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Effect of Fruit Ripening Level and Roasting Temperature on Robusta Coffee Bean Quality

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ABSTRACT

The purpose of this study is to determine the effect of roasting temperature on the chemical content of Robusta coffee. The roasting temperatures of 190°C, 200°C, 210°C, 220°C will be used. Chemical content analysis is carried out bygravimetric method and UV-VIS spectrophotometry on various of coffee beans. Maturity of coffee beans will be classified visually and RGB meter will be used to help and facilitate the selection of coffee beans based on maturity level. Temperature of the roasting process, time required at roasting time, as well as the mass, chemical content and physical parameters of robusta coffee beans will be used as variables observed. Chemical content was observed in the form of water content, fat content, caffeine, then the physical parameters observed were aroma, color, shape, taste, and characteristics of coffee beans at each level of robusta coffee fruit maturity. Chemical content and organoleptic test at each level of maturity of the coffee fruit and roasting temperature are varyous. Moisture content of dry coffee beans from fruit with different maturity varies, but for semi-ripened, ripe, and over-ripe beans. Values are almost the same (9.13% to 9.48%). Unripe coffee beans have the highest water content (10.32%).

KEYWORDS

Caffeine
Level of maturity
Organoleptic test
Roasting temperature
Robusta coff

INTRODUCTION

Coffee is one of the commodities that is in great demand in world trade so that many countries are involved both as producing countries and as consumer countries. The rate of development of coffee area in Indonesia is 2.2%. Indonesia has a coffee plantation area of 1,291 million hectares, 96% of which are smallholder coffee plantations [1]. Post-harvest processing and further processing will affect the components in the coffee that turn into complex compounds or components that are partially lost due to the process that has been passed.

Robusta coffee was developed in Indonesia in 1900 to replace Arabica coffee which is susceptible to leaf rust disease. Robusta coffee has a higher production rate than liberica coffee and has high resistance to the fungus Hemileia vastatrix. Robusta coffee growth requires three dry months followed by sufficient rainfall. This dry period is necessary for the formation of flower primordia, flora and pollination. Robusta coffee grows well at altitudes between 600 to 700 MDPL

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and air temperatures ranging from 20 - 24°C. Robusta coffee has a higher yield than Arabica coffee.

Chemical content contained in robusta coffee beans is mineral content 4.0 - 4.5%, caffeine content 1.6 - 2.4%, trigonelline content 0.6% - 0.75%, fat content 9.0 - 13 0.0 %, aliphatic acid content 1.5 - 1.2%, protein content 13.0 - 15.0%, and total content of chlorogenic acid 7.0 - 10.0%[2]. The physical quality and taste of coffee are influenced by geographical location, planting material, cultivation method, harvest method, post-harvest processing and storage. The process of processing coffee beans in producing the final product is a determining stage of the quality of coffee products [3].

The level of maturity of coffee beans can be represented by the color of the coffee fruit. There are 4 levels of maturity of coffee beans based on color which are classified into unripe (green), semi-ripe (yellow-orange), ripe (full red) and over ripe (red-brown), Coffee bean maturity can be classified visually or using technology on a scale chromameter using Colorimeter [4]. The maturity level indicates different seed conditions and quality [5].

After picking, the robusta coffee cherries are subjected to post-harvest processing to remove impurities, remove the epidermis and horns and need to be pre-dried. There are 2 ways of post-harvest processing to obtain coffee beans that can be sold commercially, namely the wet process and the dry process. Robusta coffee processing is generally done by the dry method. Drying can be done manually or mechanically. The stages of the dry processing process are the coffee beans are dried in the sun immediately after harvest until the water content is reduced to 12% (wb) [6]. Drying takes 2-3 weeks. The cherries (perfect red coffee) are dried and then peeled manually using a pestle and mortar or in a peeler to remove the pulp, skin and epidermis. The final process is cleaning the peeled coffee by winnowing and sorting the damaged beans to obtain high-quality beans.

Drying is the process of removing water from an agricultural material towards a moisture content in equilibrium with the surrounding air or at a water content level where the quality of agricultural materials can be prevented from attack by fungi, enzymes, and insect activity. The drying rate includes a constant drying rate and a decreasing drying rate. Drying of agricultural products generally occurs during a period of falling drying rate. Drying or dehydration of biological materials, especially food is used as a technique to prevent microorganisms that will cause spoilage, enzymes that cause chemical changes in food and other biological materials will not grow quickly without water. When the water content is below 10%, the microorganisms are inactive. Foods that have been dried also have a longer shelf life. At constant drying rate, the solid surface is initially very wet and a continuous layer of water is present on the drying surface. Water is included in unbound water. In the constant period solid axis much of the water that evaporates is supplied from within the solid. This period lasts continuously as long as water is supplied to the surface quickly and then evaporates.

The roasting process occurs because the energy that moves from the roaster, which comes from the metal surface or hot gas to the green beans, is described in Figure 2.3. The coffee beans will catch the heat and the water will start to evaporate in an endothermic process [7]. When the

degree of ripeness has been reached in terms of (color, taste, roast, loss of mass), the beans are removed from the roaster and cooled rapidly in a water and air cooler.

Coffee roasting is an important process to develop the specific organoleptic properties (taste, aroma and color) that underlie the quality. This process is very complex, because the amount of heat transferred to the seeds is very important. During coffee roasting, moisture is lost and a chemical reaction occurs [8]. Roasting time varies from 7 to 30 minutes depending on the type of equipment and the quality of the ground coffee [5], [9].

RESEARCH METHOD

There are five stages of the research method with four variations of temperature in the drying process of robusta coffee beans with a range of around 190 - 220 °C for 12 minutes and four variations of the level of maturity of coffee beans, namely unripe (green), semi-ripe (yellow-orange), ripe (full red), and overripe (red-brown). The five stages of the research are taking robusta coffee raw materials, post-harvest handling of robusta coffee, preliminary research by analyzing the characteristics of robusta coffee which includes measuring fat content, water content, and caffeine, before drying the robusta coffee beans, then drying the coffee beans with roasting method, as well as testing the characteristics of robusta coffee such as preliminary research using coffee beans that have been dried.

Chemical and Reagents

The equipment used is divided into main equipment and supporting equipment. The main equipment is a Colorimeter to measure the maturity level of coffee cherries based on skin color, and a Roaster to carry out the roasting process. Supporting equipment in the form of UV-Vis Spectrometer, Soxhlet, and oven, which are used to perform chemical analysis of the content of coffee beans. The materials used are divided into main materials and supporting materials and tests. The main ingredient is robusta coffee with 4 levels of maturity. Supporting materials in the form of chemicals used for chemical analysis of coffee.

Procedures

Taking the raw material in the form of robusta coffee cherries carried out in people's coffee plantations located in the Sanggabuana area, Karawang Regency by picking robusta coffee berries based on four different types of ripeness, namely unripe (green), semi-ripe (yellow-orange), ripe (full red), and overripe (red-brown). When a robusta coffee fruit is found whose color is between two levels of visual maturity, measurements are made using an RGB meter.

Robusta coffee that has been picked, the coffee maturity level is sorted using a chromatometer (RGB). Post-harvest handling of robusta coffee is carried out by the dry coffee processing method. Dried coffee processing is intended for processing at the farmer level with small land and small processing capacity. The workings of dry coffee processing is robusta coffee that has been picked and then dried for 14-20 days. Dried coffee can be ground or peeled with a huller to remove the

horns and husks [10]. There are several studies on robusta coffee beans after post-harvest including analysis of water content, fat, caffeine and antioxidants.

The roasting process was carried out at four temperature variations, namely 190°C, 200°C, 210°C, 220°C, carried out for 12 minutes. Before the coffee beans are put into the drum, the temperature of the drum is conditioned around a temperature of 200-220°C. Each level of maturity of the coffee beans is fed into the roaster through the feeder until it reaches the set temperature and time. The temperature was measured every 2 minutes.

Testing the characteristics of robusta coffee beans that have been dried using the roasting method, includes the same parameters as raw materials carried out at the Politeknik Negeri Bandung Laboratory.

DISCUSSION

Harvest and Post-Harvest Processing

The harvesting and post-harvest processing is divided into five stages, namely picking fruit, sorting by maturity level, sorting coffee quality, fruit stripping and drying. Robusta coffee fruit picking is done manually at four levels of fruit maturity, namely unripe, semi-ripe, ripe and over-ripe.

The coffee cherries that have been picked are then separated based on the level of maturity, which can be identified by the color of the coffee cherries. Green coffee cherries are classified as unripe, yellowish-red coffee cherries are classified as semi-ripe, full red coffee cherries are classified as ripe, and dark purple-red coffee cherries are classified as over-ripe. The coffee cherries that have been separated based on the level of maturity are then put into a large container filled with water for a quality sorting process. Floating coffee cherries indicate that the coffee beans are of poor quality or damaged and must be discarded, while the sinking coffee cherries indicate that the coffee beans are of good quality which are ready to be processed in the drying process.

The drying process is carried out immediately on fresh coffee cherries so that there is no change in the content of chemical compounds in the coffee cherries. The process of peeling fresh coffee cherries cannot be done using a huller because wet coffee cherries have the potential to be left behind and clog the huller, so the peeling process must be done manually. The peeled coffee beans are then washed with water to remove the remaining mucus, then drained to dry.

The coffee beans are then dried in the sun for 20 days, to a moisture content of 9-10% (w.b) as presented in Table 1. Coffee beans that have undergone drying are referred to as green beans which have met the standards for the water content of green beans.

Table 1. Moisture content (%) of robusta coffee beans after drying

No.	Maturity level	Fresh bean	Green bean
1	Unripe	67.35	10.32
2	Semi-ripe	51.31	9.13
3	Ripe	52.65	9.48

No.	Maturity level	Fresh bean	Green bean
4	Over-ripe	50.05	9.43

The moisture content of dry coffee beans from fruit with different maturity varies, but for semi-ripened, ripe, and over-ripe beans, the values are almost the same (9.13% to 9.48%). Unripe coffee beans have the highest water content (10.32%). The content of caffeine, fat, and dry coffee bean ash (Green Bean) is presented in Figure 1.

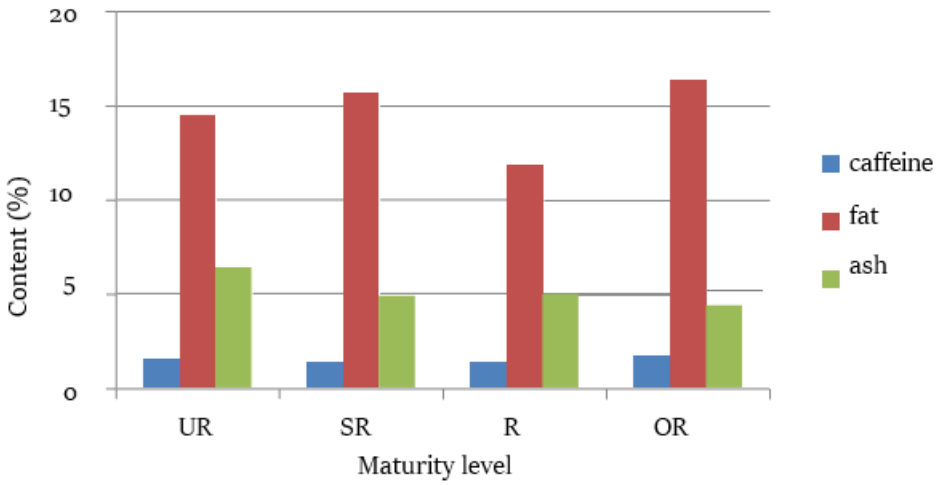

Figure 1. The content of caffeine, fat, and dry coffee bean ash (Green Bean)

Roasting Process

Coffee beans with different fruit maturity that have been dried are then roasted at various temperatures. In the roasting process, further drying occurs which takes place endothermic (there is a decrease in temperature in the roaster), followed by a "browning" process known as the Maillard reaction, which is a reaction between amino acids and carbohydrates (sugars) when given the right amount of heat. In the roasting process, the sugar in the coffee beans becomes caramelized and the fat turns into aromatic oil, thus giving the coffee its distinctive aroma and taste.

Comparison of Fruit Ripe to Roasting Temperature Changes

The roasting process carried out at a temperature of 210°C for coffee beans with varying maturity gives different temperature changes, presented in Figure 2.

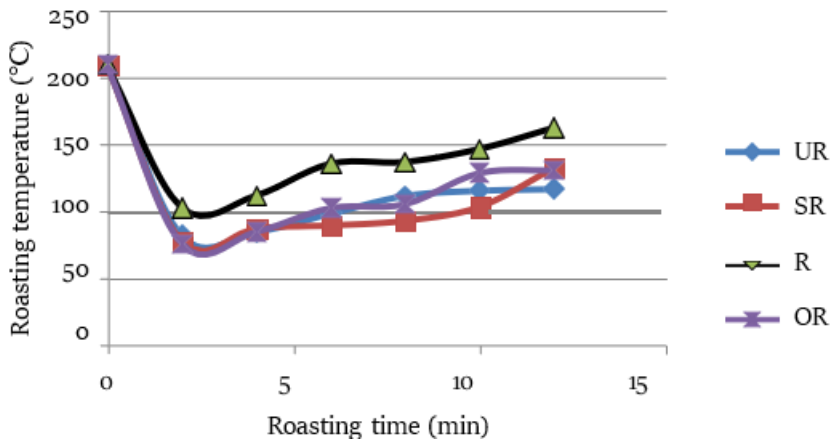

Figure 2. Effect of fruit ripening on roasting temperature changes

Ripe coffee beans experienced a significant increase in temperature in the 6th minute roasting process, after the drying process and the first crack occurred, indicating a reaction between polysaccharides and amino acids that produces water vapor (H_2O) under high pressure so that the walls cells were unable to withstand, and continued with pyrolysis and second cracking (second crack) at 10 minutes, which was exothermic.

The significant temperature change in ripe coffee beans (ripe) may be due to the relatively high polysaccharide content in ripe fruit, compared to underripe or overripe fruit. Coffee beans (endosperm) increased in mass (weight) from the time of initial fruit formation and reached the highest value when the fruit was ripe, then decreased when the fruit was ripe. The largest component contained in coffee beans is carbohydrates (37%).

Effect of Roasting Process Temperature on Ripe Coffee Beans

The roasting process for coffee beans with perfect ripeness (ripe) is carried out at various temperatures, giving different temperature changes, as shown in Figure 3. The roasting process for ripe coffee beans (ripe) at 190°C and 200°C in the first minute there is evaporation of water content is endothermic, so the temperature of the system decreases. At minute 4 there was an increase in temperature, but not large or almost constant. While the roasting process at a temperature of 210°C, after the evaporation of water is complete, in the 4th minute the temperature increases and at the 8th minute it continues to increase significantly, which indicates the occurrence of pyrolysis between compounds contained in coffee beans (exothermic).

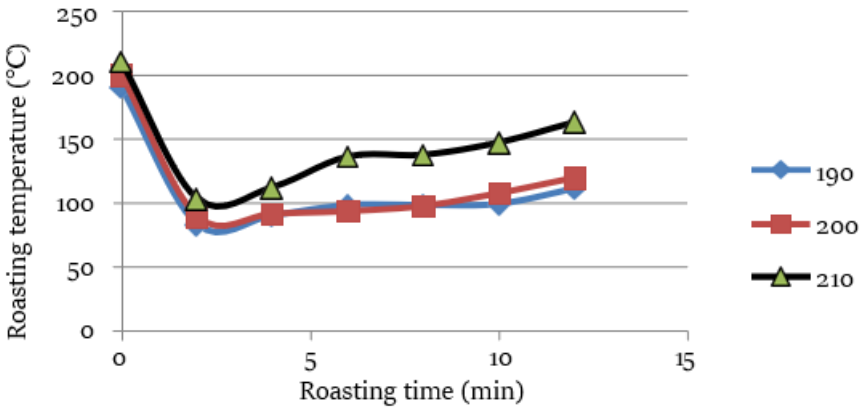

Figure 3. Effect of roasting process temperature on ripe coffee beans

From the observation of the roasting process, data also obtained that at a temperature of 200°C and 210°C, the first and the second cracking phase occurred, but at a temperature of 190°C the second crack phase was not achieved. This indicates that the roasting process will run perfectly at an operating temperature of at least 200°C.

The second cracking process is slightly smoother than the first cracking and results in a very low water content of the coffee. It is at this stage that the oil from the coffee beans emerges, which can be recognized by its slightly glossy surface. The sour taste and characteristic taste of coffee is very weak, but gives a significant bitter taste.

Physical and Chemical Properties of Coffee

Weight Change After Roasting Process

In addition to temperature observations during the roasting process, at the end of the roasting process the weight of the coffee is measured, and the results are presented in Figure 4. Coffee beans from half-ripe, ripe, and overripe fruit in the roasting process with a temperature of 190°C experienced a weight reduction of 15-20% and in the roasting process with a temperature of 200°C the weight loss is 20-22%, and continues to increase at the 210°C roasting process, which is 25%, while in the coffee beans from immature fruit there is no difference in weight loss between the roasting process at 200°C and 210°C (22 %). This is probably caused by the polysaccharide and protein content in underripe fruit that is still not optimal, so the pyrolysis process is not too large, which is indicated by a decrease in coffee mass that is not too large. The roasting process of ripe coffee beans causes a greater weight loss than underripe beans [11]. Weight loss of 11%, 15% and 22% in the roasting process is grouped as light, medium and black roasts [12].

Moisture Content

In the roasting process, in addition to a reaction that gives rise to the aroma and taste of coffee, there is also a decrease in the water content of the coffee beans. The results of the roasting process of coffee beans with various levels of fruit maturity have met the standard value set, which is between 1.99% to 3.65%. There is no significant difference in water content between variations in roasting temperature and the level of maturity of coffee beans. The results of the analysis of moisture content before and after the roasting process are presented in Table 2.

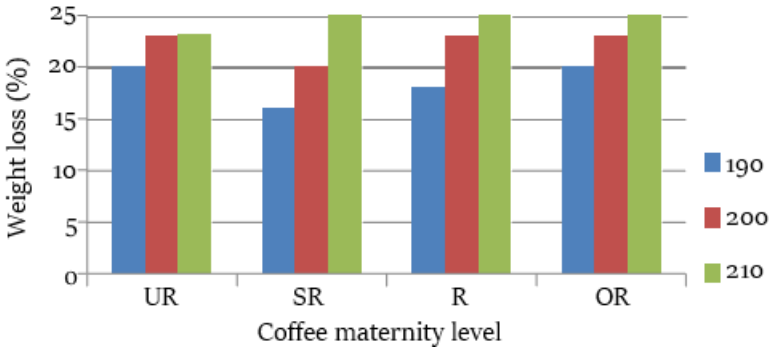

Figure 4. Changes in weight after the roasting process

Table 2. Moisture content (%) of coffee beans

No.	Roasting temp (°C)	Maternity level			
		Unripe	Semi ripe	Ripe	Overripe
1	*Green Bean*	10.32	9.13	9.48	9.43
2	190	1.99	2.34	2.35	3.55
3	200	3.53	3.33	3.48	3.65
4	210	3.49	3.35	2.90	2.96

Coffee beans contain many volatile compounds that are soluble in water, so the water content can affect the aroma and taste. The decrease in water content of coffee beans during the roasting process is an average of 67.92%.

Caffeine Content

The main role of caffeine in the body is to increase psychomotor work so that the body is maintained and provides a physiological effect in the form of increased energy. This effect is usually only seen a few hours after consuming coffee [13]. Caffeine has a bitter taste and affects the formation of a bitter taste in coffee by 10% [14], [15]. The experimental results are shown in Figure 5.

In Figure 5 there is an increase in caffeine levels after roasting compared to the initial conditions (green beans), which is 1.5%-1.7%. After the roasting process the caffeine content increases to 1.7% to 1.9% (an increase of 10%-15% of initial weight). Caffeine is a compound that

is stable on heating (roasting process up to 210°C) because of the high boiling point of caffeine [16], so that there is no change in levels during the roasting process.
The increase in caffeine levels occurs because in the roasting process there is a loss of coffee mass. The greatest increase in caffeine levels occurred in ripe coffee beans (ripe) with a roasting temperature of 200°C. This is probably because coffee beans with perfect maturity experienced the most optimum Maillard reaction and pyrolysis, and the greatest weight loss occurred.

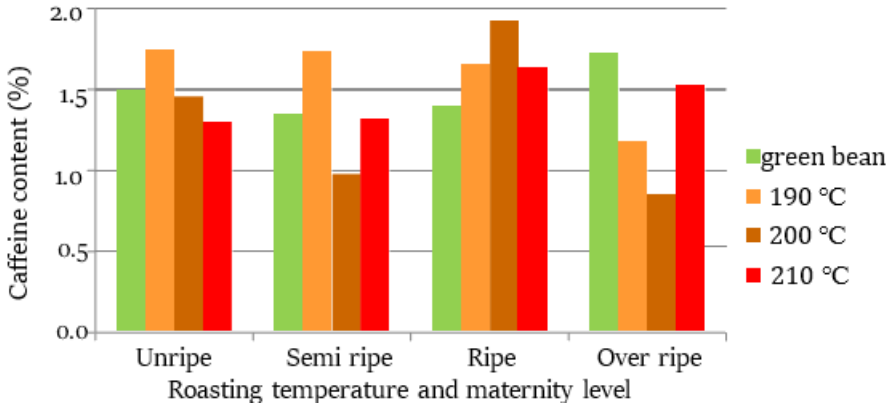

Figure 5. Effect of cooking and roasting temperature on caffeine levels

Based on SNI 01-3542-2004 the allowed caffeine content is 0.9% to 2%, thus the caffeine content of post-roasted coffee has met the standard. Wetness is caused by the decrease in water content and evaporation of volatiles from post-roasted coffee so that the final total weight is smaller [17].

Ash Content

The ash content of a food ingredient represents the mineral and metal content. Ash content is obtained from nutrients absorbed by plants during the growth period which is influenced by the location and climate of the coffee plant. Based on SNI 01-3542-2004 the maximum allowable ash content in ground coffee is 5%. Ash content in post-roasted robusta coffee tends to increase compared to before roasting. From Table 3 it is obtained data that the ash content of post-roasted coffee is at a value of 4.00-5.93%, . There was an increase in the average ash content of post-roasted coffee by 10.96%. Unripe coffee beans have a higher ash content compared to other maturity levels, namely 5.93% and the smallest is at the over ripe level. The relatively high ash content can be caused by the process of peeling the skin of the coffee beans that is not perfect, so that there are still materials that are not soluble in acid.

Table 3. Ash content (%) coffee beans

No.	Roasting temp (°C)	Maternity level			
		Unripe	Semi ripe	Ripe	Overripe
1	Green Bean	6.40	4.89	4.98	4.38
2	190	5.60	4.81	4.68	4.49

No.	Roasting temp (°C)	Maternity level			
		Unripe	Semi ripe	Ripe	Overripe
3	200	6.39	3.53	3.68	3.37
4	210	4.12	5.42	5.14	5.20

Organoleptic Test Results

Monitoring of the heating process and roasting level, apart from the loss of mass of coffee beans and chemical changes of certain components that can be measured quantitatively, can also be observed from changes in the color of the coffee beans, aroma and taste of brewed coffee (sweetness, body, acidity) which are the result of of the chemical reactions that occur during roasting, with qualitative measures.

The character of the coffee aroma in general can reflect the taste of the coffee. Aroma includes fragrance (the smell of coffee when it is powder/dry) and the aroma when the coffee is brewed with hot water. Flavor is a combination that is felt by the tongue and the aroma of steam in the nose that flows from the mouth to the nose (aroma and body). Flavor components consist of volatile compounds such as aldehydes, ketones, and esters as well as non-volatile compounds such as caffeine, protein and sugar. The results of the organoleptic test involving 15 respondents, not experts/coffee connoisseurs, so the results are less consistent.

Colour : R200 R210
Flavour : R210 R200
Taste : O200 R200

CONCLUSION

The moisture content of dry coffee beans from fruit with different maturity varies, but for semi-ripened, ripe, and over-ripe beans, the values are almost the same (9.13% to 9.48%). Unripe coffee beans have the highest water content (10.32%).

Ripe coffee beans experienced a significant increase in temperature in the 6th minute roasting process, after the drying process and the first crack occurred, indicating a reaction between polysaccharides and amino acids that produces water vapor (H2O) under high pressure so that the walls cells were unable to withstand, and continued with pyrolysis and second cracking (second crack) at 10 minutes, which was exothermic.

From the observation of the roasting process, data also obtained that at a temperature of 200°C and 210°C, first and second crack phase occurred, but at a temperature of 190°C the second crack phase was not achieved. This indicates that the roasting process will run perfectly at an operating temperature of at least 200°C.

There is no significant difference in water content between variations in roasting temperature and the level of maturity of coffee beans. The greatest increase in caffeine levels occurred in ripe coffee beans (ripe) with a roasting temperature of 200°C, because coffee beans with perfect maturity experienced the most optimum Maillard reaction and pyrolysis, and the greatest weight loss occurred. There was an increase in the average ash content of post-roasted coffee. The fat

content of semi ripe, ripe and over ripe coffee beans has increased from post-harvest coffee beans (green beans). The results of organoleptic tests involving 15 respondents are less consistent.

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