INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
23–0380/2024/31–3–167–173
DOI: 10.17957/IJAB/15.2128
http://www.fspublishers.org

Full Length Article

Physicochemical and Sensory Qualities of Arabica Coffee (*Coffea arabica*) obtained from Different Processing Methods and Roasting Degrees

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Received 20 September 2023; Accepted 21 December 2023; Publishers 14 February 2024

Abstract

Green bean coffee (*Coffea arabica* L.) processing and roasting are important factors in determining the quality of brewed coffee. This research was aimed to determine the effect of processing methods (honey, natural and full wash methods) and roasting degree (light, medium and dark) on the quality of Arabica coffee. The analysis carried out includes physicochemical and sensory analysis. The results showed that the processing method (PM) had a significant effect on the lightness level (L*) of Arabica coffee. The degree of roasting (RD) had a significant effect on color (L*, a*, b*), water content, pH, caffeine content and hedonic tests (color, aroma and taste). The higher the RD results in a decrease in all color parameters (L*a*b*) and water content. The pH value increased with increase in RD. The medium roast degree in each type of PM produces the best level of hedonic (liking) and cupping value. The highest cupping value was obtained at medium RD, reaching specialty coffee scores above 80. © 2024 Friends Science Publishers

Keywords: Arabica coffee; Cupping score; Roasting degree; Sensory quality

Introduction

Coffee (*Coffea arabica* L.) is one of the most widely consumed drinks in the world. It is estimated that more than two billion cups of coffee are consumed every day. World coffee consumption continues to increase with the increasing number of specialty coffee shops in various countries. The increase in coffee production and commercialization has made coffee one of the most traded commodities in the world (Safe *et al*. 2023). For Indonesia, coffee is one of the leading commodities which plays an important role in the country's economy. Indonesia is currently in the 4th largest coffee producer position in the world. The three largest coffee producing countries in the world are Brazil, Vietnam and Colombia (ICO 2021). Apart from being an important trade commodity, currently coffee is also an object of scientific attention by assessing the quality of the coffee produced. The quality of coffee beans can be influenced by various factors such as genetics, processing methods, brewing and serving methods (Febrianto and Zhu 2023).

Processing methods (PM) are one of the factors that influence coffee quality. In general, coffee processing consists of 3 methods, namely dry (natural), wet and semi-wet methods. Each method has a different influence on the characteristics of the coffee produced (Banti and Abraham 2021; Cao *et al.* 2023). Currently, various new methods are emerging to improve the taste (sensory) quality of the coffee produced. The processing process focuses on optimizing the fermentation process of coffee fruit and beans which will affect the coffee beans (Febrianto and Zhu 2023).

Another important factor influencing the quality of brewed coffee is the roasting process. Roasting is a complex thermal process because it allows the development of color, aroma and taste, which are very important for the quality of coffee. During roasting, a series of complex chemical and physical processes occur that produce thousands of different molecules (Franca *et al.* 2005; Iaccheri *et al.* 2015). The production mechanism of these compounds is interactive and very complex, contributing to the unique sensory properties of brewed coffee (Haile *et al.* 2020; Chindapan *et al*. 2022). Most of these volatile compounds are related to coffee aroma, including pyrazines, furans, aldehydes, ketones, phenolic compounds, and sulfur-containing compounds, which basically result from Maillard reactions, caramelization, Strecker degradation, and pyrolysis during roasting (Cao *et al*. 2023).

Uncontrolled roasting can cause further degradation of some desired volatile compounds and encourage the formation of undesirable compounds due to intensive pyrolytic reactions which can affect the quality of the final product (Toledo *et al*. 2016). The roasting classification based on color degree can be divided into three, namely light, medium and dark (Supriana *et al.* 2020). At each level of roasting, light, medium and dark can be determined using temperatures of 180, 200 and 220˚C (Mardjan *et al.* 2022). Dark roasting tends to produce more intense bitterness and a burnt taste compared to other roast levels. Different roasting profiles will produce different physical, chemical and sensory characteristics (Fibrianto *et al.* 2018). This research aims to determine the effect of PM and RD on the quality of Arabica coffee.

Materials and Methods

Materials and equipment

The main raw material used in this research was Arabica coffee (*Coffea arabica* L.) beans of the Sigararutang variety obtained from the Experimental Garden of the Gunung Putri Industrial and Refreshment Crops Research Institute (Balittri), Cianjur, West Java, Indonesia. The equipment used is a Hunterlab Miniscan EZ Chromameter, Roaster (Probat BRZ 2 propan-werke), Thermo Scientific Genesis 10S UV-VIS spectrophotometer, rotary evaporator, grinder, oven (JP Selecta), pH meter (Hanna instruments HI 2550), analytical balance, separating funnel, vortex, erlenmeyer, measuring cup, measuring flask, filter paper, spoon, glass, dropper pipette, funnel, hot plate, desicator, shaker, stirring rod, plastic wrap and test tube.

Sample preparation

The samples used were Arabica coffee beans of the Sigararutang variety which were obtained from three types of processing, namely honey, natural and full wash processing. The processed coffee beans came from the Gunung Putri Experimental Garden which has an altitude of 1200 meters above sea level. The samples were sent to Balittri, then the coffee beans were sorted by paying attention to the presence of mechanical defects, broken beans, damaged/cut, insect attacks, partially black, small stones and small wood. Next, the coffee beans were dried to ensure that the water content of the coffee beans is low enough, namely ±12%. The honey processing process is carried out by sorting the coffee berries, pulping, drying for 5–7 days and hulling. Full wash processing was carried out by sorting the coffee berries, pulping, fermenting 12–24 h, washing, drying ± 5–7 days, hulling. Meanwhile, natural processing was carried out by sorting the coffee cherries, direct drying and hulling.

Roasting coffee beans

Roasting is conducted on a laboratory scale using a mini roaster Probat BRZ 2 propan-werke. Each coffee bean sample was weighed 100 g. Next, roasting is carried out using a roasting machine with a capacity of 100 g. All Arabica coffee beans (honey, natural, and fullwash) were roasted at 200ºC until they reach the desired roast profile (light, medium, and dark). Determining the roast profile was differentiated from the time used (light with 4 min, medium with 5 min, and dark with 6 min). The working mechanism of this tool was generally the same as other roasting tools, only the capacity was small. Roasted coffee bean was ground with a grinder, then stored in a dark colored pouch until ready to be analyzed.

Product analysis

Physicochemical and sensory analyses were carried out on the roasted coffee products produced. The color of the roasted coffee beans was analyzed using a Hunterlab Miniscan EZ chromameter (Hutchings 1999), water content using the oven method (AOAC 2012), pH analysis using a pH meter (AOAC 2012) and caffeine content analysis using a spectrophotometer (Supriana *et al*. 2020). The sensory quality test of coffee was carried out using hedonic analysis and cupping test. The hedonic test was carried out by 25 panelists while cupping test was conducted by 3 Q-grader from Gayo Cupper Team (SCAA 2015).

Statistical analysis

This research was a randomized block design with three replications. The research data were analyzed using analysis of variance (ANOVA) and further tests were carried out with Duncan Multiple Range Test (DMRT) at the 5% level. The data obtained were analyzed by using SPSS statistical program (version 22.0) for windows.

Results

Physicochemical quality of roasted Arabica coffee bean

The color values (L*, a*, b*) of roasted coffee beans produced in this study varied between treatments as shown in Table 1. The results of ANOVA showed that the processing method (PM) and roasting degree (RD) had a significant ($P \leq 0.05$) effect on the brightness level (L*) of Arabica coffee. The influence of each PM and RD treatment on the lightness of Arabica coffee bean is given in Fig. 1 and 2. The redness value (a*) of the coffee grounds obtained ranged from 8.97–13.85 with an average of 11.51. The results of variance analysis showed that the RD treatment has a significant effect ($P \leq 0.05$) on the redness value (a*) of Arabica coffee grounds, while the PM and the interaction of PM and RD there was no significant effect ($P > 0.05$) on the redness value (a*) of Arabica coffee grounds (Fig. 3). The yellowness value (b*) of Arabica coffee grounds obtained ranged from 10.55–29.77 with an average of 19.27. The ANOVA results showed that the RD treatment had a significant effect ($P \leq 0.05$) on the yellowness value (b*) of

Arabica coffee grounds, while the MP and the interaction of MP and RD did not significantly affect (P>0.05) on the yellowness value (b*) of Arabica coffee grounds (Fig. 4).

The water content value of Arabica coffee grounds in this study ranged from 1.31 to 4.22% with an average of 2.69%. Results showed that the RD had a significant effect (P≤0.05) on the water content of Arabica coffee grounds, while the MP and the interaction of MP and RD had no significant effect (P >0.05) on the water content of Arabica coffee grounds (Fig. 5). The pH value of Arabica coffee grounds obtained ranged from 4.72–5.29 with an average of 4.96. The ANOVA results showed that the RD treatment had a significant effect (P≤0.05) on the pH value of Arabica coffee grounds, while the PM and the interaction of PM and RD had no significant effect (P >0.05) on the pH value of Arabica coffee grounds (Fig. 6). The caffeine content of the Arabica coffee grounds ranged from 0.43–0.51% with an average of 0.47%. The ANOVA results showed that the RD had a significant effect (P≤0.05) on the caffeine content of Arabica coffee grounds, while the PM and the interaction of PM and RD had no significant (P>0.05) effect on the caffeine content of Arabica coffee grounds (Fig. 7).

Sensory quality of brewed Arabica coffee

The hedonic test value for the color of Arabica coffee brewing obtained ranged from 2.87 (neutral) to 3.68 (liked) with an average of 3.41 (neutral). The ANOVA results showed that the RD treatment had a significant (P≤0.05) effect on the hedonic test of color of brewed Arabica coffee (Fig. 8). The hedonic value for the aroma of brewed Arabica coffee obtained ranged from 3.16 (neutral) to 3.60 (liked) with an average of 3.37 (neutral). The ANOVA results showed that the RD treatment had a significant (P≤0.05) effect on the hedonic test of the aroma of Arabica coffee brewing, while the PM and the interaction of PM and RD had no significant (P>0.05) effect on the hedonic test for the aroma of Arabica coffee brewing (Fig. 9).

The hedonic value for taste of Arabica coffee brew obtained ranged from 2.68 (neutral) to 3.04 (neutral) with an average of 2.85 (neutral). The ANOVA results showed that the RD treatment had a significant (P≤0.05) effect on the hedonic taste test of Arabica coffee brewing, while the PM and the interaction of PM and RD interaction was non-significant (P>0.05) on the hedonic taste test of Arabica coffee brewing (Fig. 10). The result of sensory analysis using the cupping test method referring to SCAA (2015) was given in Table 2. A total of 10 attributes (fragrance, flavor, aftertaste, acidity, body, balance, uniformity, clean cup, sweetness and overall) were rated from 6 to 10 with a total cupping score range of 63.50 (below specialty) to 82.25 (specialty).

Discussion

Based on Fig. 1, it can be seen that the lightness (L*) of honey and natural roasted coffee grounds is slightly higher than that of full wash. It is suspected that different skin stripping and drying processes between the three processes affect the lightness of the resulting color. However, Yulianti *et al.* (2022) showed that the color of roasted coffee from the three types of processing does not show a significant difference. In this research, the lightness value tended to decrease with increase in RD (Fig. 2). Smaller the L* value, lower was the lightness. This is due to the heating process, which triggers various reaction mechanisms such as hydrolysis, pyrolysis, Maillard reaction, Strecker degradation and other compounds, which contribute to changes in color and aroma (Toci *et al.* 2017). Higher the

Table 1: Color of roasted coffee beans

Coffee treatment	Color		
	L*	a*	b*
P1R1	29.48	13.85	29.77
P1R2	22.38	10.87	17.67
P1R3	17.58	9.72	11.96
P2R1	29.04	12.47	25.29
P2R2	22.89	12.87	21.46
P2R3	17.44	10.15	11.99
P3R1	28.53	12.17	24.56
P3R2	22.34	12.51	20.17
P3R3	16.50	8.97	10. 55

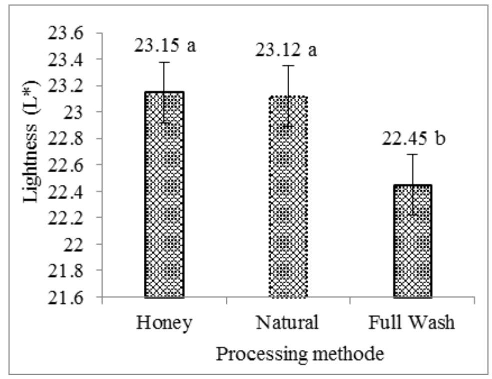

Fig. 1: Effect of processing method on lightness level (L*) (values followed by the same letter indicate no difference at $P < 0.05$)

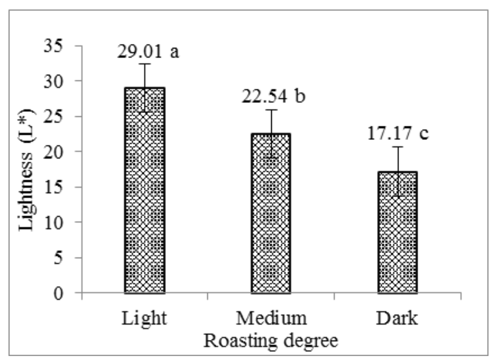

Fig. 2: Effect of roasting degree on lightness level (L*) (values followed by the same letter indicate no difference at $P < 0.05$)

heat intensity provided, the greater was the rate of change, which is in line with Kim and Kang (2018). This shows the highest level of lightness of roasted coffee beans obtained from light roasting, followed by medium and dark roasting.

A highest redness value for coffee grounds was obtained at light and medium roast degrees of 12.83 and 12.08, which showed a significant difference to the dark roast degree with a reddish value of 9.61 (Fig. 3). This result is higher than the research results of Marcell (2020), i.e., 6.88 to 4.09 and Bilfauz (2020) with the value (a*) obtained for Arabica coffee beans ranged from 6.92 to 4.20. The RD can affect the redness value of roasted Arabica coffee. The color of the coffee beans changes to blackish brown due to the Maillard reaction which results in the emergence of compounds with carbonyl groups (reducing sugars) and amino groups (Toci *et al.* 2017; Nadhiroh 2018).

Fig. 4 showed that the highest yellowness value for coffee grounds was obtained at a light roast level of 26.54 and for Arabica coffee grounds with a medium roast level it was 19.77. Meanwhile, Arabica coffee with a dark roast degree produces a yellowish value of 11.50, which shows a significant difference between light, medium and dark roast degrees. These results are higher than the results from research by Bilfauz (2020), 11.19–4.71 and Sriwanata (2020) which ranged from 26.30–22.02. The graph above shows that differences in roast profile can affect the yellowness value (b*) in Arabica coffee. A low yellowness value (b*) indicates that the color of the coffee beans is more blue (Suyatma 2009).

Fig. 5 shows that the highest water content of coffee grounds is obtained at a light roast level of 4.07%, which is different from a medium roast level of 2.46% and a dark roast of 1.53%. The research results of Corrêa *et al*. (2016) show that the water content obtained for Arabica roasted coffee ranges from 1.0 - 3.7%, not much different from Supriana *et al.* (2020) with the processing water content between 1.94 and 3.66%. This change in water content is caused by the heat that occurs in the roasting process causing the water content in the coffee beans to evaporate so that the water content of the beans decreases. Marpaung *et al.* (2021) states that the water content of coffee grounds will become lower as the roasting temperature increases. The roasting process results in heat transfer from the roasting medium to the coffee beans. This transfer will result in a change in the water mass in the coffee beans into water vapor. This result is in line with research by Purnamayanti *et al.* (2017), which states that the length of time for the roasting process will result in a decrease in the water content of coffee beans.

From Fig. 6, it can be seen that the highest pH value of coffee grounds was obtained at a dark roast of 5.21, followed by a medium roast of 4.91 and a light roast of 4.74. These results are in accordance with Fibrianto which shows that the pH of coffee increases with increasing of RD, namely 4.85, 5.1 and 5.38 at light, medium and dark roast. According to Nadhiroh (2018), the roasting process using

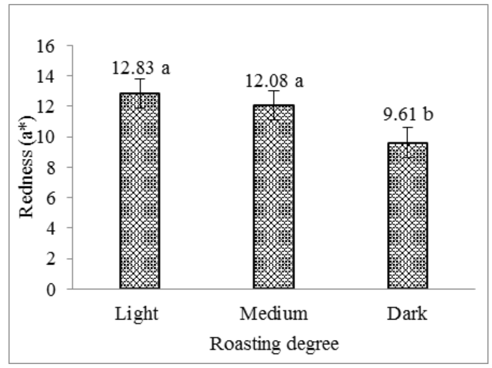

Fig. 3: Effect of roasting degree on redness value (a*) (values followed by the same letter indicate no difference at $P < 0.05$)

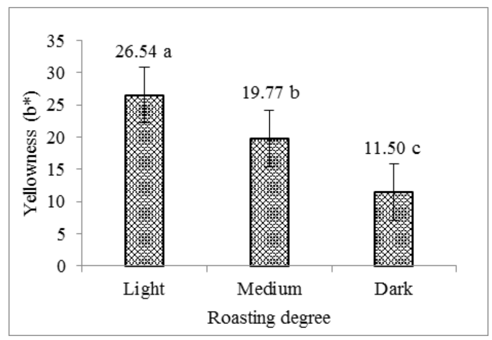

Fig. 4: Effect of roasting degree on yellowness value (b*) (values followed by the same letter indicate no difference at $P < 0.05$)

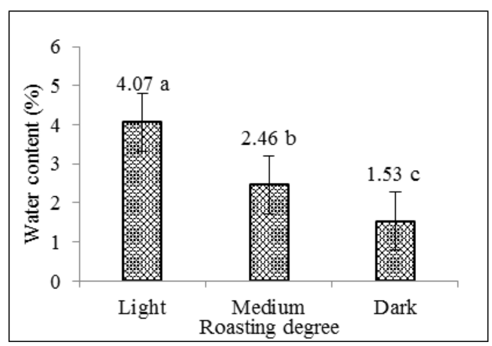

Fig. 5: Effect of roasting degree on water content (values followed by the same letter indicate no difference at $P < 0.05$)

heat will result in changes to the chemical compounds in the seeds. Roasting time can affect the pH value in coffee beans. The length of roasting time can cause the pH value, which was originally acidic to approach neutral pH. The longer the roasting process, the more Arabica coffee will be produced with a higher pH value leading to a neutral pH value. The pH value greatly influences the taste and aroma of coffee. According to Purnamayanti *et al.* (2017), in general a pH between 4.9–5.2 will provide a more favorable coffee aroma.

The caffeine content of coffee grounds tended to produce slightly higher caffeine at the dark roast, but it is not much different (Fig. 7). Several previous studies have shown that the degree of roast does not affect caffeine levels (Alamri *et al.* 2022; Honda *et al*. 2022) because caffeine is relatively stable to heat. It is suspected that this increase in caffeine levels is an apparent increase due to the loss of other compounds (such as water content and organic acid) with a higher degree of roasting.

Hedonic test results for the highest color of brewed coffee were obtained at medium and dark roast degrees of 3.60 (like) and 3.56 (like) which shows a significant difference from the light roast degree with a liking level of 3. 07 (neutral) (Fig. 8). This is thought to be because the color of the coffee beans is determined by the roasting process, namely it is close to dark blackish brown. In medium and dark, the color produced after roasting is quite good and evenly cooked, whereas in light the color of the coffee beans tends to be cinnamon yellow and uneven, so the panelists don't like it. According to Purnamayanti *et al.* (2017), during the roasting process many changes occur that can be distinguished visually. The color change starts from green, becomes cinnamon brown, then black with an oily surface. The main factor influencing the color of brewed coffee is caused by the sugar caramelization process, giving rise to a dark brown color (Fitriyah 2021).

Hedonic test results for the highest aroma of brewed coffee were obtained at a medium roast level of 3.53 (like) and at a dark roast level, caffeine was obtained at 3.39 (neutral), while the lowest level of aroma preference was obtained at a low roast level. light with a gain of 3.19 (neutral). Data showed the medium roast degree shows a significant difference with the light roast degree, however the dark roast degree does not show a significant difference with the light and medium roast degrees (Fig. 9). Based on the results of aroma testing carried out on the brewed coffee served, the most preferred Arabica coffee beans are those with a medium roast degree. This is because the medium level is the right level of maturity so that the aroma is still complete, whereas the light roast tends to be still raw with a nutty aroma and the dark itself smells more like smoke or burnt aroma. This is in accordance with Azmi *et al.* (2022), i.e 3.37 (neutral) to 3.75 (like). In research by Samin *et al.* (2018), the panelists' aroma preference level was 3.90 (like). According to Marpaung *et al*. (2021), the aroma of brewed coffee appears due to the presence of volatile compounds that are captured by the human sense of smell. Volatile compounds such as aldehydes, ketones, furfural, acids, esters and alcohols have volatile properties which are formed from the Maillard reaction or non-enzymatic browning reaction, degradation of free amino acids, degradation of trigoneline, degradation of sugars and phenolic compounds. These are influenced by volatile compounds. The sharper the aroma produced, the more volatile compound components that dissolve in the water when the coffee is brewed.

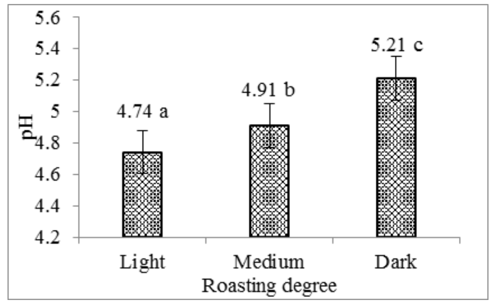

Fig. 6: Effect of roasting degree on pH value (values followed by the same letter indicate no difference at $P < 0.05$)

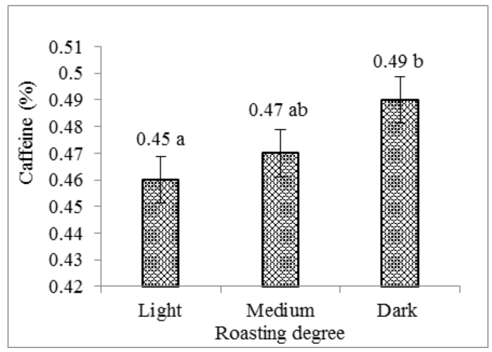

Fig. 7: Effect of roasting degree on caffeine (values followed by the same letter indicate no difference at $P < 0.05$)

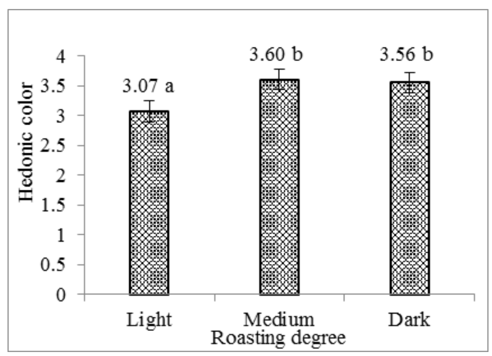

Fig. 8: Effect of roasting degree on hedonic color (values followed by the same letter indicate no difference at $P < 0.05$)

Arabica coffee processed in all types of processing methods (honey, natural, full wash) using the medium roast produces the best cupping score reaching a score range of 81.75–82.25 (specialty), followed by light roast 78.00–79.50 (below specialty) and the lowest dark roast with a range of 63.50–63.75 (below specialty). This result is in line with several studies which show that medium roast produces the highest cupping value. Edvan *et al.* (2019) research showed that the medium roast degree provides the best results because in this treatment the water content of the coffee beans tends to be neither too high nor too low so that the resulting taste is better. The results of this research are also supported by Abubakar *et al.* (2020) which states that

Table 2: Coffee sensory attribute scores using the cupping test method

Samples*	Fragrance	Flavor	Aftertaste	Acidity	Body	Balance	Uniformity	Clean cup	Sweetness	Overal	Total Score
HT1	7,00	7,00	7,00	7,00	7,25	7,00	10,00	10,00	10,00	7,00	79,25
HT2	7,75	7,50	7,25	7,50	7,50	7,25	10,00	10,00	10,00	7,50	82,25
HT3	6,50	6,00	6,00	6,25	7,00	6,00	10,00	0,00	10,00	6,00	63,75
NT1	7,00	6,75	6,50	7,00	7,25	6,75	10,00	10,00	10,00	6,75	78,00
NT2	7,75	7,50	7,25	7,50	7,50	7,25	10,00	10,00	10,00	7,50	82,25
NT3	6,50	6,00	6,00	6,25	7,00	6,00	10,00	0,00	10,00	6,00	63,75
FT1	7,00	7,25	7,00	7,00	7,25	7,00	10,00	10,00	10,00	7,00	79,50
FT2	7,50	7,50	7,25	7,50	7,50	7,25	10,00	10,00	10,00	7,25	81,75
FT3	6,25	6,00	6,00	6,25	7,00	6,00	10,00	0,00	10,00	6,00	63,50

*H (coffee processing method) = Honey, N: Natural, F: Fullwash
T (roasting degree) = T1: light, T2: medium, T3: dark

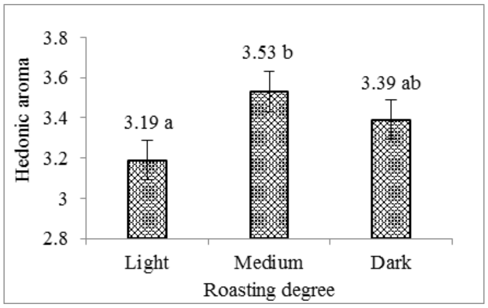

Fig. 9: Effect of roasting degree on hedonic aroma (values followed by the same letter indicate no difference at $P < 0.05$)

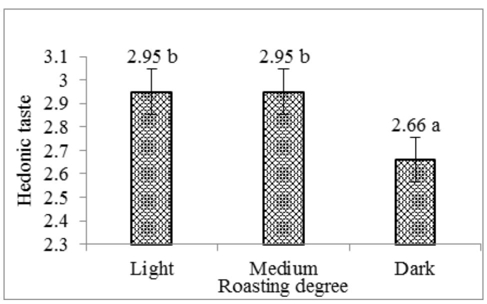

Fig. 10: Effect of roasting degree on hedonic taste (values followed by the same letter indicate no difference at $P < 0.05$)

medium roasting produces the best cupping. The most preferred cupping result is coffee with a medium roast degree because the taste contained in coffee grounds with this treatment is still complete, such as the taste content of sweet, sour, bitter and salty which is the most important part of the taste of coffee grounds.

Conclusion

The PM had a significant effect on the lightness level (L*) of Arabica coffee grounds. The RD had a significant effect on the lightness level (L*), redness value (a*), yellowness value (b*), water content, acidity level (pH), caffeine, and hedonic tests (color, aroma and taste). Higher roasting temperature changed color (L*, a*, b*), water content, acidity level (pH), caffeine content, and hedonic test. Water content decreased as the roasting temperature increased. Medium roast degree in each type of PM produced the best level of hedonic (liking) and cupping value. The highest cupping value was obtained at medium roasting, reaching specialty coffee scores above 80. Further research is needed to determine what aroma components are formed from the three types of processing and their combination with different degrees of roasting.

Acknowledgements

The authors acknowledge the Integrated Laboratory of Balittri for providing the raw material (coffee green bean) and facilities used in carrying out the research.

Author Contributions

MM, BS and AA planned and designed the experiments. BS and AA conducted the experiment. BS and MM analyzed and interpreted data. MM prepared publication manuscripts.

Conflicts of Interest

All authors declare no conflict of interest.

Data Availability

Data will be available any time upon a fair request.

Ethics Approval

Not applicable.

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