Physicochemical Properties of 'Cisalak' Robusta Coffee With Hot Air Based Roasting Method

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Abstract. The roasting technique is considered one of the coffee processing stages that can continue to be developed for sustainable innovation, both in the process and in the equipment. It is an important factor that determines the coffee's quality. This study aimed to assess the impact of the roasting method using a hot air roaster on the physicochemical properties of Cisalak robusta coffee. The method for roasting green coffee beans was conducted under six conditions based on the speed and level of roasting: slow-light, slow-medium, slow-dark, fast-light, fast-medium, and fast-dark. The bulk density, hardness of coffee beans, water content and lightness of coffee powder decreased as the roasting level increased, whereas the ash content, pH level and caffeine content increased. The slow roasting speed produced a coffee with a lower water content and hardness, whereas the ash content, L values and pH level was higher than fast roasting method. Based on the results, robusta coffee which was roasted using various methods in this study had a range 0.309-0.357 g/ml of bulk density, 5932.99-7164.87 gf of hardness, 34.44-39.98 of lightness, 0.8073-1.5556 % of water content, 4.8010-5.3643 % of ash content, 5.62-6.23 of pH level and 0.96-1.36% of caffeine content.
Keywords : Coffee roasting, Physicochemical properties, Hot air roaster, Cisalak robusta coffee, Sustainable innovation.

1 Introduction

Coffee is regarded as one of the most important commodities, alongside oil [1]. The growing number of coffee products, brands and establishments shows that coffee is necessary for society today. Various types of processed coffee can be found in the market, especially roasted, instant and ready-to-drink coffee. Coffee producers were getting more creative in conceptualizing coffee treats. Process technology and sustainable innovation are necessary to support this rapid development of coffee to keep up the quality of coffee

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products and develop a diverse concept of coffee serving. The roasting process is one of the coffee processing stages that can continue to be developed for sustainable innovation, both in the process and in the equipment.

The roasting process is essential in coffee production as it substantially impacts on the chemical, physical and sensory attributes of the resulting coffee product. It reduces coffee beans water content at a specific temperature until the bean swells up and releases a distinctive aroma [2]. The coffee beans were subjected to high temperature during the technique of roasting, resulting in structural modifications, both physical and chemical alterations can occur [3]. According to Ebrahimi-Najafabadi et al. [4], coffee beans begin to produce the compounds that contribute to the colour, flavour and aroma of roasted coffee beans when the temperatures exceed 180 degrees Celsius. The ground coffee industry recognizes three roasting levels, namely light roast, medium roast and dark roast. Different roasting level may give a different roasted coffee characteristic.

In order to achieve the intended amount of roast, the roasting process necessitated the careful regulation of bean temperature for a specific duration. This meant considering various aspects, including the air and surface temperature within the roaster chamber, the material properties of the beans and the diffusion of heat within the beans [5]. The roasting process can generally be done at several speeds, starting from slow to medium to fast. When considering heat distribution and heat exchange inside the beans, a gradual increase in roasting temperature is preferable for a uniform roast. On the contrary, a rapid temperature rise can increase the pressure during the roasting process, resulting in sufficient flavour development [5].

The rate of heat transfer and the occurrence of chemical reactions during the roasting process are influenced by two main factors: the coffee beans inherent properties and the specific method or profile employed for the roasting process. The combination of time and temperature used to achieve a spesific colour level during roasting impacts the coffee's final physical, chemical and sensory attributes [6]. Therefore, this research aimed to observe the effect of roasting speeds and levels on the physical and chemical properties of robusta coffee from Cisalak Subang.

2 Material and methods

2.1 Materials

The materials used in this investigation were coffee (green beans) and chemicals for analysis process. Samples of green robusta coffee were obtained from coffee farmers in Cisalak, Subang, West Java. The chemicals used for analysis include chloroform, calcium carbonate ($CaCO_3$) and caffeine standard.

2.2 Methods

2.2.1 Roasting process

A fluidized bed roaster carries out the roasting process and uses compressed hot air to stir and roast the coffee beans. Convection dominates heat transfer in this method [2]. The roaster had 982 millimeters of length, 500 millimeters of width and 1450 millimeters of height. This roaster was equipped with chaff and dust collector, which measures 60 millimeters in diameter and 110 millimeters in height. The blower spesifications for transferring heat and lifting the roasting bean are 220-380 Volts, 50-60 Hertz, 600 Watts, 16000 revolutions per minutes. Jet burners use liquefied petroleum gas to transfer the heat and lift the beans.

Coffee samples were roasted at two speeds: slow roast and fast roast. The samples at each speed were roasted in three levels: light, medium and dark roast. Each treatment was repeated three times. A quantity of green beans weighing up to 300 grams was introduced into the roaster chamber when the temperature reaches 180 oC. The roasted coffee beans were then rested for three days. After that, the coffee beans were ground using a grinder machine to get coffee powder with 60 mesh fineness.

2.2.2 Sample analysis

The analyzed of physical properties were bulk density, roasted coffee beans hardness and coffee powder lightness. The bulk density was determined by weighing roasted coffee beans in a 50 ml measuring cup. Determining bulk density involved dividing the sample weight by the volume of measuring cup [7]. The hardness of the sample was assessed using Texture Profile Analyzer - Stable Micro Systems, TA.XT Plus. The test method was the mode of compression, 1 mm/sec of test speed, 2 mm of distance and used P36 probe. The coffee powder colour (lightness value) was observed using a colourmeter (3NH-NH300).

The chemical properties analyzed included water content, ash content, pH of coffee brew and caffeine content. Water and ash content were analyzed according to SNI 01-2891-1992 [8] regarding the analytical techniques employed in the analysis of food and beverage samples. pH analysis was carried out using a pH meter. Five grams of sample dissolved with 50 ml of water then stirred and heated for 30 minutes. The coffee solution was filtered and then measured with a pH meter by dipping the probe into the solution. The pH value can be read after the numbers on the display are stable.

Caffeine content was determined using the spectrophotometric method at a maximum absorption wavelength of 276 nm [9]. There are several stages in the caffeine content analysis: 1) preparation of standard solutions; 2) maximum absorption wavelength determination; 3) calibration curve determination; 4) sample preparation; 5) caffeine content determination.

The study employed a completely randomized approach to investigate the impact of different roasting speeds and roasting levels on the physicochemical properties of coffee after roasting. Variance (ANOVA) was analyzed to ascertain the average disparity between the various samples. A post hoc analysis was performed using a Duncan Multiple Range Test (DMRT) method to ascertain the presence of a significant difference between various samples. The analysis was completed with a level of confidence of 95% ($p \leq 0.05$).

3 Results and discussion

3.1 Physical properties

The physical properties of roasted coffee comprised of bulk density, hardness of coffee beans and lightness of coffee powder were shown in the Table 1. Bulk density refers to measuring the mass of a substance contained in a specific volume. Determination of bulk densities required for processing, packaging, storage and transportation [7]. A large bulk density value indicates fewer cavities empty which is owned by a material and shows a solid material structure [10]. In this investigation, the range of bulk density values for roasted coffee beans was between 0.309 and 0.357 g/cm3. These results are similar to the results of study from Rodrigues et al. [11] and Yusibani et al. [12].

Table 1 illustrated that the level of roasting had a considerable impact on the coffee beans bulk density. According to the analysis results, it is known that the darker roasting level produced the lower bulk density value. This shows that the pores or cavities in the coffee beans were getting bigger as the darker roasting level, and this was indicated by the coffee beans expanding. Abrar et al. [13] described that the bulk density of roasted coffee will decrease due to the roasting because the coffee beans firmness decreases as the weight loss and volume of coffee beans increase. Similarly, Frisulo et al. [14] observed that many physical transformations took place in the coffee beans throughout the roasting procedure, such as decrease in weight and increase in volume, which can reduce the density of roasted coffee beans. Puffing and increased brittleness were additional causes of the decrease in bulk density [15].

Table 1. Physical properties of roasted cisalak robusta coffee

Roasting Speed	Roasting Level	Bulk Density (g/cm^3)	Hardness (gf)	Lightness (L*)
Slow roast	Light	0.357 ± 0.02^{c}	6921.16 ± 86.37^{de}	39.67 ± 1.79^{c}
	Medium	0.347 ± 0.01^{c}	6248.76 ± 64.44^{ab}	39.45 ± 0.15^{c}
	Dark	0.309 ± 0.00^{a}	5932.99 ± 140.21^{a}	37.20 ± 0.06^{b}
Fast roast	Light	0.351 ± 0.02^{c}	7164.87 ± 340.24^{e}	39.98 ± 1.18^{c}
	Medium	0.336 ± 0.01^{bc}	6681.24 ± 297.11^{cd}	36.03 ± 0.38^{b}
	Dark	0.316 ± 0.01^{ab}	6402.02 ± 184.98^{bc}	34.44 ± 0.11^{a}

The differences between the means with various superscript letters in the same column are statistically significant different at $p \leq 0.05$. The roasted coffee beans hardness in this study ranged from 5932.99 gf to 7164.87 gf. Based on analysis results, roasting speed and roasting level were significantly affected the hardness of roasted coffee beans. Slow roasting produced a roasted coffee with a lower hardness than fast roasting. Reciprocally, the darker roast level produced a roasted coffee with the lower hardness. The roasting speed and roasting level were principles as a matter of time. Slow roast and dark roast level were required a longer time than fast roast and light or medium roast level. The longer coffee beans were exposed to heat, the more they swelled and became brittle. Pittia *et al.* [16] observed that coffee beans undergo a reduction in strength, toughness and develop a brittle texture throughout the roasting process. During the roasting process, coffee beans undergo expansion, resulting in a significant alteration in volume. According to Sivetz and Desroier in Ameyu [17], the augmentation in the volume of coffee beans can be attributed to the weakening of the cellulose bean structure, in conjunction with the rise in pressure caused by the liberation of pyrolysis products. Because there was a process of softening as the coffee beans undergo expansion, their hardness diminishes in conjunction with the roasting procedure.

The colour was the main indicator that determined the roasting level. The present study revealed that both the roasting rate and the roasting level had a notable impact on the roasted coffee powder lightness. The coffee powder produced by the slow roast method had a higher lightness value than coffee powder produced by the fast roast. This was probably due to the heating flame used in the fast roast method which was larger than in slow roast, which caused the temperature of formed heat energy was increased rapidly. This rapid temperature increase might cause the color of coffee beans turned dark in a relatively short time.

The same explanation of the physical properties before, the lightness of coffee powder also decreased with the darker roasting level. Pittia et al. [18] reported that coffee beans would change colour during roasting due to the non-enzymatic browning and pyrolysis reactions. The yellow-green colour of the green bean changes to the brown-black roasted colour. Rodrigues et al. [11] similarly observed that coffee beans lightness (L*) decreased after roasting because the beans were getting dark due to the sugar caramelization process and Maillard reactions. The longer the roasting time required to reach the dark level of roasting, the more intense the sugar caramelization process and the Maillard reaction. This might cause the colour of the coffee beans to become darker and the lightness value to decrease.

3.2 Chemical properties

Table 2. Chemical properties of roasted cisalak robusta coffee

Roasting Speed	Roasting Level	Water content (%)	Ash content (%)	pH	Caffeine content (%)
Slow roast	Light	1.045 ± 0.16^{ab}	4.91 ± 0.09^{a}	5.73 ± 0.13^{ab}	1.34 ± 0.04^{a}
	Medium	0.807 ± 0.11^{a}	4.76 ± 0.02^{a}	5.89 ± 0.03^{c}	1.29 ± 0.04^{a}
	Dark	1.016 ± 0.12^{ab}	5.36 ± 0.16^{b}	6.19 ± 0.03^{c}	1.36 ± 0.19^{a}
Fast roast	Light	1.556 ± 0.46^{c}	4.63 ± 0.21^{a}	5.62 ± 0.07^{a}	0.96 ± 0.21^{a}
	Medium	1.262 ± 0.22^{bc}	4.80 ± 0.16^{a}	5.83 ± 0.06^{bc}	1.17 ± 0.15^{a}
	Dark	1.17 ± 0.06^{abc}	5.23 ± 0.18^{b}	6.23 ± 0.03^{c}	1.26 ± 0.02^{a}

The differences between the means with various superscript letters in the same column are statistically significant different at $p \leq 0.05$.

The pH value of roasted coffee brewed in this study ranged from 5.62 to 6.23. Based on the analysis results, the roasting level affected the pH value. The darker the roasting level, the higher the brewed coffee pH value. The results obtained from the investigation conducted in this study align with the research investigations done by Budiyanto *et al.* [9]. The higher temperatures and the longer roasting times can cause an increase in the pH value due to the degradation of various important compounds in coffee, including protein, polysaccharides, trigonelline and chlorogenic acid [21]. This aligns with the assertion made by Mulato [22] that coffee beans inherently possess a diverse array of volatile compounds, encompassing aldehydes, ketones, esters, alcohol, formic acid, furfural and acetic acid. Reducing the size of the beans can accelerate the evaporation process of volatile compounds which will be directly proportional to the pH increasing close to neutral value.

The study observed a variation in the caffeine level of roasted coffee, ranging from 0.96% to 1.36%. This result met SNI 01-3542-2004, which requires a maximum caffeine content in coffee powder of 2%. The roasting speed and roasting level did not have a substantial impact on the caffeine content of coffee powder in this study. The study observed a slight but discernible rise in the caffeine content of the coffee powder as the degree of roasting escalated. Based on the data in Table 2, coffee powder with a dark roasting level had a slightly higher caffeine content than coffee powder with a light and medium roasting level. This is in line with the result of research from Cuong et al. [21], the caffeine content of Vietnam robusta coffee was increased with the increased of roasting level.

4 Conclusions

The findings of this study suggested that the roasting process plays a significantly impacts the quality of coffee. The velocity at which coffee beans were roasted and the roasting level influenced the physicochemical characteristics of roasted coffee beans and coffee powder. The roasting speed and level affected the bulk density, hardness, lightness, water content, ash content and pH value. The caffeine content was not significantly affected by roasting speed or level. The study observed a variety of bulk density values for the roasted Robusta coffee, varying from 0.309 to 0.357 g/ml, the hardness was 5932.99 to 7164.87 gf, the lightness value was 34.44 to 39.98, the water content was 0.8073 to1.5556%, the ash content was 4.8010-5.3643%, the pH level was 5.62 to 6.23 and the caffeine content was 0.96 to 1.36%.

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