Jurnal Teknologi Industri Pertanian 34 (1): 28-34, April 2024
DOI: https://doi.org/10.24961/j.tek.ind.pert.2024.34.1.28
ISSN: 0216-3160 EISSN: 2252-3901

Terakreditasi Peringkat 2
SK Dirjen Pendidikan Tinggi, Riset, dan Teknologi No. 158/E/KPT/2021
Tersedia online http://journal.ipb.ac.id/index.php/jurnaltin

THE EFFECT OF ROASTING USING SPOUTED BED ROASTER ON PSYCHOHEMICAL ROBUSTA AND ARABICA TEMANGGUNG COFFEE

PENGARUH ROASTING MENGGUNAKAN SPOUTED BED ROASTER TERHADAP FISIKOKIMIA KOPI ROBUSTA DAN ARABIKA TEMANGGUNG

Eko Pratama Astin*), Mohammad Nafila Alfa, Lusiana Kresnawati Hartono, Astuti, Indah Kurniasari, Kokom Komariyah, Muji Susianto, Gigih Atmaji, Wahju Eko Widodo, Wahyu Bahari Setianto

Research Center for Agroindustry, Research Organization for Agriculture and Food,
National Research and Innovation Agency, Indonesia
Email: Ekop009@brin.go.id

Paper: Accepted September 5, 2023; Fixed December 18, 2023; Approved January 20, 2024

ABSTRACT

Pemanfaatan mesin sangrai kopi tipe spouted bed di Indonesia masih sangat sedikit, sehingga data kopi sangrai juga sangat terbatas. Tujuan dari penelitian ini untuk mengetahui pengaruh level sangrai menggunakan spouted bed roaster terhadap sifat fisikokimia kopi robusta dan arabika Temanggung pada level sangrai light, medium dan dark. Sifat fisikokimia yang diamati meliputi kadar air, warna, antioksidan dan kandungan kafein. Penelitian ini menghasilkan bahwa kadar air kopi menurun seiring dengan meningkatnya tingkat sangrai, dimana kadar air terendah terdapat pada robusta 1,18% dan arabika 1,27% pada level sangrai dark. Uji Warna (Chromameter) menunjukkan nilai L yaitu 30,07 (light), 26.20 (medium), dan 21,92 (dark) untuk kopi robusta dan 28,80 (light), 25,10 (medium), dan 22,85 (dark) untuk kopi arabika. Nilai dari Browning Index (BI) mempunyai pola mirip dengan nilai L*. Nilai antioksidan tertinggi yaitu level sangrai light baik untuk jenis kopi robusta (12,65 MBHA/g) dan arabika (5,99 MBHA/g) Temanggung. Nilai antioksidan berbanding terbalik dengan tingkat sangrai. Tingkat sangrai kopi berbanding lurus dengan kadar kafein dimana nilai tertinggi kadar kafein terdapat pada level sangrai dark baik untuk kopi jenis robusta (1.61 ± 0.02 g/100g d.b.) dan arabika (0,84 ± 0,03 g/100g d.b.) Temanggung.*

Kata kunci: arabika, kopi Temanggung, robusta, spouted bed, sangrai kopi

ABSTRACT

The use of spouted bed type coffee roasting machines in Indonesia is still very small, so data on roasting coffee is also very limited. The aim of this research was to determine the effect of roasting level using a spouted bed roaster on the physicochemical properties of Temanggung robusta and arabica coffee at light, medium and dark roasting levels. The physicochemical properties observed included water content, colour, antioxidants, and caffeine content. This research shows that the water content of coffee decreased as the roast level increased, where the lowest water content was found in robusta 1.18% and Arabica 1.27% at the dark roast level. The colour measurement (Chromameter) shows L values, namely 30.07 (light), 26.20 (medium), and 21.92 (dark) for robusta coffee and 28.80 (light), 25.10 (medium), and 22.85 (dark) for arabica coffee. The value of the Browning Index (BI) had a pattern similar to the L* value. The highest antioxidant value was the light roast level for both Robusta (12.65 MBHA/g) and Arabica (5.99 MBHA/g) Temanggung coffee types. The antioxidant value was inversely proportional to the roast level. The level of coffee roasting was directly proportional to the caffeine content, where the highest value of caffeine content was found at the dark roast level for both robusta (1.61 ± 0.02 g/100g d.b.) and arabica (0.84 ± 0.03 g/100g d.b.) Temanggung coffee.*

Keywords: arabica coffee, Temanggung coffee, robusta coffee, coffee roaster, spouted bed

INTRODUCTION

Coffee goes through a lengthy process before it can be served in drinks. The process begins with selecting the best coffee beans, followed by processing, drying, hulling, storing, roasting, grinding, and brewing. Each of these processes has a significant impact on the quality of the coffee, as the chemical components and physical characteristics are influenced by several variables, such as the environment, genetics, agronomic activities, and post-harvest procedures (Haile and Hee Kang, 2020)

Roasting is a crucial step in the development of coffee aroma and also significantly affects the active ingredient composition of coffee. Modern coffee roasting technology is available in a wide variety of models, with the drum roaster being the most popular for both domestic and commercial use. The drum roaster is a continuously revolving horizontal cylinder that uses hot air to roast the coffee beans placed inside it. The hot air is either rejected through the center of the cylinder or through the hollow sides to ensure the coffee beans are evenly roasted (Ilze and Kruma, 2019; Setianto *et al*., 2023).

* *Coressponding Author*

A type of machine used for roasting coffee is the fluidized bed model, which moves and heats the floating beans simultaneously. High-speed hot air is directed at the beans from the bottom of the roasting machine to achieve fluidization of the beans. A variant of the fluidized bed is the spouted bed, where coffee beans are pushed up and thrown to the sides of the roaster as hot air from below is driven through the bed of the beans. Spouted beds offer benefits such as easier manufacturing compared to fluidized beds, less air consumption, lower fluidization velocities, and high heat transfer rates (Clarke and Vitzthum, 2008). However, the use of spouted bed roasting machines in Indonesia is still very small, so data on roasted coffee is also very limited.

The purpose of this study was to determine the effect of roasting using a spouted bed roaster on the physicochemical properties of Temanggung robusta and arabica coffee.

MATERIALS AND METHODS

Materials

The robusta and arabica green beans used in this study were obtained from the Temanggung region of Central Java, Indonesia and dried naturally.

Methods

Roasting process

The coffee roasting process was carried out using a spouted bed coffee roaster at CV. Giat Kopi, Bogor, Indonesia. The roasting process involves three levels: light (220–225°C), medium (230–235°C) and dark (240–250°C). For each batch of coffee beans, which weighs 2.5 kg, roasting tests are conducted. A VSCLAB AR-09 module, which is connected to the Artisan program on the PC was used for the data acquisition from roasting machine. The VSCLAB AR-09 is an interface for the Artisan Scope software with a coffee roasting machine that functions to display and record temperature in the coffee roasting machine in the form of a temperature versus time graph.

Water Content Measurement

Data were carried out in three repetitions (n = 3). The water content was calculated using the equation (SNI 01-2891-1992):

$$\text{Water content (\%)} = \frac{w_1}{w} \text{ x } 100\%$$

Where:

W = sample weight before drying (g)

w_1 = loss weight after drying (g)

Color Measurement

The instrument utilizes a color scale with three parameters, L* (lightness), a* (red-green value), and b* (yellow-blue value), using a Chromameter (Illuminant D65, Cr-410, Minolta, Osaka, Japan) to display the test findings. In this study, only the changes in L* values and browning index (BI) are the focus of the discussion. Color measurements were carried out on roasted coffee beans in five repetitions (n = 5). Browning index can be determined using the following equation (Kim *et al*., 2019).

$$\text{Browning Index (BI)} = \frac{z - 0.31}{0.17} x100$$

$$z = \left(\frac{a* + 1.75L*}{5.645L* + a* - 3.012b*}\right) x100$$

Antioxidant Measurement (DPPH)

Powder sample (0.5 g) was taken in 100 mL Erlenmeyer Flask and extracted with 25 mL methanol using shaker 190 rpm in room temperature for 6 hour. The solution was filter in vaccum filter through whatman filter paper no 41. The supernatant was collected in brown bottle and stored at -20^{o}C till analysis (Tamilmani and Pandey, 2015). An aliquot of sample (25 µL) was mixed in the 100 µL Tris HCl (pH 7.4) and then added 125 µL DPPH in ethanol (final concentration of 250 µM). The mixture was shaken and incubate for 20 minutes in room temperature at dark room. Sample was read using absorbance 517 nm in ELISA Biotek SYNERGY HTX Multi-Mode Reader. Standard is BHA (Stock concentration of 5000 ppm). Range of BHA concentration is 43.75-700 ppm (Yamaguchi *et al*. 1998). The data were expressed as M BHA/g coffee. Data were carried out in two repetitions (n = 2).

Caffeine Measurement

Measured with HPLC instrument (model SPD M20A (Shimadzu corporation), YMIC trial C18 column pore size 5µ with internal diameter 4.6 mm length 150 mm, ODS reverse phase, flowrate 1 mL/min, temperature column at 40°C, UV detector set 275 nm, sample injection 10 µL and mobile phase: methanol: water (40:60) both HPLC grade). The conical flasks of 250 ml were filled with 0.3 g of coffee powder samples. Additionally, 200 cc of distilled water was added before the water bath was heated to 100 °C for 30 minutes. It was cooled and filtered through the Whatmann number 1 filter paper. 10 mL volumetric flasks were meticulously cleaned and subsequently filled with 1 mL of filtrate. The resulting solution was then appropriately diluted using high-performance liquid chromatography (HPLC) grade water. The sample was subsequently filtered through a 0.2 µm microfilter and transferred into HPLC vials.

Serial dilutions of the stock solution with HPLC grade water were produced using standards of 2, 4, 6, 8, and 10 ppm. The interpolation within the regression equation of the best line of fit was used to determine the caffeine content (ppm) of the individual samples (Pokhrel *et al*., 2016). HPLC. Data were carried out in three repetitions (n = 3).

Statistical Analysis

The data were statistically evaluated by analysis of variance (ANOVA). Every result was presented as mean value and standard deviations. All test procedures were made at significant level ($p < 0.05$).

RESULTS AND DISCUSSION

Water Content Measurement

In this research, the water content of Temanggung robusta and arabica coffee beans before roasting were 9.06 ± 0.12 % and 9.06 ± 0.08 %. The graph showing the water content of roasted beans at each level of roasting is presented in Figure 1.

The light roasting level has a significant influence on water content ($p<0.05$) in both robusta and arabica coffee varieties, whereas at the medium and dark roasting levels, there is no significant influence on the robusta and arabica coffee types. The decrease in the water content of coffee during the roasting process is caused by the mass transfer of water from the coffee beans due to evaporation. In the roasting process, heat is transferred from the air to the material, which causes a change in the water phase from liquid to gas due to the latent heat of vaporization (Saloko *et al.,* 2019). For comparison, Johandri (2017) reports that the water content of coffee roasted with a drum-type coffee roaster were 2.8%, 2%, 1.7%, and 1.4% for light roast, medium roast, dark roast, and very dark roast, respectively. The water content of the roasted coffee beans is in accordance with SNI-01-3542-2004.

Color Measurement

One of the factors influencing consumer acceptance of a product is color. Figure 2 shows the results of color measurements for Robusta and Arabica Temanggung at green bean and light, medium and dark roast levels. The roasting level significantly influences the lightness of the same type of coffee. The trend of L* (Lightness) values decreases along with the increase in roasting levels in Robusta and Arabica Temanggung roast beans testing. These results are in accordance with research conducted by Yeager *et al.* (2022) regarding the effect of roast levels. Increased roasting levels cause a decreased value of L*. According to Saloko *et al.* (2019), the L* value will be lower with higher temperature and longer roasting process. The color changes occur due to the Maillard reaction caused by a combination of temperature treatment and roasting time. The Maillard reaction produces melanoidin, which is characterized by a change in blackish-brown color in roasting coffee beans, resulting in a decrease in the L* value in roast coffee beans.

Figure 3. shows the browning index of Robusta and Temanggung Arabica beans at light, medium, and dark roast levels. The roasting level significantly influences the browning index (BI) in the same type of coffee. The highest browning index value in Robusta coffee was found in the light roast level (66.47 ± 1.23), and as the roast level increases the browning index value decreases, with medium roast (50.68 ± 1.01) and dark roast (29.98 ± 1.37). This pattern also applies to arabica coffee, where the browning index values for light, medium, and dark roast levels were 62.29 ± 1.58, 48.00 ± 1.20 and 35.68 ± 1.27, respectively.

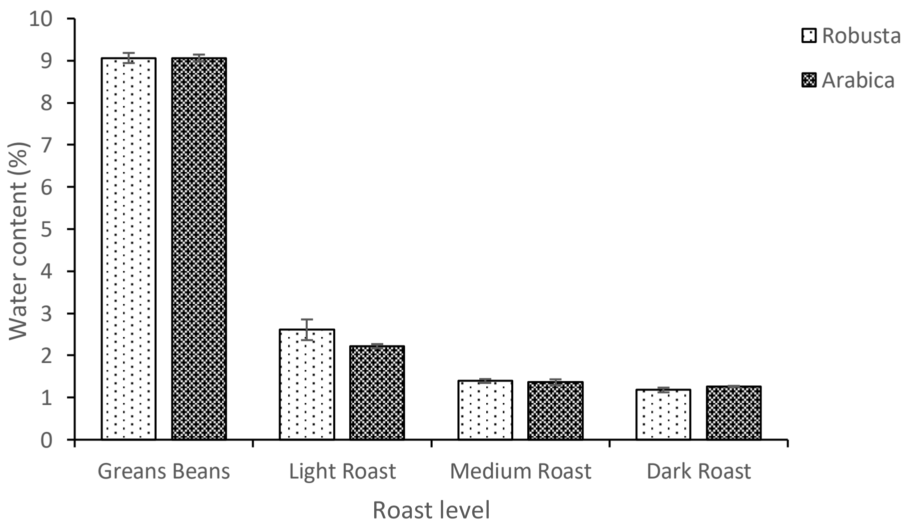

Figure 1. The water content of green beans, light roast, medium roast and dark roast of Temanggung Robusta and Arabica coffee.

Gambar 1. Kadar air pada biji kopi green bean, light roast, medium roast, dan dark roast pada kopi Robusta dan Arabika Temanggung.

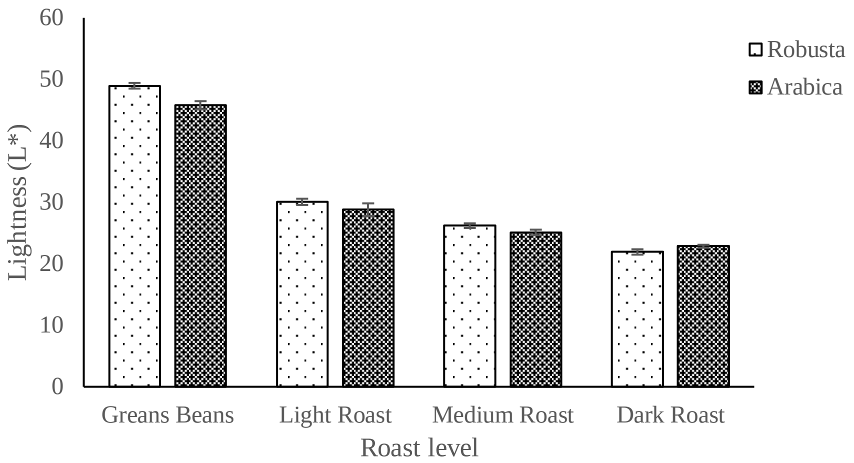

Figure 2. The lightness (L*) of green beans, light roast, medium roast and dark roast of Temanggung Robusta and Arabica coffee.
Gambar 2. Lightness (L) kopi green beans, light roast, medium roast, dan dark roast pada kopi Robusta dan Arabika Temanggung.*

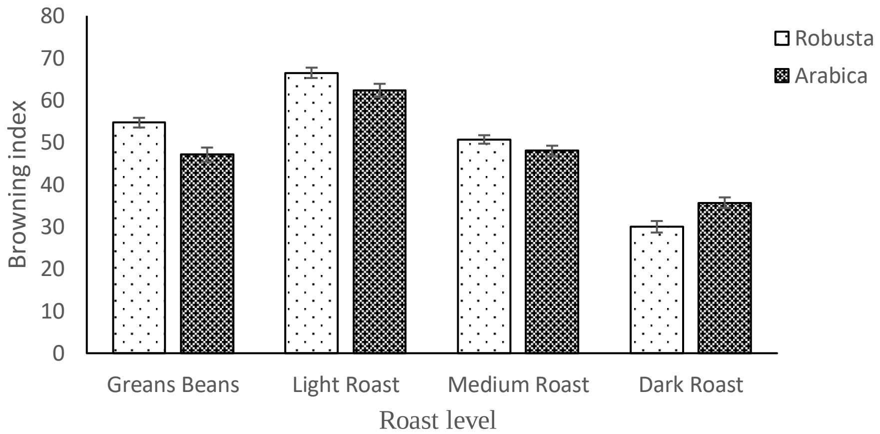

Figure 3. Browning index of green beans, light roast, medium roast and dark roast of Temanggung Robusta and Arabica coffee.
Gambar 3. Indeks pencoklatan biji kopi hijau, light roast, medium roast, dan dark roast pada kopi Robusta dan Arabika Temanggung.

The changes in browning index show similarity with color measurement using a chromameter, where the changes are caused by Maillard reactions resulting from a combination of temperature and roasting time. The browning index increases with longer roasting time but eventually decreases after a certain duration (Alamri *et al.*, 2022).

Antioxidant DPPH

Chlorogenic acid, phenolic acid, hydroxycinnamic acid, and other compounds are antioxidants produced by coffee beans during the Maillard reaction (Sunarharum *et al.*, 2014). The antioxidant of arabica green beans (25.14 ± 0.16 MBHA/g) exhibited higher than robusta green beans (24.15 ± 0.20 M BHA/g). The antioxidant value of both roasted beans has the same trend, the highest antioxidant content in roast beans was found in the light roast (5.99 ± 0.18 M BHA/g for arabica and 12.65 ± 0.92 MBHA/g for robusta), followed by medium roasts (5.40 ± 0.23 M BHA/g for arabica and 11.39 ± 1.15 M BHA/g for robusta) and dark roasts (4.86 ± 0.21 M BHA/g for arabica and 7.53 ± 0.37 M BHA/g for robusta) can be description in figure 4. The dark roasting level of robusta coffee has a significant influence ($p<0.05$) on antioxidants, but it is not significant for the light and medium roasting levels. For arabica coffee, the roasting level does not have a significant influence on antioxidants.

The antioxidant value declined with increasing roasting level, according to an analysis of the DPPH content of Commercial Arabica Coffee from local market in Australia at 3 different roasting degrees, the antioxidant content of DPPH at a light level was 148.55 mg TE/g, at a medium level was 147.86 mg/TE/g, and at a dark level was 143.32 mg TE/g (Wu *et al.*, 2022). A decrease in DPPH antioxidants was also shown during the roasting process of three types of Arabica coffee, namely Cattimor, Cattura and Bourbon. The amount of antioxidants in coffee can be decreased by increasing roasting time (Mestanza *et al.,* 2023). The antioxidants of the robusta are higher than arabica for each level roast. The antioxidant content of DPPH coffee from Vietnam's Lam Dong Province yielded a similar result the highest DPPH antioxidant content was at the medium level of robusta (296.7 ɥmol TE/g) and the lowest at the dark level of arabica (176.4 µmol TE/g) (Anh-Dao *et al*., 2022). In other studies, it was also reported that the higher the roasting level, the lower the antioxidant content of roasted coffee (Astuti *et al*., 2023; Ilze & Kruma, 2019; Moon & Shibamoto, 2009). Increasing the level of roasting will affects changes in the composition of some compounds and will reduce the antioxidant activity of coffee. One of the changes in chlorogenic acid is the antioxidant activity during the roasting process (Pérez-Hernández *et al.*, 2012). Although some antioxidants are formed during the roasting process, some are lost naturally resulting in a decrease in the main natural antioxidants in coffee (Vignoli *et al.*, 2014).

Caffeine Content

Caffeine exerts various physiological effects on the human body, such as central nervous system stimulation, elevation of blood pressure, increased metabolic rate, and a diuretic effect (Higdon and Frei, 2006). Many variables influence the caffeine content in coffee such as coffee variety, environmental conditions, and cultivation practices (Hečimović *et al.*, 2011). The results of measuring the caffeine content of green beans and roasted beans from Robusta and Arabica Temanggung at light, medium and dark roast levels are shown in figure 5.

The dark roasting level of robusta coffee has a significant influence ($p<0.05$) on caffeine content, but it is not significant for the light and medium roasting levels. For arabica coffee, the roasting level does not have a significant influence on caffeine content. At Robusta, the highest caffeine was found in the dark roast (1.61 ± 0.02 g/100g d.b.), followed by medium roasts (1.51 ± 0.03 g/100g d.b.) and light roasts (1.50 ± 0.01 g/100g d.b.) for robusta. In Arabica, the same pattern was found where the highest was dark roast (0.84 ± 0.03 g/100g d.b.), then medium roast (0.81 ± 0.004 g/100g d.b.) and light roast (0.79 ± 0.02 g/100g d.b.).

The research by Grzelczyk *et al.* (2022) likewise presents comparable findings. The caffeine content in robusta is as follows green bean (21.9 g/100g d.b.), light roasted (21.00 g/100g d.b.), and dark roasted (18.14 g/100g d.b.) The caffeine content in Arabica coffee is as follows green bean (12.95 g/100g d.b.), light roasted (12.15 g/100 g d.b.) and dark roasted (10.00 g/100 g d.b.). The roasting process and level roast will increase the caffeine content (Motora and Beyene, 2017; Vignoli *et al.*, 2011). This increase can occur due to the degradation of other components such as liquid substances and acids, leading to an increased percentage of non-liquid substances such as caffeine, minerals, and fats in coffee (Aghanuri *et al.,* 2016; Sukarno Putra and Khathir, 2017). The caffeine content of the roasted coffee beans is in accordance with SNI-01-3542-2004

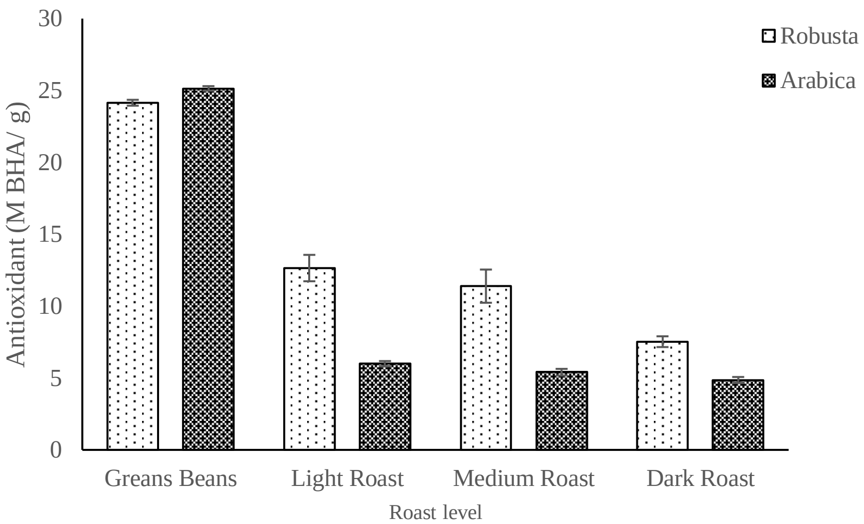

Figure 4. The antioxidants of green beans, light roast, medium roast and dark roast of Temanggung Robusta and Arabica coffee.

Gambar 4. Kandungan antioksidan pada biji kopi hijau, light roast, medium roast, dan dark roast pada kopi Robusta dan Arabika Temanggung.

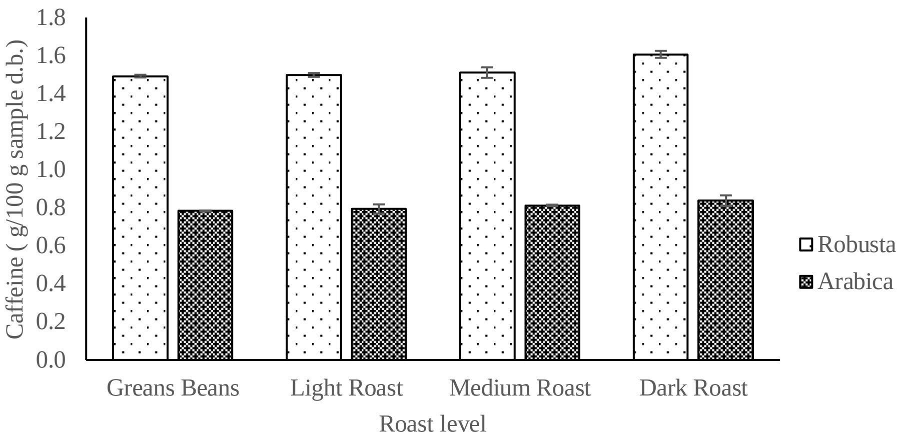

Figure 5. Caffeine content in green beans and each roasted beans of Temanggung Robusta and Arabica coffee
Gambar 5. Kandungan kafein pada green bean dan masing-masing biji sangrai kopi Robusta dan Arabika Temanggung

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The research showed that the water content of coffee decreases as the roasting level increases. Color measurements showed that brightness (L*) and browning index (BI) followed similar patterns, with higher roasting levels corresponding to lower L* values and BI. Antioxidants in roasted beans were inversely proportional to roasting degree. For caffeine content, on the other hand, the degree of roasting was directly proportional to the caffeine content of the coffee beans. These results indicate that roasting using a spouted bed roasting machine has a direct impact on the physicochemical attributes of Temanggung robusta and arabica coffee.

Recommendations

Further research needs to be carried out regarding the effect of roasting other single origin coffees in Indonesia using a spouted bed roasting machine on physical and chemical parameters as well as carrying out organoleptic tests on the roasted coffee.

REFERENCES

Aghanuri S, Salami M, and Ziarati P. 2016. Comparative study of mineral elements and caffeine in imported coffee varieties affected by the degree of roasting by HPLC analysis. *Journal of Chemical and Pharmaceutical Research.* 8 (9): 111–116.

Alamri E, Rozan M, and Bayomy H. 2022. A study of chemical Composition, Antioxidants, and volatile compounds in roasted Arabic coffee: Chemical Composition, Antioxidants and volatile compounds in Roasted Arabic Coffee. *Saudi Journal of Biological Sciences.* 29 (5): 3133–3139. https://doi.org/10.1016/j.sjbs.2022.03.025

Anh-Dao LT, Nhon-Duc L, Cong-Hau N, Thanh-Nho N. 2022. Variability of total polyphenol contents in ground coffee products and their antioxidant capacities through different reaction mechanisms. *Biointerface Research in Applied Chemistry*. 12 (4): 4857–4870. https://doi.org/10.33263/BRIAC124.48574870

Astuti, Machmudah S, Winardi S, Manalu, LP, Atmaji G, Widodo WE, Hartono LK, Komariyah K, Alfa MN, Kurniasari I. 2023. The effect of roasting Toraja Arabica coffee with a fluidized roaster on the antioxidant and proximate content. *IOP Conference Series: Earth and Environmental Science*. 1182 (1). https://doi.org/10.1088/1755-1315/1182/1/012076

Badan Standardisasi Nasional, 1992. SNI-01-2891-1992: Cara uji makanan dan minuman. Badan Standardisasi Nasional, Jakarta.

Badan Standardisasi Nasional. (2004). SNI-01-3542-2004: Kopi bubuk. Badan Standardisasi Nasional.

Clarke RJ and Vitzthum OG. 2008. *Coffee: Recent Developments*. 2nd ed. New Jersey: John Wiley & Sons.

Grzelczyk J, Fiurasek P, Kakkar A, Budryn G. 2022. Evaluation of the thermal stability of bioactive compounds in coffee beans and their fractions modified in the roasting process. *Food Chemistry*. 387 (1). https://doi.org/10.1016/j.foodchem.2022.132888

Haile M, Hee Kang W. 2020. *Coffee - Production and Research: The Harvest and Post-Harvest Management Practices' Impact on Coffee Quality*. London: IntechOpen.

Hečimović I, Belščak-Cvitanović A, Horžić D, Komes D. 2011. Comparative study of polyphenols and caffeine in different coffee varieties affected by the degree of roasting. *Food Chemistry*. 129 (3): 991–1000. https://doi.org/10.1016/j.foodchem.2011.05.059

Higdon JV and Frei B. 2006. Coffee and health: A review of recent human research. *Critical Reviews in Food Science and Nutrition*. 46 (2): 101–123. https://doi.org/10.1080/10408390500400009

Ilze L and Kruma Z. 2019. Influence of the roasting process on bioactive compounds and aroma profile in specialty coffee: a review. *Proceedings of Food Science Food Balt.* Latvia, 2-3 May 2019. https://doi.org/10.22616/FoodBalt.2019.002

Johandri V. 2017. Heat and mass transfer model for a coffee roasting process [Dissertation]. Potchefstroom: North-West University.

Kim E, Song KY, Kim Y, Kim I, Kim SH, Kim KY, Jeong Y. 2019. Antioxidant Activities of Brazilian Coffea arabica cv. Catuai coffee extracts with different roasting conditions. *Journal of the Korean Society of Food Science and Nutrition*. 48 (8): 839–846. https://doi.org/10.3746/jkfn.2019.48.8.839

Mestanza M, Mori-Culqui PL, and Chavez SG. 2023. Changes of polyphenols and antioxidants of arabica coffee varieties during roasting. *Frontiers in Nutrition*. 10: 1–9. https://doi.org/10.3389/fnut.2023.1078701

Moon JK and Shibamoto T. 2009. Role of roasting conditions in the profile of volatile flavor chemicals formed from coffee beans. *Journal of Agricultural and Food Chemistry*. 57 (13): 5823–5831. https://doi.org/10.1021/jf901136e

Motora KG and Beyene TT. 2017. Determination of Caffeine in Raw and Roasted Coffee Beans of Ilu. *Indo American Journal of Pharmaceutical Research*. 7: 463–470. https://doi.org/10.5281/zenodo.1036324

Pérez-Hernández LM, Chávez-Quiroz K, Medina-Juárez LÁ, Gámez MN. 2012. Phenolic characterization, melanoidins, and antioxidant activity of some commercial coffees from Coffea arabica and Coffea canephora. *Journal of the Mexican Chemical Society*. 56 (4): 430–435.

Pokhrel P, Shrestha S, Rijal SK, Rai KP. 2016. A simple HPLC Method for the Determination of Caffeine Content in Tea and Coffee. *Journal of Food Science and Technology Nepal*. 9: 74–78. https://doi.org/10.3126/jfstn.v9i0.16200

Saloko S, Sulastri Y, Murad, Rinjani MA. 2019. The effects of temperature and roasting time on the quality of ground Robusta coffee (Coffea rabusta) using Gene Café roaster. *AIP Conference Proceedings*. 2199 (1). https://doi.org/10.1063/1.5141310

Setianto WB, Yohanes H, Atmaji G, Susanto M, Astin EP, Lanjar. 2023. The effect of fluidized bed roaster temperature on the roasted coffee beans antioxidant activity and its sensory evaluation. *IOP Conference Series: Earth and Environmental Science*. 1246 (1). https://doi.org/10.1088/1755-1315/1246/1/012005

Sukarno PB, Khathir R. 2017. Kajian mutu kopi arabika gayo dengan perlakuan variasi suhu dan lama penyangraian (study of arabica gayo coffee quality under temperature and roasting duration treatments). *Jurnal Ilmiah Mahasiswa Pertanian Unsyiah*. 2 (2): 416–422. https://doi.org/10.17969/jimfp.v2i2.3092

Sunarharum WB, Williams DJ, and Smyth HE. 2014. Complexity of coffee flavor: A compositional and sensory perspective. *Food Research International*. 62: 315–325. https://doi.org/10.1016/j.foodres.2014.02.030

Tamilmani P and Pandey MC. 2015. Optimization and Evaluation of phenolic compounds and their antioxidant activity from coffee beans. *International Journal of Advanced Research*. 3 (4): 296–306.

Vignoli JA, Bassoli DG, and Benassi MT. 2011. Antioxidant activity, polyphenols, caffeine and melanoidins in soluble coffee: The influence of processing conditions and raw material. *Food Chemistry*. 124: 863–868. https://doi.org/10.1016/j.foodchem.2010.07.008

Vignoli JA, Viegas MC, Bassoli DG, Benassi MT. 2014. Roasting process affects differently the bioactive compounds and the antioxidant activity of arabica and robusta coffees. *Food Research International*. 61: 279–285. https://doi.org/10.1016/j.foodres.2013.06.006

Wu H, Lu P, Liu Z, Sharifi-Rad J, Suleria HAR. 2022. Impact of roasting on the phenolic and volatile compounds in coffee beans. *Food Science & Nutrition*. 10 (1): 2408–2425. https://doi.org/10.1002/fsn3.2849

Yamaguchi T, Takamura, H, Matoba T, Terao J. 1998. HPLC Method for Evaluation of the Free Radical-scavenging Activity of Foods by Using 1,1-Diphenyl-2-picrylhydrazyl. *Bioscience, Biotechnology, and Biochemistry*. 62 (6): 1201–1204. https://doi.org/10.1271/bbb.62.1201

Yeager SE, Batali ME, Lim LX, Liang J, Han J, Thompson AN, Guinard JX, Ristenpart WD. 2022. Roast level and brew temperature significantly affect the color of brewed coffee. *Journal of Food Science*. 87: 1837–1850. https://doi.org/10.1111/1750-3841.1608