neutralized using a NaOH solution that is 30 percent (drop by drop). The pH meter is used to make the measurements, and if the sample solution is alkaline, HCl is added to it until the solution turns acidic. After that, three drops of CH_3COOH with a concentration of 3 per cent are added. After the solution has been placed into the flask with a capacity of 500 ml and allowed to accumulate to the maximum level, it is homogenized. On an erlemenyer, the filtering process is accomplished by utilising filter paper. The outcomes of the filter are withdrawn to a volume of 10 ml, which is then transferred into an Erlenmeyer flask with a capacity of 250 ml, to which 15 ml of aquadest and 25 ml of Luff schrool solution are added. 10 minutes of heating the solution take place (calculated after boiling).

After the solution has been cooled again, 25 ml of H_2SO_4 6N solution is added. After the hue has changed to a brownish-yellow, add another 15 ml of KI solution, that is 20 per cent. After titrating the solution with sodium thiosulfate, 5 ml of amylum diluted to a concentration of one per cent was added in the middle of the process. Titration is performed until there is a noticeable shift in color (from purple to milky white). The identical process is followed for blanks; only equates are used in place of samples. The formula below can be used to calculate the glucose levels.

$$\text{Glucose Levels (\%)} = \frac{c}{Sampel\ x\ 1000}\ x\ fp\ x\ 100\%$$

2.2.6 Protein

Used grinds for coffee The Kjeldhl flask is loaded with as much as 2 grams of the compound, then concentrated H_2SO_4 and selenium are added. Finally, the solution is allowed to boil until it is clear. Following the completion of the cooling process, the solution is diluted before being transferred into the measuring flask. 5 ml of the solution is removed and placed in the distiller before a solution of NaOH with 30 per cent concentration, and phenolphthalein (PP) indicator is added. Distillation is performed on the combination of these solutions. Titration using a solution of 0.01 N hydrogen chloride. The formula for calculating the amount of protein is as follows:

$$\text{Protein} = \frac{(V1-V2)\ x\ N\ x\ 0{,}01\ x\ f{,}kxfp}{w}$$

Explanation. w: sample weight

V1: volume HCL 0,01 N Sample Citation Used

V2: volume HCL used blanks confiscation

N: Normality HCL

FK: Conversion factors for protein from food in general

fp: Dilution factor

3 Results and Discussion

3.1 Physical properties of coffee beans

The weight of 368 Robust coffee beans is equivalent to 100 grams, with 129 beans weighing less than 7 millimeters, 147 beans measuring between 5 and 7 millimeters, and 91 beans measuring less than 5 millimeters. The geometric diameter (GM) of coffee beans depends on their length, breadth, and thickness; samples of Robusta coffee have a GM of 10.3 millimeters. The average weight of Robusta coffee beans in the research sample was 0.27 grams. The climate during the drying process, the variety of coffee, and the geographic region in which it is grown all impact the coffee beans' weight. (Sutrisno & Sholichah, 2020).

3.2 Chemical properties of Robusta coffee grounds

3.2.1 Cider Content

The quantity of particles dissolved in the water during the brewing process is referred to as the juice or extract content of the coffee grinds. This cider's alcohol percentage is affected by various parameters, including the kind of coffee, the roasting process, the processing procedure, and the brewing technique.

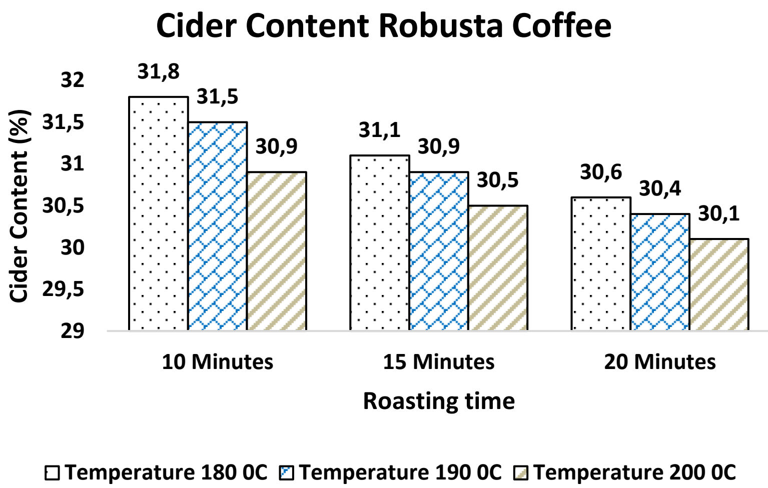

Figure 1. Cider Content Robusta Coffee Robusta

The difference in temperature and roasting time significantly impacts the amount of coffee juice contained in Robusta beans, as shown in Figure 1. The longer the coffee is roasted and the higher the temperature, the lower the percentage of coffee juice contained in the beans. The perfect amount of alcohol in cider, according to (BSN, 2004), is 20 – 36 %; to ensure that it can deliver a flavor and aroma that is pleasant and well-balanced coffee. Because it is related to the solubility of coffee pollen, juice levels that are too high can produce coffee that is too strong and bitter, while juice levels that are too low can produce coffee that is too weak and not very flavorful. This is because the higher the juice content, the higher the solubility of coffee pollen in water. The lower the juice content, the lower the solubility of coffee pollen in water (Fajriana & Fajriati, 2018; Suwarmini et al., 2017). The amount of cider present in coffee serves several purposes, including influencing the coffee's intensity and flavor, the quality of coffee goods, contributing to the measurement of acidity levels, and establishing the appropriate amount of cider to use brewing coffee.

3.2.2 Ash Content

It is recognized that the ash content indicates how clean the coffee production process was. The higher the ash level, the more likely the coffee grounds are polluted by unnatural substances or dirt (Sariwida, 2018)

Figure 2 shows that the ash content in Robusta coffee powder at the research location rises with increasing temperature and that the roasting time affects the ash content. When coffee is roasted at 200 degrees Celsius for twenty minutes, the high ash concentration is 4.16 per cent. On the other hand, it is essential to remember that the amount of ash present in coffee beans does not often substantially impact the flavor or quality of the brewed beverage.

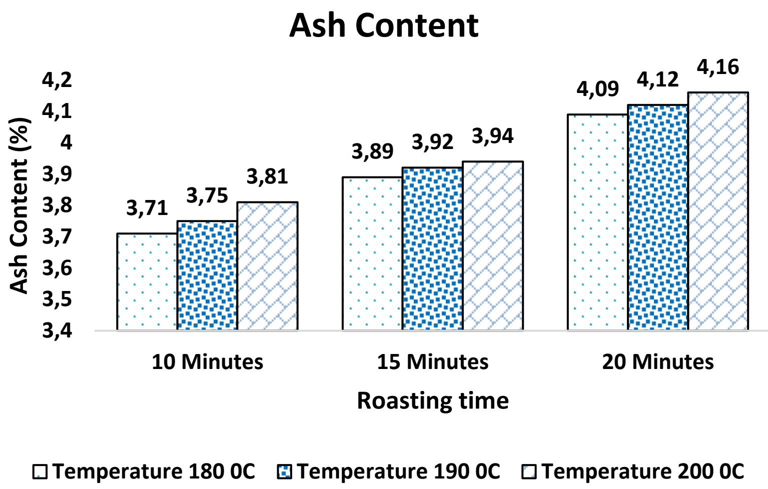

Figure 2. Ash Content of Robusta Coffee

It is common knowledge that the percentage of ash content in coffee powder offers several advantages, including the following: 1) improved coffee quality; beans that are considered to be of higher quality typically have a lower ash content; 2) improved ability to predict the consistency of the coffee flavor produced; both coffee producers and consumers can predict the consistency of the coffee flavor produced and adjust the production process; this is because the percentage of ash content in coffee powder is related to the number of minerals and organic compounds that are left behind after the coffee 3) When determining the level of maturity of coffee, the presence of a high ash content might be a good indicator that the coffee was made from fully ripe beans that were picked correctly. In addition, a high ash content might indicate that the coffee has been processed correctly and has not been harmed. According to the data presented, the amount of ash in coffee grounds (BSN, 2004) is a maximum of 5 %.

3.2.3 Caffeine Levels

Caffeine and coffee are inseparable since caffeine is one of the chemical components that form the physiological features of coffee, namely the existence of a bitter taste. Caffeine and coffee cannot be separated.

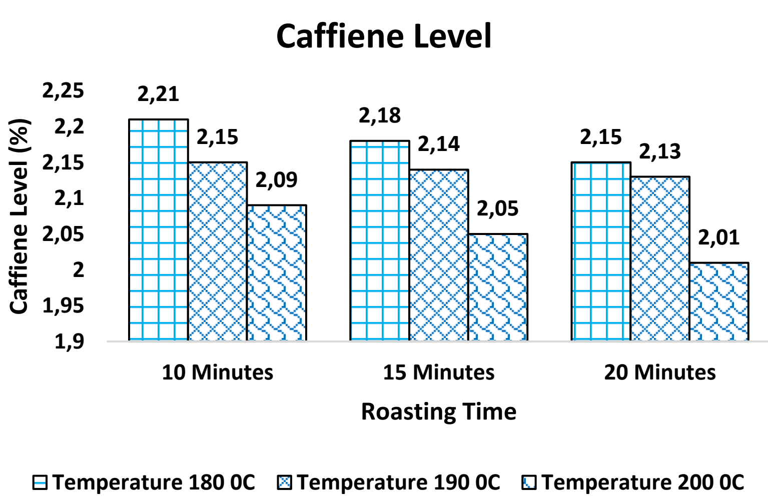

Figure 3. The caffeine content of Robusta coffee

Figure 3 depicts the caffeine percentage typically found in a cup of Robusta coffee at the location where the research was conducted, which came out to be 2.12% on average. When the coffee powder is roasted for a longer period, the temperature at which it is roasted and the amount of caffeine it contains fall to lower levels. This is also true of the temperature at which the coffee powder is roasted. The amount of caffeine that is contained in coffee is determined by several factors, one of which is the kind of coffee used, with Arabica coffee having a lower amount of caffeine than Robusta coffee (Aditya et al., 2015; Hastuti, 2018; Oktadina et al., 2013); 2) The amount of caffeine that is contained in coffee grounds can also be affected by the processing procedures that are used, including as the removal of the bean skin, drying, and grinding. 3) The pace of roasting, since coffee that is roasted for a longer period tends to have a lower concentration of caffeine: 4) The size of the coffee grain also plays a role in the determination; the more refined the surface of the coffee bean, the greater the caffeine concentration will be. 5) The temperature of the water used during the brewing process; the greater the temperature of the water used, the higher the amount of caffeine that will be present in the coffee (Zarwinda & Sartika, 2019; Agustina et al., 2019; Riyanti et al., 2020).

3.2.4 Glucose

Glucose is a simple sugar found in many different fruits and coffee beans. There is only a little amount of glucose in coffee beans, and this glucose is found in the form of starch. Glucose is produced during photosynthesis by coffee leaves, which uses the energy from sunlight to transform carbon dioxide and water into glucose. After it has been generated, the glucose will be digested by the coffee cells throughout the process of creating coffee beans. During the roasting process (*roasting coffee beans*), glucose may also react with other compounds in the coffee beans, forming numerous chemicals that give roasted coffee beans their flavor, fragrance, and color. These reactions can take place during the roasting process.

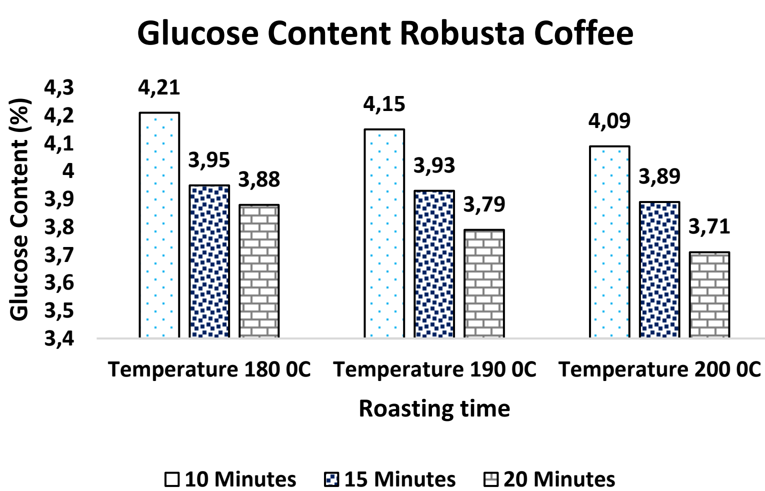

Figure 4. Glucose Content Robusta Coffee

The roasting process also affects the glucose level in coffee; as shown in Figure 4, the higher the temperature and the longer it takes to roast the coffee, the lower the percentage of glucose. It was roasting coffee beans at lower temperatures for extended periods results in lighter coffee beans that have a flavor and aroma that is more nuanced—on the other hand, roasting coffee beans at higher temperatures for shorter periods results in darker coffee beans that have a flavor and aroma that is bolder and more concentrated. The ideal roasting temperature is 190 degrees Celsius, and the optimal roasting duration is ten minutes. Roasting coffee at temperatures higher than 190 degrees Celsius or longer than ten minutes will decrease the coffee's quality (Edvan et al., 2016). By (Kurniawan et al., 2015), The heating process causes the process of breaking down complex sugars into simple sugars. The amount of sugar in food affects the amount of water in food; the better the texture of food, the greater the sugar content (Nilasari et al., 2017). The presence of caffeine in coffee also affects the presence of glucose in coffee (Hsu, 2021). One element that determines the amount of glucose in coffee is the altitude at which it is grown (Avelino et al., 2005; Kurniawan et al., 2015; Rodrigues, et al, 2009).

3.2.5 Protein

Even though coffee is not one of the vegetable products that produce protein, there is still protein present in coffee beans, which can assist the body in satisfying its requirements for protein. According to the investigation findings, the following is the composition of the Robusta coffee at the location in Figure 5.

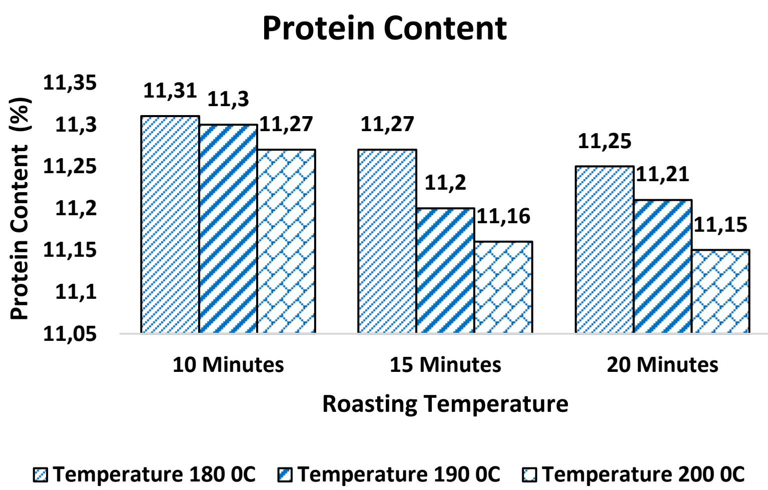

Figure 5. Protein Content Robusta Coffee

According to Figure 5, it is known that the protein content in the coffee powder drops both the more it is heated and the longer it is heated, and the percentage also decreases the longer it is heated. The Millar reaction during the roasting process of coffee is responsible for the unusually low protein level of Robusta coffee powder, which averages 11.24 per cent. This is because of the Millar reaction. When coffee is roasted, the proteins in the coffee beans contribute to the development of a bitter flavor; the smaller the percentage of protein in the beans, the more bitter the coffee will be (Fitriyah et al., 2021). Denatured proteins can also result from being exposed to high temperatures, which can induce a shift in the three-dimensional structure of protein molecules. The denaturation process can lower the capacity of proteins to carry out their intended functions in the body, as well as the amount of protein accessible for the body to take in. The protein found in coffee is often composed of basic amino acids like glutamic acid, aspartic acid, and serine, among others. Protein is one of the macronutrients that may be created from a combination of various elements, including carbon (C), hydrogen (H), oxygen (O), and nitrogen (N).

4 Conclusion

The Robusta coffee beans exhibit an average weight of 0.27 grams per individual bean, with a geometric dimension (GM) measuring 10.3 millimeters. Notably, a quantity of 368 coffee beans is present in every 100 grams of Robusta coffee. As the roasting process unfolds, there is a decline in the levels of juice, caffeine, glucose, and protein, which is more pronounced with prolonged roasting time and higher temperatures. The reduction in these components can be attributed to the effects of heat, causing evaporation and denaturation. Concurrently, the ash content increases proportionally to the applied temperature and duration of roasting. Elevated ash content signifies that the coffee beans were harvested at complete maturity, and it also suggests well-executed processing, indicative of minimal damage to the coffee beans.

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