Effect of bean maturity and roasting temperature on chemical content of robusta coffee

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Abstract. This study aims to determine the effect of roasting temperature on chemical content of coffee beans at various fruit maturity. Robusta coffee was obtained from Karawang Regency, West Java. After picking, sortation, and drying in the sun to 10% moisture content, the coffee beans were roasted at 190 °C, 200 °C, 210 °C for 12 minutes. Physical properties observed were weight loss during the roasting. The chemical content observed were water, caffeine, fat, chlorogenic acid and ash before and after roasting. Chemical content analysis was performed using gravimetric methods, soxhlet extraction, and UV-Vis spectrophotometry. The color, aroma and flavor of roasted bean were conducted by organoleptic test. The results obtained, the ripe coffee bean with roasting temperature of 210 °C is the best, which gives the lowest yield. The unripe green beans have the highest water content. The roasting temperature did not provide a significant difference in fat, caffeine, chlorogenic acid, and ash content. Organoleptic test results (color and aroma) showed that the mature beans with roasting temperature of 200-210°C were the most preferred, while the coffee brew most preferred was overripe bean with the roasting temperature of 200°C.

1. Introduction
Coffee is a very important commodity for Indonesia, which is the fourth largest coffee exporter in the world, but the production has declined in the last two years. Indonesia’s coffee exports in 2017 amounted to 468,000 tons with a value of USD 1.2 million, in 2018 it decreased to 280,000 tons, with a value of USD 818 billion (40% lower) [1]. The decline in the volume of coffee exports is likely due to the lack of rejuvenation of coffee trees, also due to an increase in domestic coffee consumption, whether traded in ready-to-consume packaging or served in cafes. One of the reasons of this is that many young Indonesians are affected by coffee habits in countries where they study. Increasing local consumption means opening up real opportunities downstream in the value chain, such as baking, mixing, packaging and marketing. Almost all coffee traded consists of Arabica and Coffea canephora (robusta) species. Most roasted and commercial coffee grounds are mixtures of both species.

Several studies have been carried out on Arabica and Robusta beans, either concerning on different chemicals content of developing bean, or the effect of the roasting process on the chemical composition of coffee. The changes of chemical content of arabica coffee at various levels of fruit maturity was measured with the electrospray ionization mass spectrometry fingerprinting method [2] the chemical changes in Arabica and Robusta coffee from fruit formation to ripe bean [3], the effect of roasting on
caffeine levels of Arabica coffee from Ethiopia [4], the decreasing carbohydrate, protein, and chlorogenic acid content during the roasting [5]. There was investigation on the factors that influence the organoleptic nature of coffee [6]. This study aims to determine the combined effect of coffee fruit maturity and the effect of roasting temperature on water content, caffeine content, fat content and antioxidants, using simple methods as well as organoleptic properties (color, aroma, and taste of coffee brewing).

2. Materials and research methods
Robusta coffee was obtained from community coffee plantations in the Sanggabuana area, Karawang regency, West Java (altitude 600-700 masl), manually picked, sorted according to visual maturity, i.e. unripe (green), semi ripe (yellow-orange), ripe (full red), and overripe (red-brown), then an analysis of fat, water, and caffeine levels were performed. Furthermore, the coffee fruit was sorted based on its quality using water, then being sun dried for 14-20 days to a maximum water content of 12%. Fruit peeling to separate the coffee beans from the skin was done manually. The dried coffee beans were roasted in a drum roaster at temperatures of 190 to 210°C for 12 minutes. The temperature of the drum was set at 200-220°C before feeding the coffee beans into the drum.

During the roasting process the temperature was measured in a span of 2 minutes. The results of the roasting process were tested for the characteristics of coffee beans. The equipment used were analytical balance, oven, Soxhlet, and UV-Vis Spectrometer.

3. Results and discussion
Coffee beans that have undergone drying were referred to as green beans with water content as in table 1, which met the standard.

| Maturity Level | Fresh Bean | Green Bean |
|---------------|------------|------------|
| Unripe        | 67.35      | 10.32      |
| Semi-ripe     | 51.31      | 9.13       |
| Ripe          | 52.65      | 9.48       |
| Over-ripe     | 50.05      | 9.43       |

Moisture content of wet coffee bean (fresh bean) decreased due to bean maturity, and so did the dried coffee bean (green bean). This is consistent with research of Amorim et.al [2], that coffee water content decreases according to the level of fruit maturity. The contents of caffeine, fat and ash of green bean are presented in figure 1.

3.1. Effect of fruit maturity on roasting temperature
Roasting process of coffee beans with varying maturity at a temperature of 210°C resulted in different temperature changes. Ripe coffee beans experienced a significant temperature increase at 6 minute after the drying process, then first cracking occurred, indicating the reaction between polysaccharides with...
amino acids that produced high-pressure water vapor and CO$_2$ so that the cell wall is unable to resist, and followed by pyrolysis and second cracking at the 10 minute, which takes place in exothermic.

![Graph](image)

**Figure 2.** Effect of fruit maturity on roasting temperature.

Significant temperature changes of ripe coffee beans due to the high polysacharide content in ripe fruit. Coffee beans endosperm have increased weight within the developing fruit and reach the highest value when the fruit is ripe, then decrease when the fruit is over ripe [5]. Sucrose content increased gradually within the developing endosperm [6]. The largest component contained in Robusta coffee beans is polysacharide which reach 54.4% w [7].

### 3.2. Effect of roasted process temperature on ripe coffee beans

The roasting process of ripe coffee beans at temperatures of 190$^\circ$C and 200$^\circ$C was started by the drying phase after cold beans fed to the roaster, the heat inside the machine falls before rising slightly after 4 minute, then increasing almost constantly.

![Graph](image)

**Figure 3.** Effect of roasted process temperature on ripe coffee beans.

The roasting process at a temperature of 210$^\circ$C, after the evaporation of water is complete, there is an increase in temperature and at the 8$^{th}$ minute continues to increase quite significantly, which indicates the pyrolysis of compounds contained in coffee beans (exothermic).

At the roasting temperature of 200$^\circ$C and 210$^\circ$C the coffee bean underwent first cracking and second cracking, but the roasting at a temperature of 190$^\circ$C the second crack was not reached. After the second crack the oil comes out from the coffee beans, which can be recognized by a slightly shiny surface.

### 3.3. Physical and chemical properties of post-roasted coffee

**3.3.1. Change in weight after the roasting.** The roasting of coffee beans at a temperature of 190$^\circ$C, 200$^\circ$C and 210$^\circ$C resulted in a weight reduction of 15-20%, 20-22%, and continues to increase to 25%, whereas in coffee beans of immature fruit there is no difference in weight loss between roasting processes at 200$^\circ$C and 210$^\circ$C. This is probably due to the low polysaccharide and protein levels in unripe fruit, so that the pyrolysis process is not too large, which is identified by a small decrease in coffee mass. This indication is strengthened by the research of Hameed et al. [8], that the roasting process of...
ripe beans results in a greater weight loss than un-ripe bean. Redgwell et al. reported that up to 40% of the polysaccharides were degraded after a long roast [9].

![Figure 4. Weight loss after roasting process.](image)

3.3.2. **Water content.** The water content of the roasted coffee beans with various level of fruit maturity have met the specified value, which is between 1.99% to 3.65%. There is no significant difference in water content between different roasting temperature and the maturity of coffee beans. The decrease in water content during the roasting process by an average of 67.92%.

![Figure 5. Moisture content of dry and roasted coffee beans.](image)

3.3.3. **Caffeine content.** Caffeine causes several effects such as stimulating central nervous system; increasing respiratory rate, bronchodilatation, lipolysis, and diuresis, gastrointestinal disturbances, cardiac arrhythmias [10]. After the roasting process caffeine content increase from 1.5% -1.7% to 1.7% - 1.9% (10% -15% initial weight). Caffeine is a compound that is stable on heating due to the high boiling point [3], so there is no change in the mass of caffeine during the roasting process. Increased caffeine levels occur due to coffee mass and water loses during the roasting process. The biggest increase in caffeine levels occurs in ripe coffee beans with a roasting temperature of 200 °C. This is likely to occur because coffee beans with perfect maturity experience the optimum Maillard and pyrolysis reactions, and the greatest weight loss occurs. Based on SNI 01-3542-2004 the allowed caffeine content is 0.9% to 2%, thus the post-roasted coffee caffeine content meets the standard.

According to Motora and Beyene research, an increase in caffeine content in post-roasted coffee is 10-15% of the initial caffeine content, which is caused by a decrease in water content and evaporation of volatile material from post-roasted coffee so that the final total weight is smaller [11].
3.3.4. Ash content. Ash content in food represents mineral and metal content. Ash content is obtained from nutrients absorbed by plants during growth which is influenced by the location and climate of the coffee plant. Based on SNI 01-3542-2004 the maximum ash content permitted in the ground coffee is 5%. The results of the experiment are shown in table 2, ash content in robusta coffee after roasting tends to increase compared to the green bean. The level of post-roasted coffee is between 4.00 and 5.39%. An average increase in ash content in post-roasted coffee was 10.96%. Unripe coffee beans have a greater ash content than other levels of maturity, and the smallest is at the level of over ripe.

| Roasting Temperature (°C) | Maturity Level | Unripe | Semi Ripe | Ripe | Overripe |
|--------------------------|----------------|--------|-----------|------|----------|
| Green Bean               |                | 5.40   | 4.89      | 4.98 | 4.38     |
| 190                      |                | 5.60   | 4.81      | 4.68 | 4.49     |
| 200                      |                | 5.39   | 3.53      | 3.68 | 3.37     |
| 210                      |                | 4.12   | 5.42      | 5.14 | 5.20     |

3.3.5. Fat content. The results showed at Table 3 that the green beans fat content decreased from the level of unripe, semi-ripe, and ripe maturity. This is consistent with research Amorim et.al., that coffee fat content decreases according to the level of fruit maturity. The fat content in coffee is mostly found in coffee oil in the endosperm and a small portion in the outer layer of coffee beans. With the roasting process, fat content increases, due to a decrease in water content [2].

| Roasting Temperature (°C) | Maturity Level | Unripe | Semi Ripe | Ripe |
|--------------------------|----------------|--------|-----------|------|
| Green Bean               |                | 14.5   | 15.69     | 11.81|
| 210                      |                | 12.59  | 16.98     | 12.95|

3.3.6. Organoleptic test results. The result of the heating process and roasting level can be observed from changes in the color of coffee beans [8], aroma, and taste of coffee brewing (sweetness, body, acidity) which indicating the chemical reaction that occurs during roasting, in qualitative measures. The general aroma of coffee can reflect the taste of the coffee. Flavor is a combination that is felt by the tongue and the aroma of steam in the nose that flows from mouth to nose (aroma and body). The constituent components of flavors consist of volatile compounds such as aldehydes, ketones and esters as well as non-volatile compounds such as caffeine, protein and sugar. Organoleptic test results involving 15 respondents indicated that the most preferred color was ripe bean, roasted at 200 °C, the most preferred fragrance was ripe bean, roasted at 210 °C, and the most preferred brew was from over ripe bean, roasted at 200 °C.
4. Conclusion
Coffee beans of ripe maturity and roasting temperature of 210°C is the best condition, with the level of caffeine, fat, and ash do not change significantly between the green bean and roasted bean, and by organoleptic test on the color and aroma of coffee showed that the ripe beans with roasting temperatures of 200-210°C were the most preferred, while the most preferred coffee flavoring was from the ripe and over-ripe coffee bean with roasting temperatures of 200°C.

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