Physicochemical properties of Robusta coffee at various roasting levels using different roaster types

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Abstract. Coffee roasting is the process to bring out flavors of green coffee beans by applying heat through the chemical changes. The objective of this study was to investigate the effect of roasting process at various levels using different types of roasting machine on the physicochemical properties of robusta coffee beans. Coffee beans were roasted using two types of roasting machine, namely semi-hot air and hot air. The roast levels used in this study include: light, medium, and dark. The results showed that the types of roasting machine only had a significant effect on the color of coffee powder. Coffee powder produced by a semi-hot air roasting machine had a higher L*, a* and b* values (43.29-53.63; 5.54-11.09; 7.99-18.58). The roast level factor had a significant effect on bulk density of coffee beans, water content, ash content, caffeine levels and color of coffee powder. The bulk density, water content, and color (L*, a*, b* values) decreased, however ash content and caffeine levels tended to increase with the increase of roasting level. The coffee produced in this study had a bulk density ranging from 0.41-0.52 g/ml, a water content ranging from 1.24-2.57%, ash content ranging from 4.53- 5.00% and caffeine level ranging from 1.86-2.02%.
Keyword: Coffee Roasting, Robusta Coffee Beans, Physicochemical Properties, Roasting Process, Roasting Machine Types

1 Introduction

Coffee is a widely consumed beverage known for its unique tastes and scents. The intricate process of coffee roasting plays a pivotal role in unlocking the hidden potential of green coffee beans, transforming them into the flavorful and aromatic brew we enjoy. During roasting, heat application triggers a cascade of chemical reactions that develop the complex profiles of coffee.

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Understanding the physicochemical properties of coffee at different roasting levels is crucial for coffee producers and enthusiasts alike. Variations in roasting levels can profoundly impact the sensory attributes and overall quality of coffee. Additionally, the choice of a roasting machine can introduce further variations in the final product due to differences in heat transfer mechanisms and other operational parameters.

Coffee roasting is a complex process involving physical and chemical transformations within the coffee beans. Heat application initiates numerous chemical reactions, including Maillard browning, caramelization, and degradation of various compounds. These processes help coffee beans develop flavors, aromas, and other physicochemical alterations. Roasting machines are critical in determining the heat transfer mechanisms and overall roasting conditions. Different types of roasting machines, such as hot air roasters, drum roasters, and fluidized bed roasters, have distinct characteristics that can influence the roasting process and, ultimately, the physicochemical properties of the roasted coffee.

Several studies have investigated the impact of roasting on coffee properties. For instance, [1] explored the effect of roasting temperature on the volatile compounds and sensory attributes of Arabica coffee. Their findings indicated that higher roasting temperatures increased volatile compounds associated with desirable aroma notes. The physicochemical properties of Arabica coffee beans roasted using different methods, including drum and hot air roasting. The study revealed that the roasting method influenced the coffee's acidity, antioxidant activity, and sensory characteristics [2]. The roasting temperature significantly impacted the coffee beans' physicochemical properties. Increasing the roasting temperature resulted in beans with lower moisture content, higher density, a darker color, and acidity [3].

Effect of roasting duration on the physicochemical properties of Robusta coffee beans. Findings indicated that the roasting time had a substantial impact on the physicochemical properties of the coffee beans. Increasing the roasting time resulted in beans with a lower moisture content, a higher density, a darker color, and a higher acidity [4]. The physicochemical and sensory characteristics of Robusta coffee roasted using different types of roasting machines. Results revealed that the type of roasting machine significantly impacted the coffee beans' physicochemical and sensory properties. The drum- roasted beans had the highest moisture content, density, and colour. The hot air-roasted beans had the lowest moisture content, density, and color. The convection roasted beans had an intermediate moisture content, density, and color [5]. The effects of increasing the roasting temperature resulted in beans with lower moisture content, higher density, darker color, and higher acidity. The longer roasting times have resulted in beans with a higher concentration of volatile compounds [6]. The physicochemical and sensory properties of Robusta coffee roasted using different roasting methods: drum roasting, hot air roasting, and convection roasting; The results showed that the roasting method had a significant impact on the physicochemical and sensory properties of Robusta coffee. Drum-roasted coffees had the highest moisture content, density, and color. Hot air-roasted coffees had the lowest moisture content, density, and color. Convection-roasted coffees had an intermediate moisture content, density, and color. The sensory evaluations showed that drum-roasted coffees were the most popular, followed by convection- roasted and hot air-roasted coffees [7]. The roasting conditions had a significant impact on the physicochemical, sensory, and volatile compounds of Robusta coffee. Increasing the roasting temperature resulted in beans with lower moisture content, higher density, darker color, and higher acidity. The longer roasting times have resulted in beans with a higher concentration of volatile compounds [8-11].

Understanding the impact of roasting methods and machine types on Robusta coffee can provide valuable insights for coffee producers aiming to optimize the roasting process and

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achieve desired flavor profiles. Therefore, this study aimed to fill this research gap by systematically examining the physicochemical properties of Robusta coffee beans from South Subang West Java at different roasting levels using two roasting machines. The findings will contribute to enhancing our understanding of the effects of roasting on Robusta coffee and guide the selection of optimal roasting methods for desired flavor outcomes.

2 Materials and methods

2.1. Materials

The raw materials used in this study were Robusta coffee beans collected from coffee farmers in Subang, West Java. Materials used in chemical analysis include chloroform, calcium carbonate (CaCO3) and caffeine standard.

2.2. Methods

2.2.1. Roasting process

The roasting process was carried out using two type of machine, namely semi-hot air roaster and hot air roaster. The green bean of Robusta coffee samples treated on three roasting degrees, namely light, medium and dark roast. The roasted coffee beans were then stored to rest for about three days. After resting, the coffee was then ground using a grinder machine to further analysis its characteristics.

2.2.2. Sample analysis

Coffee powder samples were analyzed for their physical and chemical properties. The physical properties that are analyzed were bulk density color of coffee powder. While the chemical analysis carried out included water content, ash content and caffeine content. The samples' bulk densities were calculated by calculate the ratio between the sample weight and the volume of measuring cup [12]. The color of coffee powder (L*, a* and b* value) was measured using a colormeter (3NH-NH300).

The water content and ash content were analyzed refers to SNI 01-2891-1992 (BSN, 1992). Caffeine content was measured by using the spectrophotometric method. In the caffeine analysis carried out several stages: 1) preparation of standard solutions; 2) maximum absorption wavelength determination; 3) calibration curve determination; 4) sample preparation; 5) caffeine content determination at a maximum absorption wavelength of 276 nm [13].

2.2.3. Statistical analysis

Data were statistically analysed using SPSS 16.0's ANOVA technique. Further use of the Duncan multiple range test was made to confirm the p0.05 significance level between the mean values.

3 Result and discussion

3.1. Moisture content

Table 1 displayed the amount of moisture in roaster machine of coffee. The moisture content of the semi hot air roaster machine consisted of 2.57% (Light), 1.64% (Medium), 1.24% (Dark) and hot air machine consist of 2.13% (Light), 1.40% (Medium) 1.34% (Dark), respectively.

Table 1. Result of moisture content, ash content and bulk density of roasting level on coffee roaster machine.

Roaster Machine	Roasting Level	Moisture Content (%)	Ash Content (%)	Bulk Density
Semi hot air	Light Medium Dark	2.57±0.001^{d} 1.64±0.221^{b} 1.24±0.277^{a}	4.63±0.115^{ab} 4.53±0.207^{a} 4.77±0.040^{b}	0.52±0.010^{d} 0.49±0.009^{c} 0.46±0.005^{b}
Hot air	Light Medium Dark	2.13±0.208^{c} 1.40±0.077^{ab} 1.34±0.116^{a}	4.60±0.040^{ab} 4.70±0.040^{ab} 4.99±0.087^{c}	0.54±0.017^{e} 0.49±0.004^{c} 0.41±0.001^{a}

a, b, c, d, and e letters refer to significant difference ($p<0.05$) in the same column.

The decreasing of water content from Light to Dark on semi hot air roaster machine. On the hot air of roaster machine showed decreasing moisture content from Light to Dark. The paired t-test's findings demonstrated that the roasting process caused changes to occur in both coffee beans treated on semi-hot air and hot air roaster machines, with significant differences, $p<0.05$. The green beans were often roasted by either exposing them to hot gas or placing them on a scorching metal surface. Drying, roasting, and cooling are the three phases that make up the roasting process. During the drying process, water and other volatile compounds slowly release. Roasting reactions that follow cause the bean's chemical and physical characteristics to change significantly [14, 15]. The amount of water vapor released from green coffee during the first stage of processing might reach up to 70% of original levels [16]. In relation to the roasting process, the hot air flow distribution in the roaster was the reason why the moisture content decreased.

3.2. Ash content

The examination of the residual mineral content in edible substances is to identify the mineral and organic compound composition of combustion residues present in the tested material in order to assess the processing method's effectiveness, identify the type of material used, and establish a parameter for the nutritional value of foodstuffs [17]. More minerals are present in food goods, which is shown by the higher ash content [18]. The variables of interest in this study encompassed the total ash content and acid insoluble ash content. High metal elements may be present in the sample or material as shown by the high ash content of culinary ingredients and products. Sand or other impurities are present when there is a high concentration of acid-insoluble ash [19]. It was determined from the analysis's findings that the coffee powder from semi-automatic the ash content falls within the specified range of 4.53% - 4.77%. The ash content with the highest concentration was in semi hot air roaster machine of dark coffee color, while the lowest ash content was in process used semi hot air roaster machine medium coffee color (4.53%). But on hot air roaster machine have the highest ash content was in hot air roaster machine of dark coffee color. Increasing ash content was started on semi and hot air roaster machine of light to dark coffee color (4.60%-4.99%). This provided evidence that the ash content of hot air roaster machine in this study was higher than semi hot air roaster machine.

3.3. Bulk density

The bulk density of the semi hot air roaster machine consisted of 0.52% (Light), 0.49% (Medium), 0.46% (Dark) and hot air machine consist of 0.54% (Light), 0.49 (Medium) 0.41 (Dark), respectively. The decreasing of bulk density from Light to Dark on Semi hot air roaster machine. On the hot air roaster machine showed decreasing bulk density from Light to Dark. The paired t-test analysis revealed that there was a significant change observed in both coffee bean samples was processed on semi hot air and hot air roaster machine There were notable variations as a result of roasting, (t (4)), p 0.05. Individual porosity was higher than green bean porosity due to roasting, however bulk the porosity of the roasted bean was lower than that of green bean. Bulk porosity contrasted with individual porosity in having the opposite qualities. High-level pressure from the roasting process' rising temperatures, which transformed the cell walls' structure from hard to rubbery, led to the expansion of individual porosity. As a result, it was extending the single bean porosity as well as the volume of each coffee bean. The decrease in volumetric porosity of coffee beans that have undergone a single roasting process can be attributed to alterations in their dimensions, including length, breadth, and thickness.

3.4. Caffeine

This study used 2 types of roasters, namely hot air and semi hot air. The difference between these two types of roasters was in the mechanism of transferring heat energy to the coffee beans. Temperature and heat transmission mechanisms were 2 very important things and determine the physical and chemical characteristics and quality of roasted coffee. The semi-hot air roaster is a type of roasting equipment that utilizes a combination of hot air and other heating elements to roast various materials. The transfer of heat to the beans can occur through the processes of conduction and convection, specifically when the beans come into direct contact with heated metal surfaces. The hot air roaster is a device used for the purpose of roasting various food items. The transfer of heat to the beans can occur through either free or forced convection, which is induced by a flowing liquid. During the process of coffee roasting, it can be observed that caffeine exhibits a moderate level of thermal stability [20]. Factors that affect caffeine levels in ground coffee include roasting time (66.6%), roasting temperature (19.3%), fermentation time (9.86%) and drying time (0.5%) [21]. The caffeine content of Robusta coffee after going through the roasting process using the hot air and semi hot air methods was shown in Figure 1.

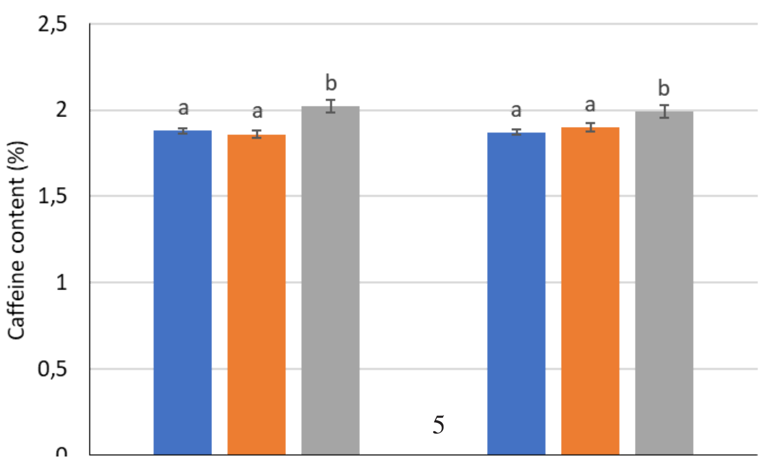

Fig 1. Caffeine content of coffee used a roaster with a hot air and semi hot air types.

The results showed that caffeine content of coffee processed using a roaster with a hot air and semi hot air system were not significantly different. The caffeine content of coffee roasters with semi-hot air was in the range of 1.88 – 2.02% and the caffeine content of coffee roasters with hot air was in the range of 1.87-1.99%. Increasing the roasting level from light to medium to dark shows a trend of increasing caffeine levels in coffee. This was in line with [22] which shows that increasing the temperature and roasting level of Robusta coffee from Temanggung significantly increases the caffeine content of coffee. The roasting level used was divided into 3 levels, namely light (205 ºC 9 minutes), medium (226 ºC 13 minutes) and dark (228 ºC 16 minutes). Increasing the roasting level increases the caffeine content, namely green bean 0.64%, light 1.16%, medium 1.48% and dark 1.58%. The limit for caffeine content in pure ground coffee is based on the Indonesian National Standard (SNI 01-3542-2004) which is 0.90-2.00% [23]. This showed that Robusta coffee roasted using hot water and semi hot water meets SNI standards.

3.5 Color

The green bean's color changes as a result of roasting. The color, aroma, and flavor of coffee are the result of a complex interaction that took place during roasting. When coffee is roasted, the distinctive color, aroma, and flavor develop [24]. Coffee color analysis using a chromameter has a standard in the form of the symbol L* which indicates brightness (score range between 0 – 100). The symbol a* with a* score between 0-60 shows red, a* with a* score between 0-(-60) shows green. Symbol b* has a* score range between 0-60 which indicates a* yellow color, and a* score between 0- (-60) indicates a* blue color. The results of the analysis of the color of coffee roasted using hot air and semi hot air are shown in Table 2.

The roasting method using a hot air roasting machine produces significantly darker coffee colors at all roasting levels from light, medium, and dark. The hot air coffee roaster has to deliver heat to the coffee beans by convection with a stable temperature so as to produce a uniform color of coffee beans. Semi hot air roasting machine has 2 mechanisms of heat transfer to coffee beans, namely by convection (hot air flow) and conduction (temperature rise through the cylinder). This causes an increase in the temperature of the coffee beans during roasting which varies, resulting in a variety of coffee bean colors. So that at light, medium and dark levels coffee processed with semi hot air significantly higher than coffee beans roasted with a hot air machine.

Tabel 2. Color difference of coffee with hot air and semi hot air roaster machine.

Roaster machine **Roasting Level** **L*** **a*** **b***	Roasting Level	L*	a*	b*
Semi hot air	Light	53.64±0.026^{f}	11.10±0.024^{f}	18.59±0.010^{f}
	Medium	48.31±0.086^{d}	9.27±0.127^{d}	13.44±0.247^{d}
	Dark	43.27±0.009^{b}	5.54±0.011^{b}	7.99±0.011^{b}

Hot air	Light	49.15±0.065[e]	9.75±0.022[e]	14.23±0.027[e]
	Medium	45.68±0.008[c]	7.48±0.014[c]	11.21±0.020[c]
	Dark	41.28±0.011[a]	3.77±0.024[a]	5.65±0.020[a]

a, b, c, d, e, and f letters refer to significant difference ($p<0.05$) in the same column.

According to the findings of the investigation, it was established that the brightness value of coffee roasted with hot air ranges from 41.28 ± 0.011 to 49.15 ± 0.065, while for coffee roasted with semi hot air it ranges from 43.27 ± 0.009 to 53.64 ± 0.026. A coffee score ranging from 3.77 to 11.10 indicates coffee has a dark brown color. The b* score on coffee ranging from 5.65 to 18.59 indicates that the coffee was dark brown in color. Green coffee turns into light brown, brown, and dark brown depending on the degree of roasting. The rate of color change rises as anticipated [12]. Darker coffee results from roasting at greater temperatures and for longer periods of time [25]. As the level of roasting increases as well, the intensity of lightness in the coffee also lowers. Roasting time and temperature had an impact on the physical, chemical, and flavor characteristics of coffee. Nonenzymatic browning and pyrolysis processes are responsible for coffee color shifts. Roasted coffee's original yellow-green hue changes to a brown-black hue. Reduced L*, a*, and b* values were a hallmark of browning [12].

4. Conclusion

Roaster semi hot air dan hot air have difference types of roasters was in the mechanism of transferring heat energy to the coffee beans. Semi hot air roaster, the beans can be exposed to the heat by conduction and convection. While hot air roaster, the beans can be exposed to the heat by free or forced convection. These different energy transfer mechanisms produce coffee with different characteristics. The moisture content of dark coffee from semi-hot water was the lowest compared to other treatments, namely 1.24 ± 0.277%. The ash content of dark coffee roasted with hot air types has the highest number, namely 4.99 ± 0.087%. The increased roasting level from light-dark showed a decrease in bulk density in all treatments. The caffeine content is stable to heat treatment, so the type of roaster does not affect the caffeine content of coffee. Increasing the roast level increases the caffeine content of coffee. The color of coffee roasted using hot water is significantly darker than coffee roasted using a semi hot air tool, indicated by a score of L* 41.28, a* 3.77, and b* 5.65.

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