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Effect of Variations of Roasting Temperature on the Physicochemical Properties of Robusta Coffee (*Coffea canephora L.*)

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ABSTRACT

Robusta coffee has become the most planted coffee in Indonesia and a vital commodity. Robusta coffee is characterized by a more caffeine content, bitter taste, and slightly more acidic compared to that of Arabica coffee. The roasting process is important factors contributing to shape taste, aroma, and the physical characteristics of coffee beans. This study seeks to compare the physicochemical properties of Robusta coffee originated from West Lampung and Tanggamus, and to assess the impact of roasting temperature (light at 190°C, medium at 200°C, and dark at 210°C). Measurement was conducted in duplicate. The findings indicated significant differences ($p<0.05$) in ash content, moisture content, and pH between coffee from West Lampung and Tanggamus, while color and caffeine content did not differ significantly ($p>0.05$). The geographic origin of coffee beans influences their physicochemical properties. Moreover, all examined parameters (ash content, moisture content, pH, color, and caffeine content) show a direct relationship with the roasting temperature. Consequently, roasting temperature plays a pivotal role in shaping the physicochemical properties of coffee beans.

1. INTRODUCTION

Coffee is a staple for Indonesian society across all demographics, with a percentage of coffee enthusiasts in Indonesia reaching 57% (Hamni, 2013). Following Vietnam, Brazil, and Colombia as the world's top coffee producers, Indonesia comes in at number four (Budi *et al*., 2020). According to data from the Central Statistics Agency (BPS) in 2021, coffee production in Indonesia has increased over the past three years. Indonesia produced 752,510 tons of coffee in 2019, with 1.31% increase in 2020 to 762,200 tons, and a further increase in production to 774,600 tons in 2021 (BPS, 2021). The percentage of coffee planted in Indonesia is 90% for Robusta coffee and 10% for Arabica coffee (Edowai, 2019).

Robusta coffee (*Coffea canephora L*) in several studies has shown considerable resistance to disease attacks. Therefore, Robusta coffee has become one of the most planted types of coffee in Indonesia and a leading commodity. Robusta coffee is characterized by a higher caffeine content, bitter taste, and slightly more acidic as compared to Arabica coffee (Budi *et al*., 2020). The bitterness in coffee arises from the roasting process, where pyrolysis occurs, resulting in chemical changes in the coffee, including the degradation of rough fibers, formation of volatile compounds, evaporation of acidic substances, and the formation of coffee aroma (Sutarsi *et al*., 2016; Afriliana, 2018).

The roasting process is one of the factors contributing to coffee's bitter taste and also affects the physical characteristics of coffee beans. The roasting process is the formation of taste and aroma released through heat treatment over a specified period, allowing the resulting coffee product to emit desired aroma and preferred flavor by consumers (Poerwanty *et al*., 2020). Darker roasting results such as medium and dark roasts will produce roasted aroma and bitter taste from roasting (Caporaso *et al*., 2022).

Caffeine ($C_8H_{10}N_4O_2$) compound, which is part of the coffee compound, occurs naturally in coffee beans. Consuming coffee can have beneficial effects on the body by increasing focus for consumers, but excessive caffeine consumption can have negative effects on the body such as excessive heart palpitations, headaches, anxiety, restlessness, nervousness, and difficulty sleeping, as well as stomach upset (Aprilia *et al*., 2018). The high caffeine content in coffee powder can be harmful to health, so it is important to know the maximum limits for consuming caffeine (Wijayanti & Anggia, 2020). Therefore, caffeine has a maximum dose of 50 mg once and 200 mg per day (Aryadi *et al*, 2019). The BPOM Regulation No. 21 of 2016 in the food category suggests that coffee should have a caffeine content of no more than 2% (BSN, 2019). Previous studies have stated that the caffeine content in West Lampung Robusta coffee from the dry process is 1.11% (Adrianto *et al*., 2020) and Tanggamus coffee has caffeine content ranging from 0.08-2.19% (Grace, 2017). The caffeine content in coffee can also be influenced by geographical location, such as the altitude of the planting area and the conditions of the coffee planting area (Fadri *et al*., 2019).

The roasting process and geographical location of coffee-producing regions will result in different caffeine content, pH, ash content, and moisture content of coffee. This study is conducted to compare the caffeine content, moisture content, ash content, pH, and color of Robusta coffee harvested from two different regions, namely Tanggamus and West Lampung. This study also seek the effect of different roasting temperature to meet the SNI standard for powdered coffee.

2. MATERIAL AND METHODS

2.1. Research Time and Location

This research was conducted from December 2022 to March 2023 at the Chemistry and Food Nutrition Laboratory, Food Engineering Laboratory, and Engineering Laboratory of the Sumatera Institute of Technology.

2.2. Material and Equipment

The materials used in this research were green coffee beans obtained from West Lampung and Tanggamus, anhydrous caffeine from pharma lab, chloroform ($CHCl_3$) (emsure), sodium carbonate (Na_2CO_3) (pudak scientific), laboratory standard alcohol, laboratory standard distilled water, V60-01 filter paper sized 20-25 µm. The equipment used in this research included a roaster (Wiliam Edison, W600i SE), 250 mL glass beaker (pyrex), 250 mL erlenmeyer flask (pyrex), 10 mL volume pipette (pyrex), 250 mL separating funnel (pyrex), 10 mL, 25 mL, and 100 mL volumetric flasks (pyrex), 50 mL volumetric flask (pyrex), rotary evaporator (RV 10 Digital V, IKA), analytical balance (biobase), hot plate type S-301 (Maspion), spectrophotometer (UV-Vis double beam, biobased), pH meter type PH-920 (biobased), desiccator (Duran), chromameter (CR400, konica Minolta), oven (memmert), muffle furnace (memmert), and cups.

2.3. Preparation of Materials

Coffee was obtained from West Lampung (-5.025367, 104.067886) and Tanggamus (-5.349618, 104.717173) in the form of dried coffee. The coffee was divided based on control treatment or without undergoing roasting process and roasting temperature levels, namely light roast with a temperature of 190 °C, medium roast with a temperature of 200 °C, and dark roast with a temperature of 210 °C for 10 min for each roasting type. The temperature tolerance for each roasting was ±2 °C. Sample preparation was conducted twice for each roasting temperature level.

2.4. Analysis Procedure

The following are the procedures for analyzing caffeine, moisture content, pH level, color test, and ash content.

2.4.1. Caffeine Content Determination

A caffeine standard solution of 10 mg was placed into a 100 mL volumetric flask and dissolved using hot distilled water up to the mark, resulting in a standard solution concentration of 100 mg/L. The concentrations of standard solutions used were 2.5; 5; 7.5; 10; 12.5 mg/L. These standard solution was measured using a spectrophotometer (UV-Vis double beam, biobased) at a maximum wavelength of 285 nm, and the calibration curve was constructed to establish the equation to calculate caffeine content from the absorbance.

One gram of coffee powder sample dissolved in 100 mL hot water. By using filter paper and a funnel sit on an Erlenmeyer flask, the solution was filtered. One gram of Na_2CO_3 powder was added to the solution and placed into a separating funnel, then extracted for 3 cycles with the addition of 25 mL chloroform. The chloroform fraction at the bottom layer was collected and evaporated using a rotary evaporator to obtain caffeine extract. This extract was transferred into a 50 mL flask and diluted by adding distilled water. More dilution was performed by pipetting 2 mL of the solution into a 50 mL flask and added with distilled water up to the mark. The absorbance of the solution was read at a wavelength of 285 nm (Rabani & Fitriani, 2022). The caffeine content was calculated using the following formula:

$$Caffeine\ content\ (mg/g) = \frac{\text{Concentration}\ \left({}^{mg}/_{L}\right)\ x\ Dilution\ Volume\ (L)\ x\ FP}{\text{Sample Weight (g)}} \tag{1}$$

where Concentration (mg/L) is calculated from linear regression equation ($y = bx + a$), and FP is the dilution factor (Fajriana & Fajriati, 2018)

2.4.2. Moisture Content Test

Moisture content was analyzed according to the procedure in AOAC (2005). Two gram of sample was placed into a pre-weighed cup and then heated at 105 °C in an oven. The sample was cooled in a desiccator for 30 min, and reweighed. This step was repeated until a constant weight was obtained. Moisture content was calculated using initial weight (W_1) and final weight (W_2) according to (AOAC, 2006):

$$Moisture\ Content(\%) = \frac{W_1 - W_2}{W_1} \times 100\% \tag{2}$$

2.4.3 pH Test

pH testing was performed according to the pH test procedure in AOAC, 2005. Sample measurement using a pH meter began with pH meter neutralization for 15-30 min to obtain a neutral pH of 7. Ten gram of coffee was diluted with 100 mL pre-heated distilled water at 100 °C. The diluted sample was cooled, and the precipitate was separated using filter paper in a glass beaker. The dissolved sample was then measured with a pH meter by dipping it into the sample and waiting until the pH meter reading stabilized. The pH value was displayed on the pH meter monitor (AOAC, 2006).

2.4.4 Color Analysis

Color intensity measurements were conducted using a chromameter (CR400, Konica Minolta). The principle of the tool involves measuring the color difference obtained from the surface of the tested material. The color intensity was displayed as the values of L*, a*, and b*. The brightness parameter of the sample is indicated by the L* value, ranging from 0 (darker color) to 100 (lighter color). The a* value represents the reflected light causing a red-green chromatic color with a more positive a* value indicating a red color, while a more negative a* value results in a green color. The b* value indicates the chromatic mix of blue and yellow, where yellow is given by positive b* and blue is by negative b* (Indrayati *et al*., 2013). Once all L*, a*, and b* values are obtained, the ΔE calculation is carried out to observe the total color difference in the coffee.

2.4.5 Ash Content

Ash content testing was conducted following the ash content test procedure in AOAC, 1995. Three grams of coffee powder were taken and placed on a cup with known weight. The sample was heated in a muffle furnace for 5 hours at a temperature of 550 °C. After heating, the sample was placed in a desiccator for 15 minutes, and then weighed. The ash content in the sample was calculated using the following formula (AOAC, 1995):

$$Ash\ Content\ (\%) = \frac{W_2}{W_1} \times 100\% \tag{3}$$

where W_1 is sample weight before ashing (g), and W_2 is sample weight after ashing (g)

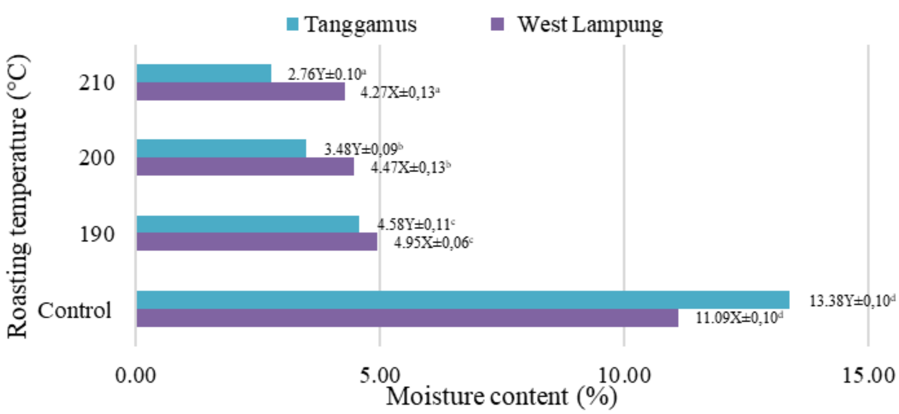
2.5 Data Analysis

The experimental design employed in this study was a Factorial Completely Randomized Design (CRD) with two factors, namely geographic origin and roasting temperature. The obtained data were analyzed using Two-Way Analysis of Variance (ANOVA) at 95% significance level (α = 0.5%) to determine if there were significant differences in each factor. If the results obtained were significant ($p \leq 0.05$), the analysis was followed by the Duncan Multiple Range Test (DMRT) at 95% significance level of (α = 5%) to observe differences among factors (Rabani & Fitriani, 2022).

3. RESULTS AND DISCUSSION

3.1 Moisture Content

The moisture content of the material is crucial as water can affect its flavor and shelf life (Tyas, 2022). Optimal moisture content needs to be achieved to maintain the quality of coffee. If the moisture content is outside the optimal range, compounds bound to the coffee beans may become prone to detachment and degradation, leading to a decrease in coffee bean quality even during storage. According to the Indonesian National Standard (SNI) for determining the quality of powdered coffee based on moisture content, the maximum allowable moisture content for coffee is 7%. The results of the moisture content of West Lampung and Tanggamus powdered coffee with different treatments, including control (without roasting process) and different roasting temperatures, are shown in Figure 1.



*X-Y Dissimilar letters indicate significant differences between West Lampung and Tanggamus.
**a-d Superscripts indicate significant differences between coffee bean treatments.

Figure 1. Moisture content of Tanggamus and West Lampung powdered coffee (control vs. different roasting temperatures)

The analysis results regarding moisture content testing indicate that there is a significant difference in moisture content among temperatures ($p < 0.05$), as well as among regions, and there is an interaction between temperature and region. The DMRT test results show that unroasted coffee (green beans) or control coffee yield significantly different results compared to other types of coffee. Control coffee refers to coffee without the roasting process. Coffee roasted at 190 °C differs significantly from coffee roasted at 200 °C. Similarly, coffee roasted at 200 °C differs significantly from coffee roasted at 210 °C.

The highest moisture content of Robusta coffee was found in the control samples (green beans) or those without roasting, with values of 11.09% for West Lampung Robusta coffee and 13.38% for Tanggamus Robusta coffee. The moisture content in the control samples of West Lampung, which had not undergone roasting, met the general requirements for coffee bean moisture content according to SNI 01-2907-2008, with a maximum moisture content limit of 12.5%. Based on Figure 1, the decrease in moisture content is directly proportional to the roasting temperature. The higher the temperature, the faster the heat transfer into the food material and more water is the evaporated from the material (Estiasih & Ahmadi, 2017), resulting in a higher decrease in coffee powder moisture content (Agustina *et al.*, 2019). This is because at higher temperatures, more materials release water and undergo some reactions including caramelization, pyrolysis, and Maillard reaction. Consistent with literature statements (Mardjan *et al.*, 2022), higher roasting temperatures lead to a decrease in moisture content due to the evaporation process.

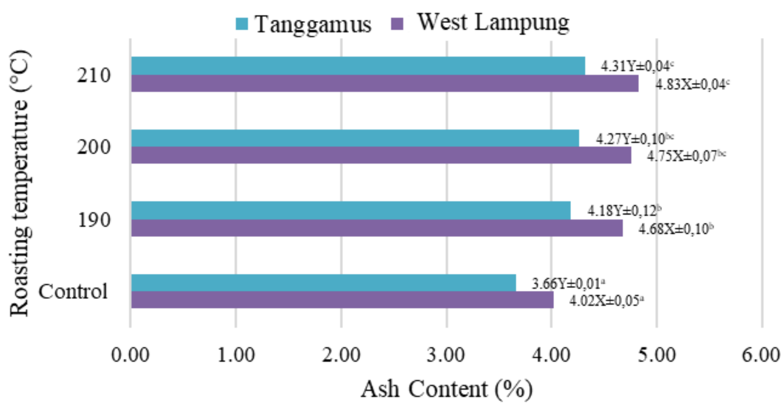
Temperature variation during roasting is a significant indicator in the drying process of a material (Budiyanto *et al.*, 2021). AT higher temperature, more water is evaporated, causing changes in the material (Cuong *et al.*, 2014). The expected moisture content of the product resulting from the treatment is the lowest moisture content. This will preserve the material's resistance to damage by microorganisms during storage (Purnamayanti *et al.*, 2017). The lowest moisture content is found in Robusta coffee powder roasted at 210°C. Overall, the moisture content of West Lampung and Tanggamus Robusta coffee powder after roasting ranges from 2.76% to 4.95%. The moisture content obtained in each treatment meets the quality requirements of powdered coffee according to SNI 01-3542-2004. Moisture content is a factor that can affect the shelf life of a product. A product with lower the moisture content has longer shelf life, and vice versa. A product with high moisture content, its shelf life will not be long-lasting (Agustina *et al.*, 2019). The purpose of setting maximum moisture content limits for materials is to maintain their quality. High moisture content can facilitate the growth of bacteria, mold, and yeast, leading to changes in food materials (Sandjaja, 2009).

The moisture content of West Lampung and Tanggamus Robusta coffee differs significantly. This is influenced by the processing of coffee beans during the drying process after harvesting. Temperature, air, relative humidity, and air flow are among the factors that affect coffee moisture content (Aditya *et al.*, 2016). West Lampung has a higher moisture content after roasting compared to Tanggamus due to differences in planting elevation. West Lampung is located at a higher altitude than Tanggamus, and the higher the altitude, the lower the ambient air temperature, which can increase moisture content during post-harvest processes (Putri & Dellima, 2022a). In contrast, after roasting, the moisture content of Tanggamus coffee is lower than that of West Lampung coffee because the husks and coffee skins attached to the green beans have been removed from the coffee beans, resulting in a lower moisture content.

3.2. Ash Content

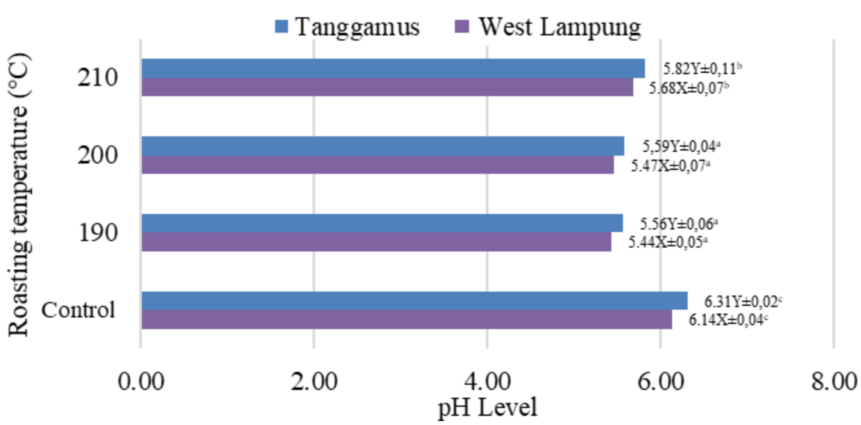
Ash content testing is intended to determine the purity of a substance, the cleanliness of a process, and the mineral content present in the material (Bhernama & Nuzlia, 2019). Ash content testing is also conducted to determine whether the ash content in coffee meets the Indonesian National Standards (SNI). The maximum ash content value in SNI is 5%. The ash content results of West Lampung and Tanggamus coffee powder with different treatments (without roasting process) and different roasting temperatures can be seen in Figure 2. The analysis results regarding ash content testing with temperature comparison show that there are differences ($p<0.05$), as well as comparisons between regions. However, there is no interaction between temperature and region ($p>0.05$). The DMRT test results show that coffee without the roasting process (green bean) or control coffee significantly differs from other types of coffee. Coffee roasted at temperature of 190 ºC does not significantly differ from coffee with a roasting temperature of 200 ºC. Similarly, coffee with a roasting temperature of 200 ºC does not significantly differ from coffee with a roasting temperature of 210 ºC. However, coffee with a roasting temperature of 190 ºC significantly differs from coffee roasted at 210 ºC. As the roasting temperature increases, the resulting ash content also increases. This is consistent with (Widodo, 2018) stating that temperature treatment affects the ash content. The increase in ash content correlates with the moisture content, indicating that higher roasting temperature resulted in lower moisture content, and leading to an increase in ash content with the increase in roasting temperature due to more water evaporates (Cuong *et al.*, 2014).

The analysis results regarding ash content testing between regions with ANOVA show that there are differences ($p<0.05$). In the DMRT test, it is stated that the comparison of ash content between West Lampung and Tanggamus significantly differs. This is in line with statements (Winarno & Berangin-angin, 2021) and (Bhernama & Nuzlia, 2019) that coffee from different regions with different processing methods is an external factor in determining the influence of ash content values. Therefore, dirt and residual husks affect the ash content results of coffee beans, as each region has different processing conditions depending on its drying environment. The elevation of the planting position also affects the ash content of coffee because the higher the planting area, the lower the ash content obtained. The planting elevation of West Lampung coffee is at 800 meters above sea level (masl), and Tanggamus is at an elevation of 600 masl. This is consistent with the literature that at elevations of 400-600 masl, the ash content obtained is lower compared to the ash content obtained at elevations of 800-1,000 masl. Overall, the ash content of Robusta coffee powder from West Lampung and Tanggamus ranges from 3.66% to 4.83% in each treatment, meeting the quality requirements of SNI 01-3542-2004 for coffee powder.



*X-Y Different letters indicate significant differences between West Lampung and Tanggamus.
**a-d Different letters indicate significant differences between coffee bean treatments.

Figure 2. Ash content of Tanggamus and West Lampung coffee powder comparison of control and different roasting temperatures



*X-Y Different letters indicate significant differences between West Lampung and Tanggamus.
**a-d Different letters indicate significant differences between coffee bean treatments.

Figure 3. Comparison of pH levels of Tanggamus and West Lampung coffee powder (different roasting temperatures vs. control)

3.3. pH Level

The pH value of coffee is formed by the acidic content it possesses (Aditya *et al*., 2016). The pH value or acidity level in coffee indicates that it originates from chlorogenic acid and other organic acid compounds (Budi *et al*., 2020). The larger the pH value of coffee, the lower its acidic content, and vice versa (Gunawan, 2006). The acidity level (pH) in coffee significantly affects the final coffee outcome (Purnamayanti *et al*., 2017). The pH level of West Lampung and Tanggamus coffee powder with different treatments, including the control (without roasting process) and various roasting temperatures, can be seen in Figure 3. The analysis regarding pH level testing shows that the comparison of pH levels between temperatures has a significant difference, thus significantly affecting acidity (p<0.05), as well as between regions. However, there is no interaction between temperature and region (p>0.05). The DMRT test results show that coffee without the roasting process (green bean) has significantly different outcomes compared to other coffees. Coffee roasted at 190 ºC does not significantly differ from coffee roasted at 200 ºC. However, coffee roasted at 190 ºC and 200 ºC significantly differs from coffee roasted at 210 ºC.

The highest pH of Robusta coffee is found in the control sample, with a value of 6.14 for West Lampung and 6.31 for Tanggamus. After roasting, the pH level of coffee decreases, becoming more acidic, and the acidity degree of coffee is influenced by the roasting temperature, where higher roasting temperatures increase the pH contained in coffee (Mardhiyah, 2021). For instance, the pH level after the roasting process at 210 ºC is 5.68 for West Lampung and 5.82 for Tanggamus. This occurs because chemical compounds in coffee degrade during the roasting process, such as proteins, polysaccharides, trigonelline, and chlorogenic acid (Budiyanto *et al*., 2021), leading to the pyrolysis of acidic compounds, causing their degradation due to the heat-sensitive nature of acids (Widodo, 2018). Roasting at 190 ºC produces the lowest pH level, indicating a high acid content in the coffee (Gloess *et al*., 2014).

The analysis of pH levels between regions shows a difference ($p<0.05$). The pH value of coffee beans is also influenced by several factors such as plant growing locations, roasting temperatures, roasting equipment, and roasting methods (Aditya *et al*., 2016), in accordance with the literature (Simbolon *et al*., 2020), environmental factors of plant growth such as altitude affect the physical and chemical properties of plant productivity, including the acidity level of coffee. The altitude of Tanggamus is lower than that of West Lampung, resulting in a lower environmental temperature in West Lampung compared to Tanggamus. The optimum environmental drying temperature for coffee is 30°C; if the environmental temperature is less than 30 °C, it may slow down the drying process, thus affecting the pH value of the coffee (Saripah *et al*., 2021). This makes the drying process in Tanggamus faster, resulting in a higher pH value compared to West Lampung, which has a lower pH value.

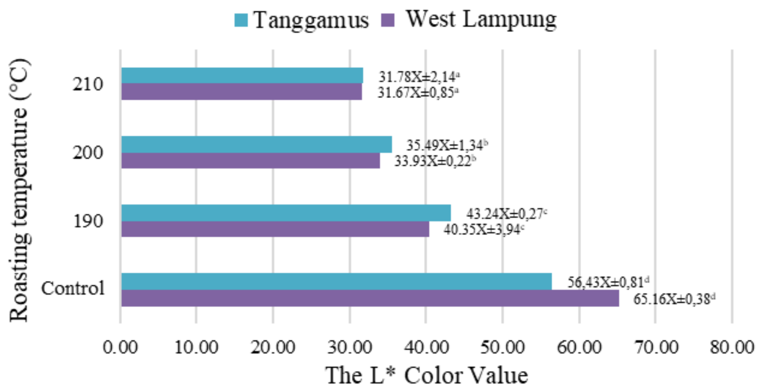
Table 1. Roasted coffee powder

Region	Roasting Temperature		
	190 °C	200 °C	210 °C
West Lampung			
Tanggamus			

3.4. Color

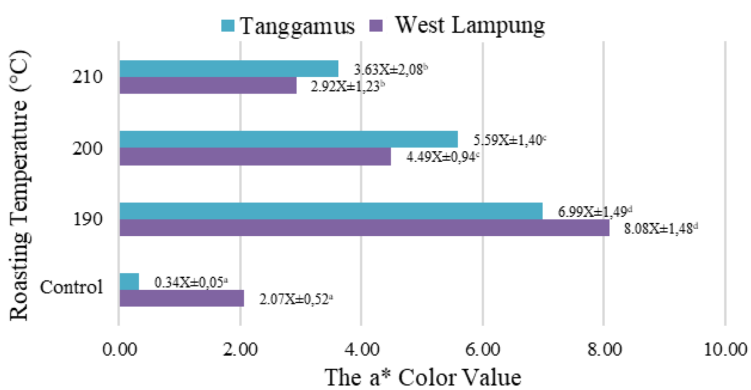
During the roasting process, changes in color occur, which can be visually distinguished and confirmed using a chromameter (Purnamayanti *et al*., 2017). Visual differences in coffee can be seen in Table 1. The purpose of color measurement is to observe color changes in Robusta coffee powder under each treatment. The higher the temperature used during roasting, the closer the coffee bean color will be to dark brownish (Agustina *et al*., 2019). The coffee roasting process affects coffee color because there is a Maillard reaction due to the interaction between reducing sugars in roasted Robusta coffee and amino acids in coffee (Yuniastri *et al*., 2019; Almada, 2009).

The analysis of color testing results in L^* values shows that the comparison of L^* values between temperatures has differences, thus significantly affecting brightness ($p<0.05$), and there is an interaction between temperature and region. The L^* color values between regions do not differ ($p>0.05$) in determining coffee brightness levels as seen in Figure 4. DMRT test results show that coffee that does not undergo the roasting process or control coffee (green bean) has significantly different results from coffee that undergoes the roasting process. Coffee with a roasting temperature of 190 ºC is significantly different from coffee with a roasting temperature of 200ºC. Likewise, coffee with a roasting temperature of 200 ºC is significantly different from that of roasting temperature of 210ºC. The L^* values is presented in Figure 5. It can be seen that the lowest L^* value is obtained for coffee with a roasting temperature of 210 ºC, both for West Lampung and Tanggamus Robusta coffee. The highest L^* value is obtained from control coffee or coffee that does not undergo the roasting process with values ranging from 56.43 to 65.16. This is because the L^* value indicates the brightness level of the tested sample. The brighter the sample color, the higher the L^* value obtained.



*X-Y Different letters indicate significant differences between West Lampung and Tanggamus
**a-d Different letters indicate significant differences between coffee bean treatments

Figure 4. Color L^* value of Tanggamus and West Lampung coffee powder (different roasting temperatures vs. control)

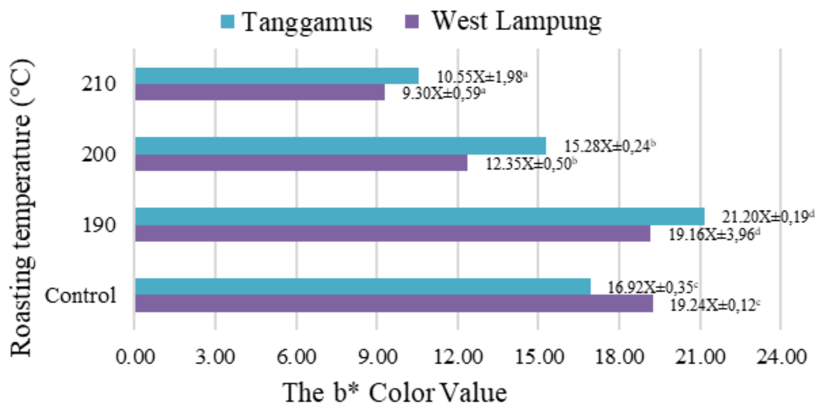


*X-Y Different letters indicate significant differences between West Lampung and Tanggamus.
**a-d Different letters indicate significant differences between coffee bean treatments.

Figure 5. Color a^* value of Tanggamus and West Lampung coffee powder (different roasting temperatures vs. control)

The analysis of color testing results in a^* values (Figure 5) shows that the comparison of a^* values between temperatures has differences ($p<0.05$). The a^* color value between regions does not differ, and there is no interaction between temperature and region ($p> 0.05$). DMRT test results show that coffee that does not undergo the roasting process (green bean) or control coffee has significantly different results from other coffee. The a^* value indicates that 0 to +60 represents reddish color and 0 to -60 represents greenish color. The lowest a* value is obtained for control coffee or coffee that does not undergo the roasting process with a value of 2.07 for West Lampung coffee and 0.34 for Tanggamus coffee. As the name suggests, control coffee is green beans that have not undergone the roasting process, so they have very low a* values because the coffee beans have a dominant green color. The highest a* value is obtained for coffee with a roasting temperature of 190ºC with a light brown color, approaching reddish color.

The analysis of color testing results in b^* values shows that the comparison of b^* values between temperatures has differences ($p<0.05$), and there is an interaction between temperature and region. The b* color value between regions does not differ ($p>0.05$). DMRT test results show that coffee with each different temperature treatment has significantly different results. The b^* values can be seen in Figure 6. The b^* value indicates that 0 to +60 represents yellow color and 0 to -60 represents blue color. The lowest b^* value is obtained for coffee with a roasting temperature of 210 ºC with a value of 9.30 for West Lampung coffee and 10.55 for Tanggamus coffee. The highest b^* value is obtained for coffee with a roasting temperature of 190 ºC.



*X-Y Different letters indicate significant differences between West Lampung and Tanggamus
**a-d Different letters indicate significant differences between coffee bean treatments

Figure 6. Color b^* value of Tanggamus and West Lampung coffee powder (different roasting temperatures vs. control)

The ΔE value is obtained by calculating the total color of L^*, a^*, and b^* values, so the total color difference in coffee can be quantitatively proven, not only based on visual observation. Coffee ΔE values can be seen in Table 2. According to literature (Purnamayanti et al., 2017), if the ΔE value <0.2, it does not have an effect on the color of food ingredients; the ΔE value 0.2-1.0 has a very small effect on the color of food ingredients; the ΔE value 1.0-3.0 has a small effect on the color of food ingredients; the ΔE value 3.0-6.0 has a moderate effect on the color of food ingredients, and if the ΔE value> 6.0, it has a significant effect on the color of food ingredients. This statement is proven by research results that the ΔE value is greater than 6.0, which means that the roasting temperature treatment has a significant effect on the color of West Lampung and Tanggamus Robusta coffee.

Table 2. ΔE color values of coffee

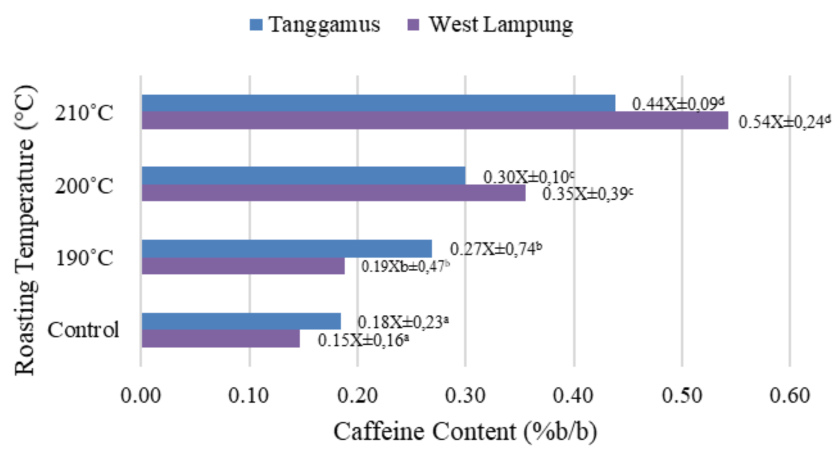
Roasting Temperature	Region	
	West Lampung	Tanggamus
Control	0	0
190 ºC	25.5	15.4
200 ºC	32.1	21.6
210 ºC	34.9	25.7

3.5 Caffeine Content

Caffeine is one of the substances found in daily food or beverages such as coffee, chocolate, and tea (Widyotomo & Mulato, 2007). Caffeine can stimulate the nerves and heart muscles, so excessive consumption can have adverse effects on health. Therefore, the caffeine content in coffee has a maximum level of 2% w/w based on SNI 01-3542-2004 (Rahmawati et al., 2021). The caffeine content in West Lampung and Tanggamus coffee powder can be seen in Figure 7. The analysis of caffeine content testing shows that the comparison of caffeine content between temperatures differs significantly (p<0.05), but the caffeine content between regions does not differ (p> 0.05), and there is no interaction between temperature and region. DMRT test results show that coffee at each roasting temperature has significantly different results. The caffeine content in control coffee (green bean) or coffee that has not undergone roasting differs significantly from coffee roasted at 210 ºC.

Control coffee or coffee that has not undergone the roasting process contains caffeine and chlorogenic acid but in small amounts, as shown in the literature with a green bean caffeine content of 0.64% (Clifford, 1999), and the lowest caffeine content is found in control coffee samples or coffee that has not undergone the roasting process with values of

0.15% for West Lampung and 0.18% for Tanggamus coffee. Compared to the caffeine content of control coffee, the highest caffeine content is in coffee samples roasted at 210 ºC with values of 0.54% for West Lampung coffee and 0.44% for Tanggamus coffee. In accordance with the literature (Putri & Dellima, 2022b), which states that coffee that has undergone the roasting process has a higher caffeine content compared to green beans.



*X-Y Different letters indicate significant differences between West Lampung and Tanggamus.
**a-d Different letters indicate significant differences between coffee bean treatments

Figure 7. Caffeine content of of Tanggamus and West Lampung coffee powder (different roasting temperatures vs. control)

The caffeine content increases with the increasing temperature used in roasting. The increase in caffeine content in coffee is due to the expansion or increase in the volume of coffee beans and the evaporation of bound water in coffee beans due to the roasting process. Therefore, the larger the cavity of the coffee beans after roasting, the easier it is for caffeine compounds to come out during the grinding process, thus facilitating the extraction process. This statement is supported by the literature (Agustina *et al*., 2019) stating that the percentage of caffeine content is directly proportional to the roasting temperature; the higher the temperature, the higher the percentage of caffeine content obtained. This is because there is evaporation of water content and degradation of acidic compounds such as chlorogenic acid during roasting (Saloko *et al*., 2019).

The caffeine content obtained from this study ranges from 0.15-0.54% from control samples to roasting treatment with a temperature of 210ºC. The Indonesian National Standard (SNI) for caffeine content in coffee powder ranges from 0.4-2%, therefore, the caffeine content results that meet the SNI criteria for coffee powder are coffee with roasting treatment at a temperature of 210ºC. The caffeine content in coffee is obtained by extraction using organic solvents, and the extraction efficiency is influenced by the solvent, temperature, time, and ratio of solvent composition to material.

After brewing, the extraction process continues using a solvent to draw out the caffeine content in coffee. Caffeine is an alkaloid that is nonpolar, so a nonpolar solvent is needed, following the principle of "like dissolve like," meaning that a compound will dissolve in a solvent with the same degree of polarity (Roossenda & Sunarto, 2016). Polar solvents will dissolve polar compounds, and similarly, nonpolar solvents will dissolve nonpolar compounds. Chloroform, which is nonpolar, can bind caffeine in a coffee solution and is located in the lower layer because it has a higher specific gravity than the coffee solution.

The caffeine content that does not meet the SNI standard is due to the brewing time used not reaching one minute, so the caffeine content obtained is not maximal, whereas to obtain maximum extraction results, brewing can be done for 10 minutes (Putri & Ulfin, 2015). This is supported by (Widodo, 2018) stating that short extraction times can cause all secondary metabolites to not be extracted optimally. Therefore, in the coffee brewing process, the longer the time used, the longer the contact between water and coffee, so the extraction process becomes more perfect (Rohdiana, 2008).

4. CONCLUSIONS

The geographic origin of coffee cultivation influences the physicochemical properties of coffee beans. The coffee beans harvested from Tanggamus have significantly different characteristics ($p<0.05$) as compared to that of West Lampung in term of moisture content, pH, and ash content, whereas color and caffeine content are not significantly different ($p>0.05$) based on their regions. In addition, all testing parameters (ash content, moisture content, pH, color, and caffeine) are directly proportional to the roasting temperature. Therefore, roasting temperature is vital to achieve the preferred physicochemical characteristics of coffee beans.

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