THE CHEMICAL CHARACTERISTICS OF ARABICA AND ROBUSTA GREEN COFFEE BEANS FROM GEOPARK RINJANI, INDONESIA

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ABSTRACT

Green coffee beans are also called unroasted coffee beans. The chemical composition of green coffee beans plays a vital role in determining the final product's aroma. The main objective of this research was to characterize the chemical properties of Arabica and Robusta green coffee beans grown in different regions of Geopark Rinjani, Lombok Island, Indonesia. The water, ash, protein, carbohydrate, total solids, and caffeine contents, total acidity, and pH were determined. Data were analyzed by analysis of variance. The results revealed significant differences in the moisture contents of Arabica beans from Sembalun, Sajang, and Sapit and Robusta beans from Rempek, Selelos, and Genggelang. Additionally, the ash contents of Arabica Sajang and Arabica Sapit showed notable differences compared to other samples. However, the total fat contents of Arabica Sajang, Arabica Sapit, Robusta Rempek, and Robusta Genggelang did not exhibit significant variations. On the other hand, significant differences were observed in the protein contents of all samples, particularly between Arabica Sembalun and Arabica Sapit, compared to Arabica Sajang, Robusta Rempek, Robusta Genggelang, and Robusta Selelos. Robusta coffee beans appeared to have a slightly lower pH than Arabica beans. The latter exhibited consistent acidity in the range of 0.20–0.21, whereas the former showed higher acidity levels (0.23–0.25). Arabica beans had a lower caffeine content, averaging 1.09%, whereas Robusta beans exhibited an average caffeine content of 2.09%. This research provides valuable insights into the chemical composition of green coffee beans from different species and locations within Geopark Rinjani, contributing to a better understanding of the factors influencing the aroma and quality of coffee.

Keywords: arabica coffee, geopark rinjani, green coffee bean, robusta coffee

INTRODUCTION

There are 130 coffee species identified worldwide but only two are responsible for most of the global coffee trade. *Coffea arabica* L. and *Coffea canephora* account for approximately 60–65% and 35–40% of the global coffee production, respectively. The coffee industry is a substantial contributor to the global economy, with an annual production of approximately 10 million tons and an income of approximately USD 200 million. This industry also supports the livelihoods of millions of smallholder farmers, who account for approximately 60% of coffee farms in tropical regions (Cassamo *et al.* 2022).

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The quality of coffee beans is primarily determined by their physical and chemical properties, which are closely linked to the coffee species/genotype, microclimate conditions during the fruit and bean maturation process, soil characteristics, and agricultural crop management practices. Environmental conditions during fruit development also substantially affect the final bean quality (Ahmed *et al.* 2021). Shade and altitude positively affect coffee bean quality and are vital in producing high-quality coffee. Higher altitudes and shade at lower altitudes may enhance the physical and chemical properties of the beans as a result of the lower temperatures and higher air humidity. These climate conditions can extend the fruit and bean maturation period, increasing the accumulation of sugars and aroma-related phenolic compounds. In addition, Mendes *et al.* (2022) reported that beans grown at higher altitudes tend to have higher levels of sugars, lipids, amino acids, trigonelline, and chlorogenic acid isomers, leading to higher-quality coffees compared to beans from lower altitudes. By contrast, coffees of the same genotype grown at lower altitudes have lower quality and lower levels of the abovementioned compounds.

The chemical composition of green coffee beans plays a vital role in determining the final product's aroma. The Maillard reaction, which occurs during roasting, is the primary process that generates aroma through a reaction between amino acids and reducing sugars, forming nitrogenous heterocycles and brown melanoidins. This non-enzymatic browning generates many volatile compounds that shape the sensory experience of coffee. Arabica has a sweet, caramel-like aroma when roasted, whereas Robusta has an earthy, spicy aroma. Arabica contains higher levels of sucrose, which are essential for developing organoleptic properties and enhancing aroma formation in coffee (Liu *et al.* 2019). In addition, the caffeine content varies among the different cultivars and species. This variability can also be seen in other parts of the coffee plant, with the highest levels of caffeine found in the beans, flowers, and leaves. Additionally, it was reported that younger plant tissues contain more caffeine than mature parts (Dessalegn *et al.* 2008).

The main objective of this study was to characterize the chemical properties of Arabica and Robusta green coffee beans grown in different regions of Geopark Rinjani, located on the island of Lombok, Indonesia. This is an important geological and natural heritage site that UNESCO has recognized as a Global Geopark. The Geopark Rinjani-Lombok covers five districts/cities: North Lombok, East Lombok, Middle Lombok, West Lombok, and Mataram City. The altitude of the region where samples were collected was between 500 and 1500 meters above sea level (masl) (Figure 1). The parameters analyzed were the moisture, ash, protein, carbohydrate, total solid, and caffeine contents, total acidity, and pH. This is the first report on the chemical composition of green coffee beans from this region.

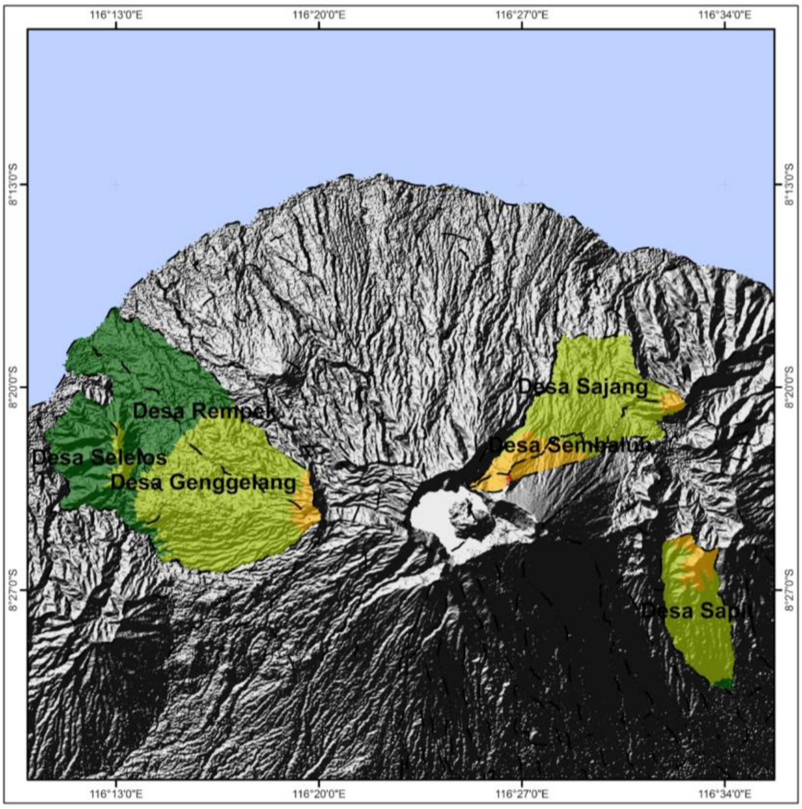

Figure 1 Distribution map of Arabica and Robusta green coffee bean plantations in Geopark Rinjani, Lombok Island, Indonesia. The different colors indicate different altitudes: dark green (0–500 m), light green (500–1500 m), and light brown (1500–2500 m).

MATERIALS AND METHODS

Materials

Arabica green bean samples were collected from various coffee-growing locations in Geopark Rinjani, Lombok, Indonesia. The Arabica coffee beans were from the Sembalun, Sajang, and Sapit regions, East Lombok. Meanwhile, Robusta green beans were collected from the Rempek, Selelos, and Genggelang regions, North Lombok Regency. Other materials used in this research were distilled water, Kjeldahl tablets, H_2SO_4, 0.1 N NaOH, a standard caffeine solution, Na_2CO_3, chloroform, a catalyst, boric acid, a phenolphthalein indicator, and diethyl ether. The tools used included Soxhlet extraction equipment, a drying oven (UNB 400, Memmert), a pH meter, a chromameter (MSEZ), a spectrophotometer, a weighing scale, and a blender.

Sample preparation

All green beans went through natural processing by drying for 2–3 weeks. The green beans were ground using a blender. Then, the ground coffee was sifted using a 40-mesh sieve. Fine powders from Arabica and Robusta green bean samples were packaged in aluminum foil Ziplock bags (approximately 100 g per sample per package) for further analysis.

Research design

A randomized block design (RBD) was used with a grouping of six samples, with the single factor being green beans from villages around Geopark Rinjani. Each sample comprised four replicates, resulting in 24 experimental units. The observed parameters were pH (AOAC, 1980), moisture content (AOAC, 1996), total fat content (AOAC, 2005), ash content (AOAC, 2000), protein content (AOAC, 2005), carbohydrate (by difference) (AOAC, 2005), total solid content (AOAC, 2005), total acidity (AOAC, 2005), and caffeine content (AOAC, 2005).

RESULTS AND DISCUSSION

Moisture content

The moisture content of coffee beans is essential as it can affect the taste, aroma, and overall quality of the coffee. Figure 2 shows that the moisture content of the Arabica samples (collected from Sembalun, Sajang, and Sapit) was significantly different compared to that of the Robusta samples (collected from Rempek, Selelos, and Genggelang). The Arabica sample from Sembalun was significantly different from those from Sajang and Sapit. However, there were no significant differences in the moisture contents of the Robusta samples.

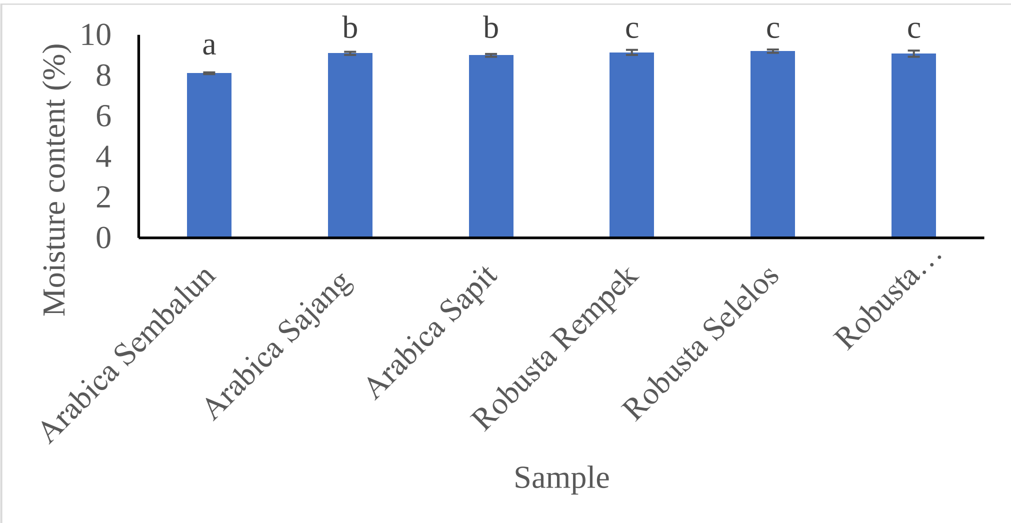

Figure 2 The moisture content of Arabica and Robusta green beans from different regions of Geopark Rinjani, Lombok Island, Indonesia. Different letters indicate significant differences ($P \leq 0.05$).

For the Arabica samples, the water content ranged from 8.11% to 9.09%, with the highest value corresponding to the Sajang sample. However, the water content in the Robusta samples was slightly higher, ranging from 9.07% to 9.20%. The highest value was found in the Selelos sample. The moisture contents of the Arabica and Robusta green beans met the requirement in the Indonesian standard (SNI 01-2907-2008), which states that the maximum moisture content of the green beans should be 12%.

It is essential to monitor the water content of green coffee beans as it can affect various aspects of coffee quality, such as flavor and aroma during storage and roasting. In addition, Reh *et al.* (2006) reported that the moisture content is considered the essential quality factor for green coffee, as it affects fermentation and mold growth during storage and transportation, potentially causing undesirable flavors or the formation of mycotoxins. The water content of the coffee bean can also vary depending on the specific growing conditions, processing methods, and storage conditions (Collazos-Escobar *et al.* 2020). The variability in the moisture content of the Arabica samples may be related to different environmental conditions in each planting area where the samples were obtained and also to differences during processing.

Ash content

The ash contents of the Arabica and Robusta green coffee beans were measured, and the results are shown in Figure 3. The ash content ranged from 4.5072% to 5.5182% for the Arabica samples, with the lowest value observed in the Sajang sample. The ash content of Arabica Sajang and Arabica Sapit was significantly different compared to that of other samples. However, the ash contents of Robusta Rempek, Robusta Selelos, and Robusta Genggelang were not significantly different.

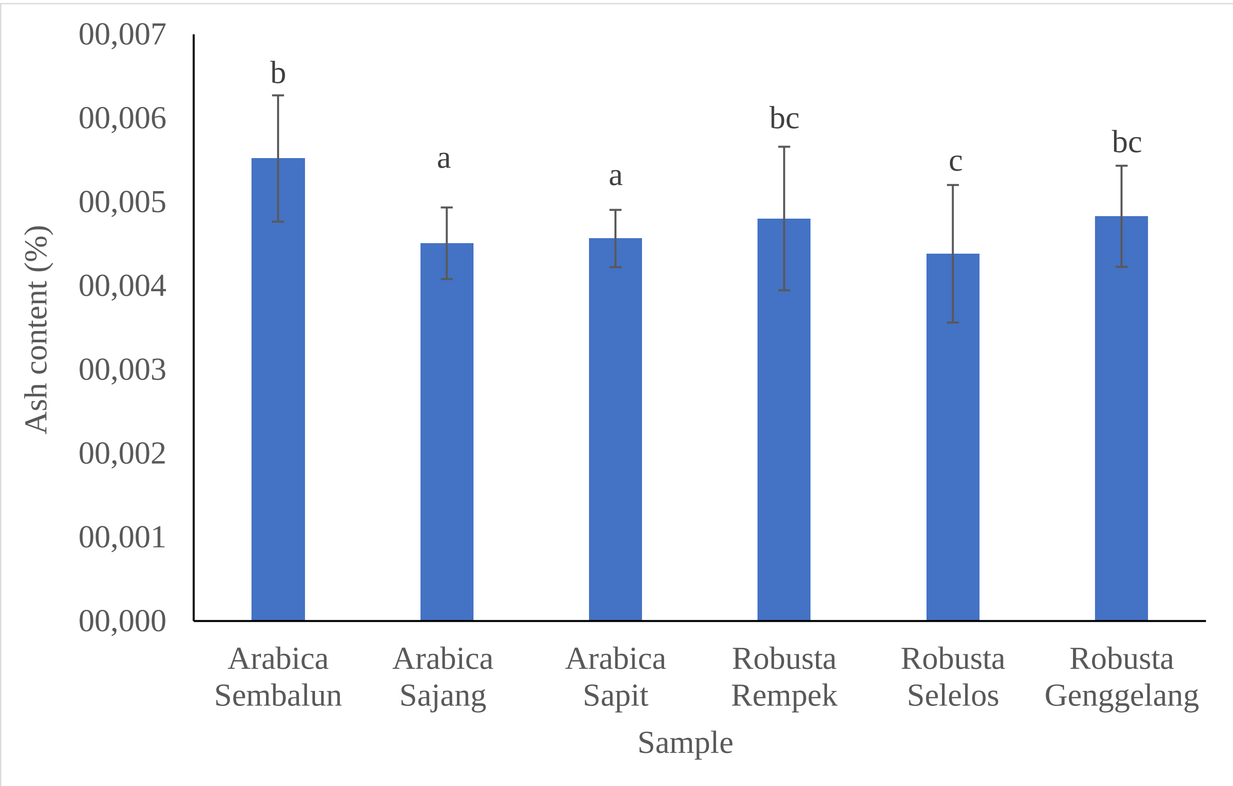

Figure 3 The ash content of Arabica and Robusta green beans from different regions in Geopark Rinjani, Lombok Island, Indonesia. Different letters indicate significant differences ($P \leq 0.05$).

The ash content of coffee beans is an essential factor to consider as it can provide information on the quality and processing of the beans. A high ash content may indicate the presence of impurities, whereas, a low ash content may indicate under-roasting or poor-quality beans. Pizarro *et al.* (2004) reported that the ash content in coffee beans reflects the mineral content in the beans. A high ash content may indicate a high mineral content. The high ash content in the Arabica sample from Sembalun may be associated with the mineral content of the soil in the planting area because this is the closest area to Mount Rinjani, a volcano that erupted. Additionally, impurities and residual silver skin may also affect the ash content. Differences in the origin of raw materials, such as the maturity of the beans and environmental factors that may be related to chemical characteristics or other aspects of the soil are external factors that affect the ash content in coffee beans.

Total fat content

The lipid component in coffee beans is primarily found in the endosperm. Although the Indonesian National Standard does not use fat content to assess the quality of green beans, lipids are closely associated with coffee quality, and their content may differ among coffee cultivars.

Figure 4 shows the variations in the total fat contents of the different coffee species and growing areas for the same species. Arabica Sembalun had the lowest total fat content (9.86%), whereas Robusta Selelos had the highest total fat content (18.97%). The data also showed that the total fat contents of Arabica Sajang, Arabica Sapit, Robusta Rempek, and Robusta Genggelang were not significantly different. Robusta coffee beans are known for their strong and bold flavor, which is possibly related to their higher lipid content. The obtained result also suggests that the lipid content can vary considerably among different coffee genotypes and may be influenced by factors such as the specific growing and processing conditions, including the drying time. Benoit *et al.* (2006) reported that the lipid content in coffee beans increases with an increase in the altitude of the growing area.

The total fat content of coffee beans can affect the overall quality and taste of coffee. Lipids contribute to the aroma and flavor of coffee. Thus, a higher lipid content can result in a more intense and complex aroma and flavor. However, a higher lipid content also results in greater susceptibility to rancidity, which can negatively affect the flavor and aroma of coffee.

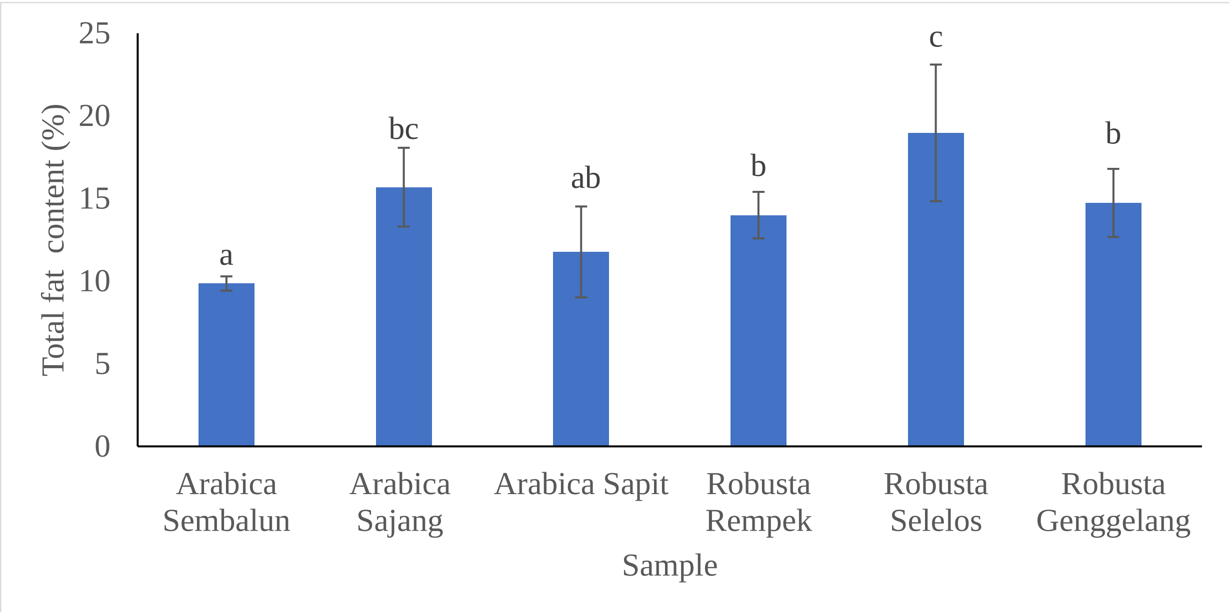

Figure 4 The total fat content of Arabica and Robusta green beans from different regions in Geopark Rinjani, Lombok Island, Indonesia. Different letters indicate significant differences ($P \leq 0.05$).

Protein content

As illustrated in Figure 5, the protein contents of the samples showed significant differences. The protein content of the Robusta beans appeared to be higher than that of the Arabica beans. The protein content of Arabica coffee beans was between 11.06 and 12.02%, whereas the Robusta coffee beans contained protein levels ranging from 13.55 to 14.50%. Arabica Sembalun had the lowest protein content among all the samples, whereas Robusta Selelos had the highest protein content. The differences in protein content among the different coffee varieties may be due to various factors, such as the growing conditions, genetics, and post-harvest and processing methods (Wibowo *et al.* 2021). According to Marcone (2004), differences in the protein contents of green coffee beans may be due to variations in the maturity level of the coffee fruit, leading to diverse chemical compositions. The average protein content in dried green coffee beans ranges from 8% to 12%. Arabica Sapit green beans underwent the longest drying process, as it took three weeks, compared to other green beans, which only took two weeks to dry. Prolonged drying or sun-drying can result in protein degradation. In excessive natural fermentation during prolonged drying, microorganisms can use the protein in coffee beans as well as other nutrients such as carbohydrates and fats as energy sources (Wibowo *et al.* 2021).

Total carbohydrate content

Carbohydrates are essential components in coffee. Figure 6 shows the total carbohydrate contents of Arabica and Robusta green coffee beans from different growing areas. The results revealed that the carbohydrate contents of Arabica Sembalun and Arabica Sapit were significantly different than those of Arabica Sajang, Robusta Rempek, Robusta Genggelang, and Robusta Selelos. Among the coffee bean samples, the highest carbohydrate content was found in Arabica Sembalun (65.46%), whereas the lowest carbohydrate content was found in Robusta Selelos (52.95%). The data suggests that Arabica beans tend to have a higher carbohydrate content than Robusta beans. However, there was considerable variation in the two types of coffee, as indicated by the high standard deviation values.

The carbohydrate content can affect the flavor of roasted coffee, as it is responsible for the formation of desirable flavors during the roasting process. Furthermore, the carbohydrate composition can also affect the functional properties of the final product, such as the body and mouthfeel of coffee. Therefore, a higher carbohydrate content may contribute to a more full-bodied and smoother coffee, whereas a lower carbohydrate content may result in a lighter and more acidic coffee. However, the correlation between the carbohydrate content and coffee flavor profile is complex and can be affected by many factors (Arya & Rao 2007).

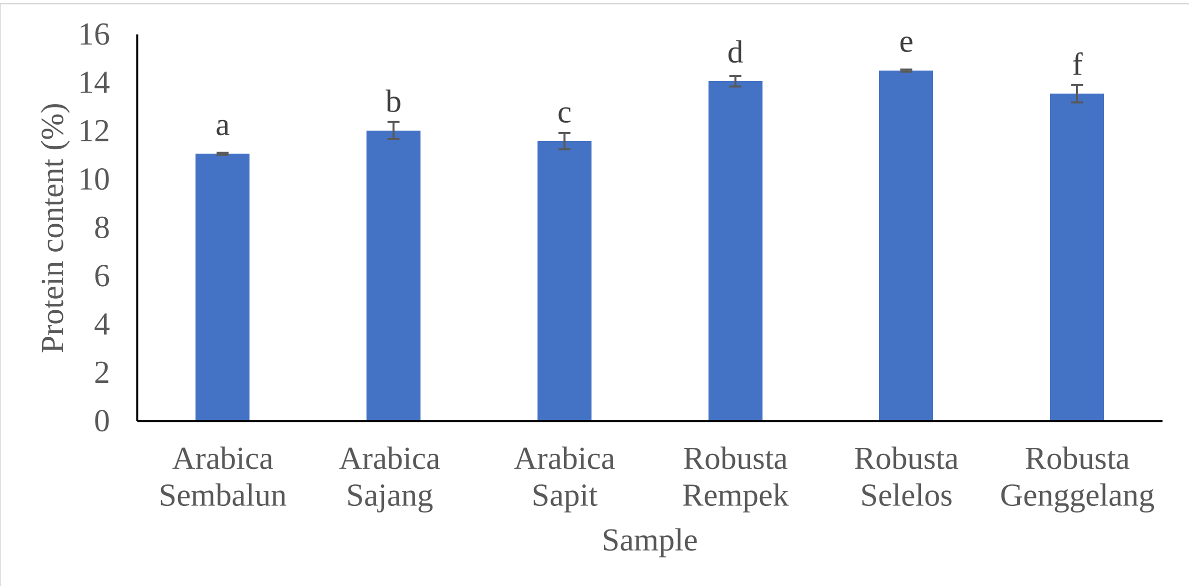

Figure 5 The protein content of Arabica and Robusta green beans from different regions in Geopark Rinjani, Lombok Island, Indonesia. Different letters indicate significant differences ($P \leq 0.05$)

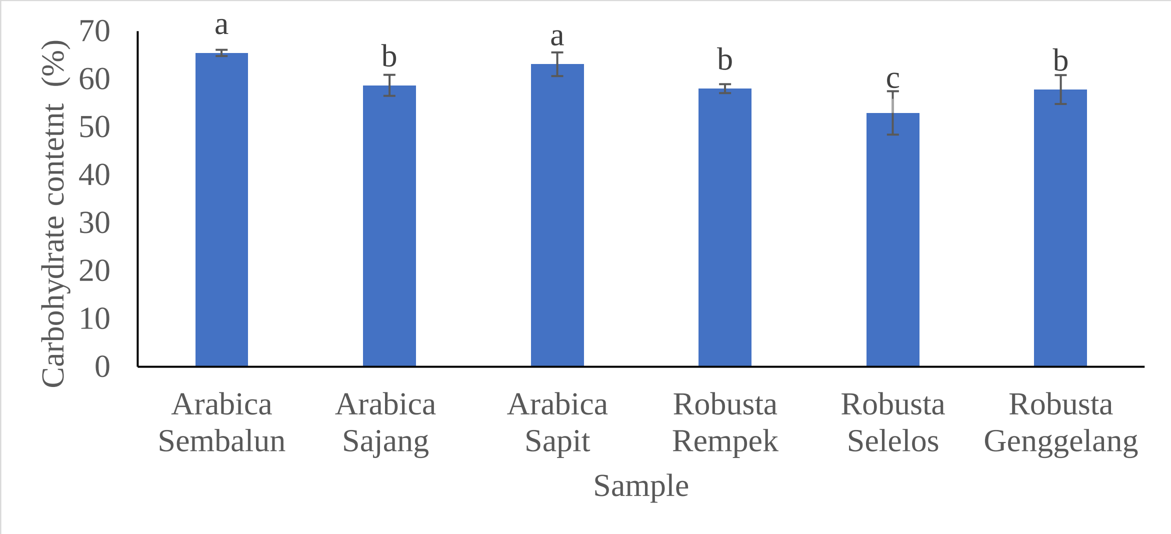

Figure 6 The total carbohydrate content of Arabica and Robusta green beans from different regions in Geopark Rinjani, Lombok Island, Indonesia. Different letters indicate statistically significant differences ($P \leq 0.05$)

pH

As shown in Figure 7, Arabica Sembalun has the highest pH (5.81) among the Arabica samples. Arabica Sajang and Arabica Sapit have slightly lower pHs, at 5.55 and 5.33, respectively. The Robusta samples have slightly higher pHs, with Rempek having the lowest (5.4675), followed by Selelos (5.4525), and Genggelang (5.595). These data suggest that the pHs of the Arabica beans from three different locations were more consistent than those of the Robusta beans, as indicated by their lower standard deviations. Moreover, the Robusta coffee bean samples appeared to have a slightly lower pH than the Arabica samples. Saputri et al. (2020) reported that Arabica Gayo coffee beans have an average pH of 5.66, which is slightly higher than that of Robusta Gayo coffee beans (4.89). However, Lee *et al.* (2017) reported that the pH of Arabica coffee beans is lower (4.60–5.60) than that of Robusta coffee beans (5.30–6.10).

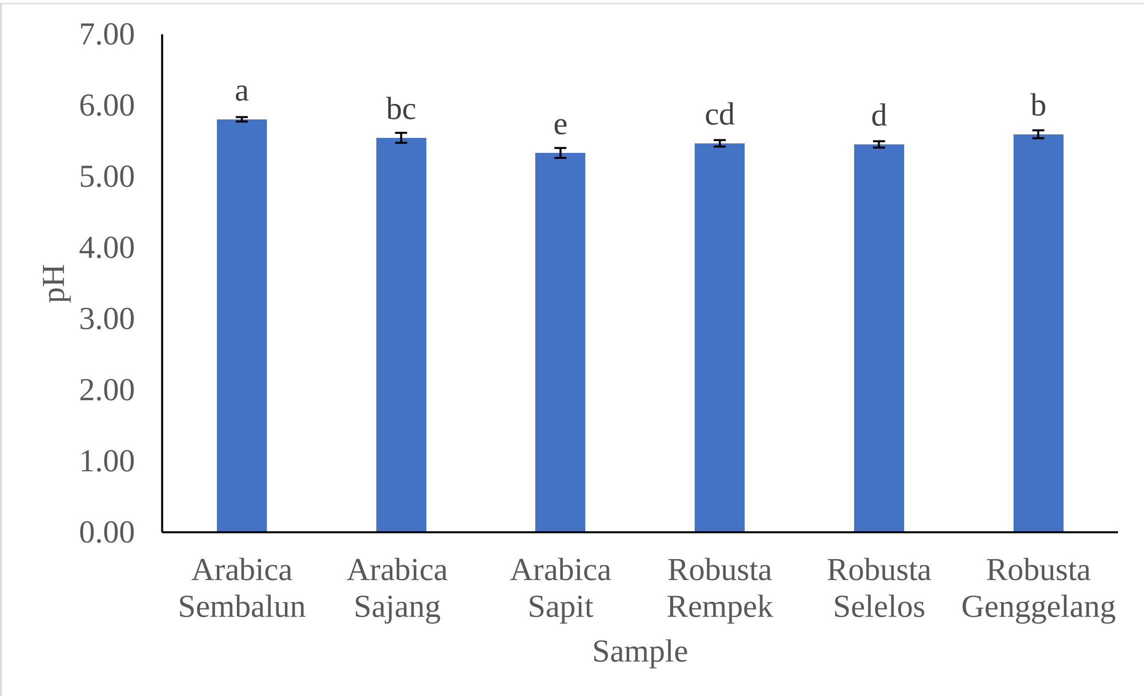

Figure 7 The pH of Arabica and Robusta green beans from different regions in Geopark Rinjani, Lombok Island, Indonesia. Different letters indicate significant differences ($P \leq 0.05$)

The pH of coffee beans is influenced by acidic compounds, specifically carboxylic acids. These acids are present in the free form after their release by the breakage of glycoside bonds. Variations in the pH values of coffee may be influenced by the location where the plants are grown. Sajang Village has andosol soils and is located in Geopark Rinjani at an altitude greater than 800 masl; its soil pH ranges from acidic to neutral (pH 5.0–7.0). Meanwhile, Sapit Village has regosol soils. Based on its geography, Sapit Village has a 25–40% slope and less than 2500 mm/year of rainfall with a soil pH ranging from 6 to 7. On the other hand, Rempek, Selelos, and Genggelang, where the Robusta samples were obtained, have inceptisol soils with a thick layer of approximately 1–2 m and pH in the range of 5.0–7.0. The three soil types in the coffee-growing areas of Geopark Rinjani-Lombok are derived from the volcanic ash of Mount Rinjani, and the pH ranges from 5 to 7.

Total acidity

The acidity of coffee beans is essential as it can affect the flavor profile. Generally, Arabica beans are considered to have a milder and more nuanced flavor, whereas Robusta beans are known for their bold and robust flavor. The difference in acidity levels between these two types of beans may contribute to these distinct flavor profiles.

Figure 8 shows that the Arabica and Robusta coffee samples from different regions in Geopark Rinjani had distinct acidity levels. The Arabica samples had similar acidity levels, ranging from 0.20 to 0.21, whereas the Robusta samples had higher acidity levels, ranging from 0.23 to 0.25. These differences in acidity may be due to variations in the growing conditions of the different samples, such as soil composition and climate, as well as genetic differences between the Arabica and Robusta coffee plants. Towaha *et al.*, (2014a) proposed that altitude affects the acidity level of Arabica coffee beans.

The processing methods and roasting techniques can also influence the acidity of coffee beans. According to Kasim *et al.* (2020), the titrated acidity in the dry-processed Robusta coffee is 3.65%, whereas in the wet-processed Robusta coffee is 3.42%. On the other hand, according to Winarno *et al.* (2021), the free acidity in dry-processed Arabica coffee is approximately 0.05%, and that of wet-processed Arabica coffee is approximately 0.07%.

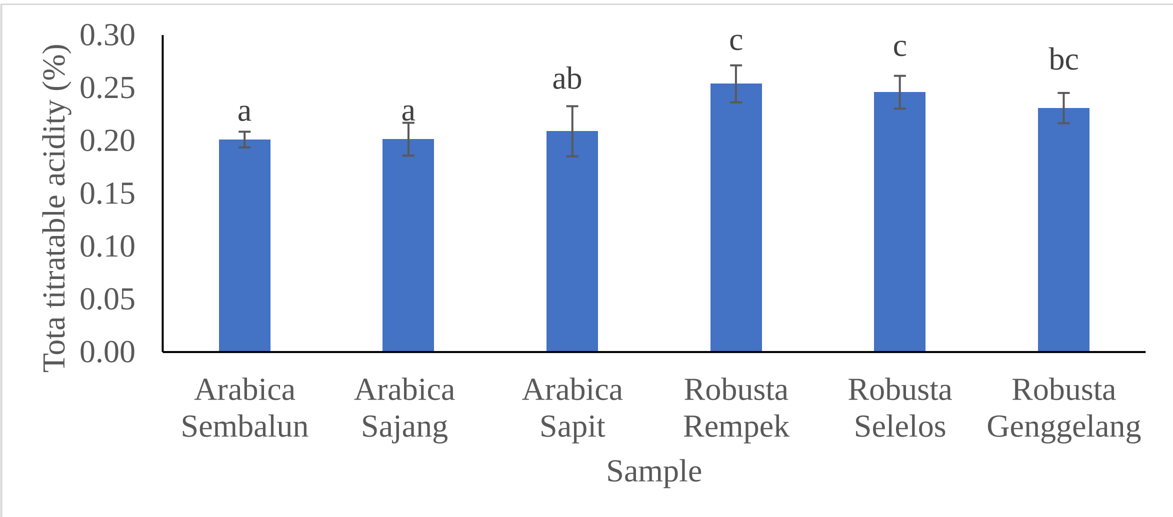

Figure 8 The total acidity of Arabica and Robusta green beans from a different region in Geopark Rinjani, Lombok Island, Indonesia. Different letters indicate significant differences ($P \leq 0.05$)

Total solid content

The total solid content refers to the percentage of dry matter in the coffee beans, indicating the quality and taste of coffee. Arabica Sembalun had the lowest total solid content (4.43%), whereas, Arabica Sajang had the highest total solid content (7.45%). Moreover, Robusta Rempek had a total solid content of 7.275% (Figure 9). The total solid content can affect the flavor of coffee. Saputri *et al.* (2020) reported that Robusta coffee beans showed a higher total solid content compared to Arabica coffee beans. This result was consistent with the lower levels of organic acids and amino acids found in Arabica coffee beans compared to Robusta coffee beans. The total solid content can consist of organic acids, amino acids, and simple carbohydrates, which can contribute to the taste and aroma formation of coffee during the roasting process.

Caffeine content

Caffeine, one of the most well-known compounds found in coffee, plays an important role in the strength, body, and bitterness of coffee, and is responsible for many of the physiological effects associated with coffee consumption (Buffo and Cardelli-Freire 2004). Figure 10 shows a significant difference between the caffeine of Arabica and Robusta coffee beans produced in Geopark Rinjani. Arabica beans had a lower (avg. 1.09%) caffeine content than Robusta beans (avg. 2.09%). This result aligns with the general understanding that Arabica beans typically have a lower caffeine content than Robusta beans. Moreover, the data shows that there were variations in the caffeine contents of beans of the same species but from different areas, which can be attributed to factors such as growing conditions, processing methods, and genetics. Towaha *et al.* (2014) also reported that Arabica coffee beans produced at different altitudes exhibited different caffeine levels.

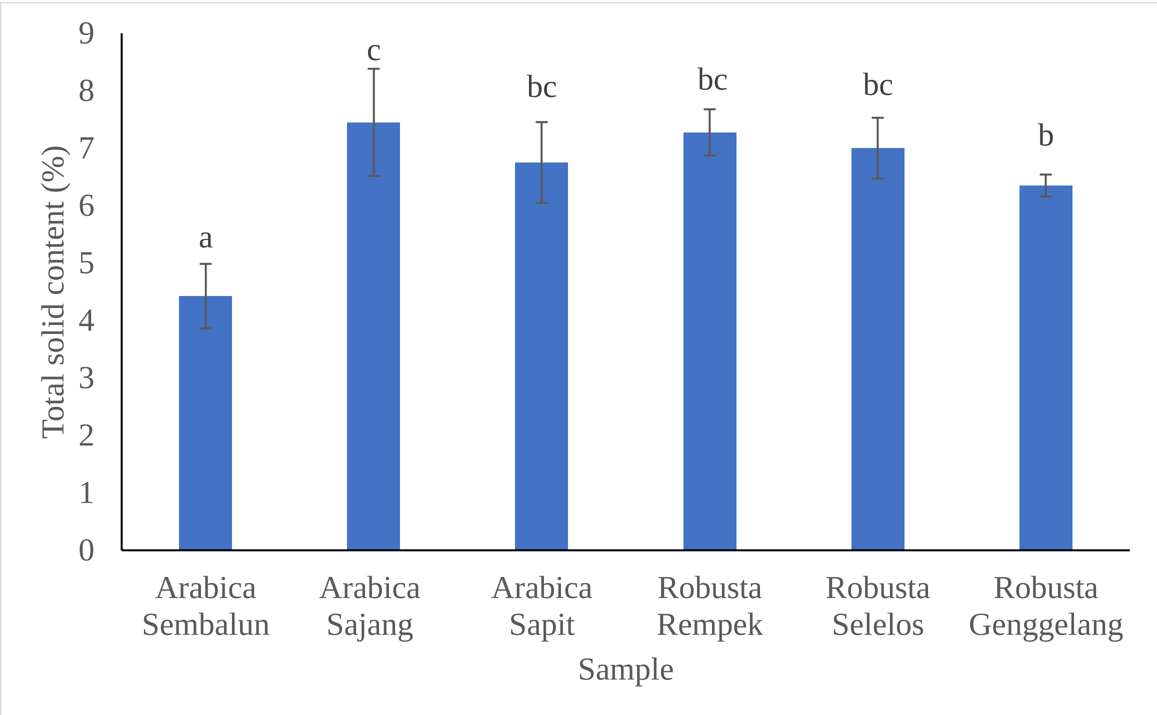

Figure 9 The total solid content of Arabica and Robusta green beans from different regions in Geopark Rinjani, Lombok Island, Indonesia. Different letters indicate significant differences ($P \leq 0.05$)

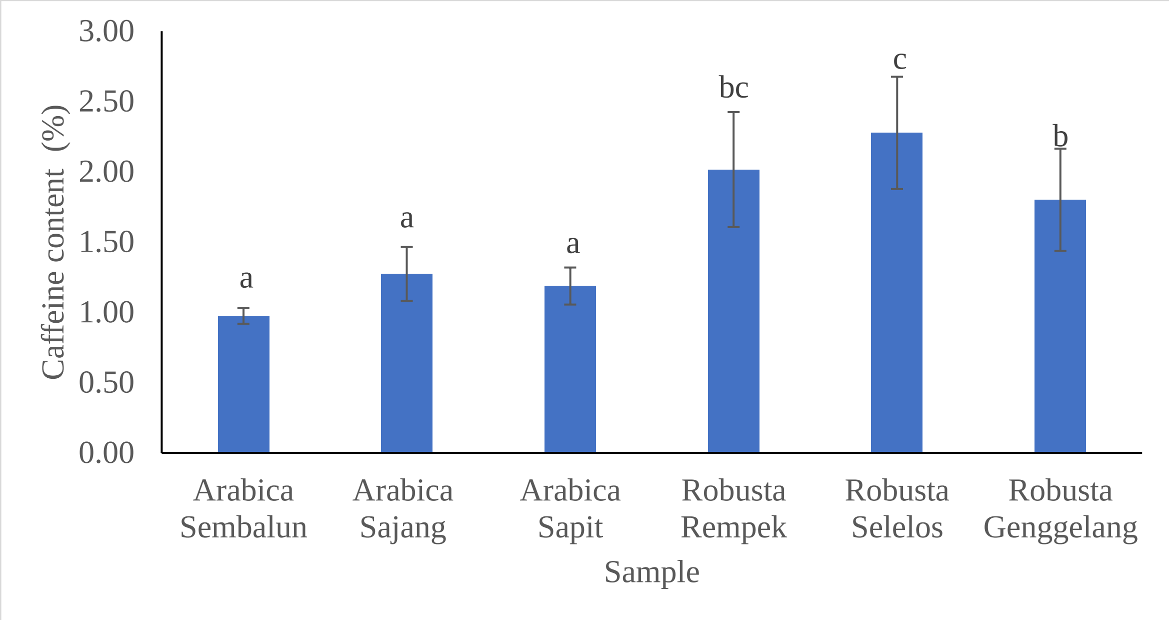

Figure 10 The caffeine content of Arabica and Robusta green beans from different regions in Geopark Rinjani, Lombok Island, Indonesia. Different letters indicate significant differences ($P \leq 0.05$)

According to Clemente *et al.* (2013), the chemical elements in the soil (particularly potassium, K) can affect the caffeine content of coffee beans. K plays an essential role in coffee plant reproduction, especially in the size and yield of coffee beans. In addition, K affects the taste of coffee by activating the polyphenol oxidase enzyme and determining the caffeine and phenol content in coffee beans. Moreover, the caffeine content is not only influenced by the growing location but may also be affected by the processing methods (Zhang *et al.* 2013).

CONCLUSION

The chemical composition of Arabica and Robusta coffee beans was found to be significantly ($P \leq 0.05$) different. Arabica beans have a lower pH, acidity, and caffeine content than Robusta beans. Meanwhile, Robusta beans have a higher total solid content than Arabica beans. These results suggest that the growing conditions, processing methods, and genetics of coffee beans determine their chemical composition, which in turn can contribute to the distinct flavor profiles of Arabica and Robusta coffee beans.

ACKNOWLEDGMENTS

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