P-ISSN: 1693-1246
E-ISSN: 2355-3812
June 2022

Jurnal Pendidikan Fisika Indonesia 18 (1) (2022) 25-32
DOI: 10.15294/jpfi.v18i1.27889

http://journal.unnes.ac.id/nju/index.php/jpfi

Chlorogenic Acid Content of Local Robusta Coffee at Variations of Roasting Temperature

Misto, N. P. Lestari, E. Purwandari*

Jurusan Fisika, Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Jember, Indonesia

Received: 27 February 2022. Accepted: 5 April 2022. Published: June 2022

Abstract

The roasting process has become the most necessary post-harvest handling process to be awarded in controlling coffee quality. In this research, the effect of roasting temperature has been investigated to the chlorogenic acid content on pure robusta coffee of local varieties and its mixture with soybeans as a parameter to control the quality. The temperature of roasting had variated at 195°C, 215°C, 225°C, 230°C, and 240°C. The chlorogenic acid contents have been obtained based on their maximum absorbances measured by a UV-Vis spectrophotometer at 290 nm wavelength range. The increase in roasting temperature reduces the chlorogenic acid levels because some have turned into melanoidin compounds. To increase the weight of Robusta coffee and change the taste of coffee, soybeans have been added as a coffee mixture. The results of the study were then extended to the observation of coffee quality on the content of chlorogenic acid it produces. The addition of soybeans by 10% can increase the chlorogenic acid content at a roasting temperature of 230°C around 5.12%, and there will be a decrease when the temperature is lowered. The addition of soybeans with a mass fraction of 20% of the total amount of coffee has increased the absorbance due to other antioxidant substances from the soybeans. The results of this study are expected to add insight to the public about the temperature required for the roasting process to obtain quality coffee with chlorogenic acid content that is still present after the roasting process.

Key words: chlorogenic acid, roasting temperature, robusta, soybean, UV-Vis spectrophotometer

INTRODUCTION

As an agricultural commodity, Robusta is one of the most widely cultivated types of coffee in Indonesia (Choiron, 2010). One of the areas developing Robusta coffee with their popular product called Argopuro Robusta is Jember Regency (Yulian, Kusardhani, & Amilia, 2019). This type of coffee is grown around the slopes of the Argopurpo mountains. In 2013, it was reported that in several areas distributed with an area of 125.29 Ha, 255.47 Ha, 290 Ha, 388.39 Ha, and 107.82 Ha, coffee production reached 359.98 tons, 644.20 tons, 819.80 tons, 1,234.49 tons, and 354.31 tons respectively (Yulian, Kusardhani, & Amilia, 2019). The aroma and content of this coffee are unique due to geographical differences in where the coffee is grown and cultivated (Triyanti, 2016).

The formation of taste and aroma in coffee beans depends on the roasting process. Fadri, Sayuti, Nazir, & Suliansyah (2019) explained that during roasting, a very complex chemical reaction occurs and produces a distinctive coffee character due to heat treatment. Therefore, time and temperature are influential factors in the roasting process. Mangiwa, Futwembun, & Awak (2015) have investigated the effect of roasting temperature on chlorogenic acid levels in Arabica coffee beans from Wamena, Papua. The temperature variations used are 75°C, 150°C, and 225°C. This study resulted in the levels of chlorogenic acid in Arabica coffee beans from Wamena ranging from 6.93% to 9.33%. The dependence of the chlorogenic acid content of Arabica coffee on the roasting temperature is of course also found in other types of coffee. Therefore, it is necessary to analyze the chlorogenic acid content of Robusta coffee on the roasting temperature factor, especially in Argopuro

*Correspondence Address:
Email: endhah.fmipa@unej.ac.id

Robusta coffee. The results obtained are expected to be one indicator to determine the quality of coffee produced by the agricultural sector in the Jember Regency area.

In addition to the distinctive aroma and taste, coffee also provides health benefits due to the content of chlorogenic acid as an antioxidant. Chlorogenic acid is generally formed from caffeic acid and quinic acid. Chlorogenic acid and caffeic acid have strong antioxidant activity in vitro. However, the content of chlorogenic acid in coffee beans decreases during the roasting process because chlorogenic acid will be hydrolyzed into caffeic acid and quinic acid (Grace, 2017). The visible indicator of the decrease in chlorogenic acid levels is the darkness of the roasted coffee beans (Belay and Gholap, 2009). The antioxidant activity decreases as the roasting temperature increases (Cammerer and Kroh, 2006). According to Mulato, Widyotomo, and Lestari (2001), the brown color produced during the roasting process is due to the presence of melanoidin compounds. Melanoidin compounds are formed because tannins and acetic acid react with amino acids during the roasting process and the amount can increase up to 25% (Ciptaningsih, 2012). Belay and Gholap (2009), have investigated the levels of chlorogenic acid in Arabica coffee from southwest Ethiopia which is roasted with light roast, medium roast, and dark roast levels. The result is that the higher the roasting level or the higher the roasting temperature, the lower the chlorogenic acid levels. The levels of chlorogenic acid at the light roast level reached 4.83% and then decreased to 4.22% in the medium roast and 3.39% in the dark roast.

The levels of chlorogenic acid in coffee were calculated based on the absorbance measured using the spectrophotometric method. Spectrophotometry is an analytical method to measure the concentration of a compound based on the ability of the compound to absorb incident light. When white light is passed through a colored solution, radiation with a certain wavelength will be selectively absorbed (absorption) and other radiation will be transmitted (transmitted). Absorbance is the ratio of the intensity of the absorbed light to the intensity of the incident light. This value depends on the levels of substances contained in it. In other words, absorbance is directly proportional to the concentration of the substance contained in a sample.

The principle of the spectrophotometric method is stated in the Lambert-Beer law where the amount of visible light radiation absorbed or transmitted by a solution is an exponential function of the concentration of the substance and the thickness of the solution. This is expressed in the Equation (1),(2), and (3).

$$\boldsymbol{T = \frac{I_t}{I_0} = 10^{-abc}} \quad (1)$$

$$\boldsymbol{\log(T) = \log\frac{I_t}{I_0} = -abc} \quad (2)$$

$$\boldsymbol{-\log(T) = \log\frac{1}{T} = \log\frac{I_0}{I_t} = abc = A} \quad (3)$$

where

A : absorbance
I_0 : intensity of incident light
I_t : intensity of light transmitted
T : transmittance
a : absorption constant
b : cell thickness
c : concentration in a substance that absorbs the electromagnetic wave

In the spectrophotometric method, incident light hitting the surface of the material and passing through the material cannot be measured, except for its transmittance or absorbance value (Neldawati, Ratnawulan, & Gusnedi, 2013). The absorbance measurement results can be related to the chlorogenic acid content of the material through a mathematical relationship between the chlorogenic acid content and absorbance. The formulation was obtained semi-empirically with the help of fitting a linear equation between the two parameters.

In order to observe the effect of roasting temperature on chlorogenic acid levels of pure Argopuro robusta coffee, absorbance measurements were made for Robusta coffee samples, which had been roasted with certain temperature variations. In addition, the identification of the characteristics above was also carried out for the type of mixed coffee between Robusta and soybeans. The addition

of soybeans is mostly done in the community to increase the weight of the coffee powder produced and add to the taste of the coffee powder to be more delicious. The importance of this research is because most types of coffee from various regions have not identified their chlorogenic acid content, which is one of the determinants of the quality of the coffee. Ridwansyah (2003) stated that the content of chlorogenic acid in Robusta coffee after undergoing the roasting process was (3.9-4.6) %. Each coffee plantation area will have coffee with different chlorogenic acid content (Moon, Yoo, & Shibamoto, 2009).

METHOD

Materials and Equipment

The green coffee of Robusta was prepared from the Argopuro plantation of Jember. They were ground and roasted at heating temperatures of 195oC, 215oC, 225oC, 230oC, and 240oC. This process utilizes a roaster, which is equipped with temperature control and a grinder for roasted coffee beans. The soybean seeds, as an ingredient mixed in robusta coffee, were prepared separately to form seed powder. Three samples examined for chlorogenic acid content included pure robusta coffee, a mixture of robusta with 10% and 20% soybeans. Three samples tested for chlorogenic acid content included pure robusta coffee, a mixture of robusta with 10% and 20% soybeans. The content was obtained based on absorbance measurements using a UV-Vis spectrophotometer with GENESYS 10S specifications. The stages of measuring the chlorogenic acid content in Robusta coffee and its variations are shown in Figure 1.

Sample Preparation for Calibration Process.

Standard chlorogenic acid (100 mg) was dissolved with methanol in an Erlenmeyer flask (reached 100 ml) producing a chlorogenic acid solution with a concentration of 1000 ppm. The solution is diluted by mixing 1 ml of the main solution with 10 ml of methanol in a volumetric flask to produce 100 ppm of concentration. This sample was then scanned to determine its absorbance using a UV-Vis Spectrophotometer ranging from 200 to 400 nm. The same procedure was applied to find the absorbance of the chlorogenic acid solution at a concentration of 200, 300, and 400 ppm, by dilution using 2 ml, 3 ml, and 4 ml of methanol respectively.

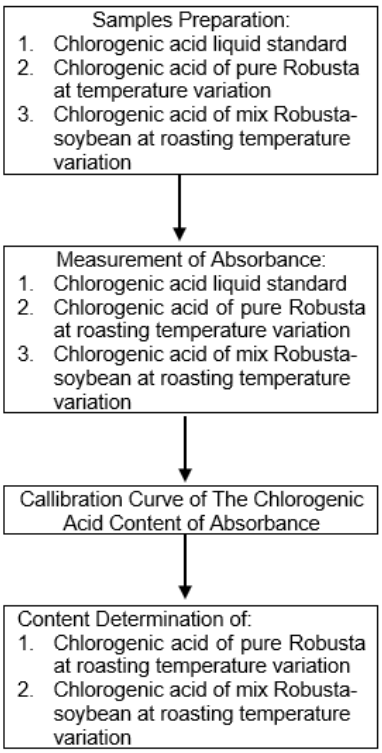

Figure 1. The Stages of Measuring The Chlorogenic Acid Content in Pure Robusta Coffee and Mixing Robusta-Soybean (10% and 20%) at a variety of roasting temperatures

Sample Preparation for Measurement of the Chlorogenic Acid Content of Robusta Coffee.

Ground coffee of Robusta (2 g) was dissolved in 150 ml hot aquadest. The coffee solution is filtered using a funnel and filter paper. The filtrate was put into a separatory funnel, while 1.5 g of calcium carbonate (CaCO3) was added to remove caffeine from the chlorogenic acid solution. Furthermore, the solution was extracted by adding 25 ml of chloroform into a separating funnel. We need to shake and take the bottom of the solution as a result of chlorogenic acid extraction. The extracted liquid was then filtered again and then diluted in a 50 ml volumetric flask using methanol. The same treatment was also conducted for the mixture of Robusta coffee

and the soybean with a mass fraction of 10% and 20% from the total sample prepared.

Analysis Data Absorbance.

Absorbance measurements were carried out for each sample at a wavelength of 290 nm using a UV-Vis spectrophotometer. In this spectrum, chlorogenic acid shows the maximum absorbance across variations in the standard concentration of chlorogenic acid. Both parameters are then plotted to get the fit line. The linear equation showing absorbance as a function of chlorogenic acid concentration is represented by Equation 4.

$$\boldsymbol{y = mx + c} \quad (4)$$

where y represents the average value of absorbance (without units), x represents the concentration of the solution (in ppm), m represents the gradient, and c represents the constant. By measuring the absorbance of a sample, we get the concentration/content of chlorogenic acid (in ppm) from the solution, through this equation. The content of chlorogenic acid in mg/g is calculated by Equation 5.

$$\boldsymbol{Content\ (mg/g) = \frac{x \times weight\ of\ extract \times Fp}{sample\ weight}} \quad (5)$$

where x is the concentration (mg/g) obtained from equation 4, the weight of the extract is the weight of the chlorogenic acid extract from each diluted sample, $\boldsymbol{Fp}$ is the dilution factor which is the number of dilutions carried out, and the sample weight is the weight of the ground coffee sample before dissolved ($\boldsymbol{g}$). The chlorogenic acid content obtained from Equation 5 has units of mg/g. In percent (%), the chlorogenic acid content is calculated by the following equation 6.

$$\boldsymbol{Content\ (\%) = \frac{Content\ (mg/g)}{1000} \times 100\%} \quad \textbf{(6)}$$

RESULT AND DISCUSSION

The standard absorbance measurement of chlorogenic acid using a UV-Vis spectrophotometer is reported in Table 1. This value was obtained at a wavelength of 290 nm with the maximum absorption of electromagnetic waves, as stated by Singh, Maithani, Saraf, & Gupta (2008). Graphically, the data in Table 1 is represented in Figure 2. The relationship between the maximum absorbance of chlorogenic acid and the concentration was adjusted linearly using Ms. Excel. The fitting is shown as Equation (7).

$$y = 0{,}0003x + 0{,}5025 \quad (7)$$
$$R^2 = 0{,}9798$$

where y represents the absorbance of chlorogenic acid and x is the concentration of chlorogenic acid (in ppm). Sartika (2011) states that the absorbance value is influenced by the concentration of the solution as shown in the Lambert-Beer equation, where the absorbance value will be greater if the concentration of the solution is greater so that it can be depicted in a graph that increases linearly. Furthermore, Equation 7 is used to determine the concentration of chlorogenic acid in coffee samples based on the absorbance.

Table 1. Maximum Absorbance at Variation of Chlorogenic Acid Concentration

The Concentration (ppm)	Maximum Absorbance
100	0.536
200	0.564
300	0.587
400	0.631

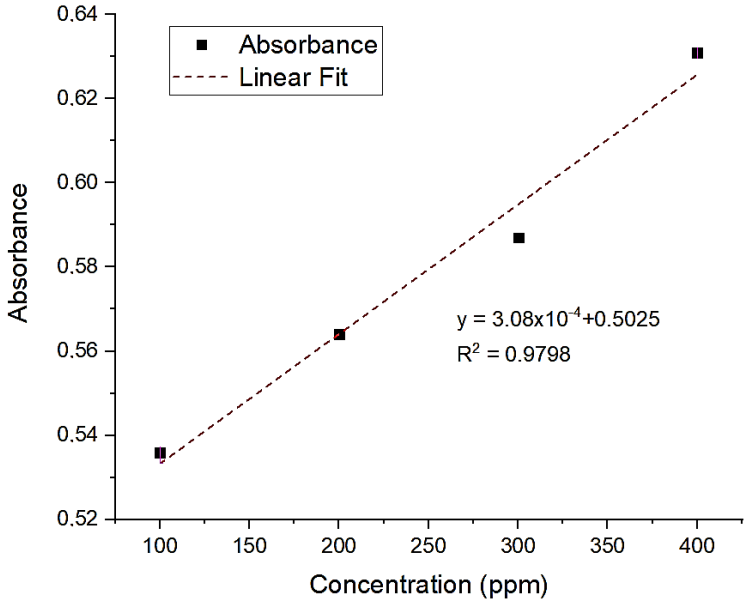

Figure 2. Calibration Curve of Chlorogenic Acid Standard Solution, where x is the concentration of chlorogenic acid (ppm) and y is the maximum absorbance

The absorbance measurement of each coffee sample was carried out using a UV-Vis Spectrophotometer at a wavelength of 290 nm. The wavelength shows the absorbance peak which indicates the maximum absorption of electromagnetic waves from chlorogenic acid. The results of absorbance measurements of all coffee samples at various roasting temperatures (195-240)℃ are presented in Table 2.

Table 2. Maximum Absorbance of pure Robusta and mix Robusta-Soybean at Variation of Roasting Temperature

Samples	Roasting Temperature (°C)	Absorbance	The Content of Chlorogenic Acid (%)
Pure Robusta	195	1.018 ± 0.004	4.30 ± 0.031
	215	0.967 ± 0.003	3.87 ± 0.028
	225	0.887 ± 0.003	3.20 ± 0.021
	230	0.875 ± 0.017	3.10 ± 0.139
	240	0.750 ± 0.002	2.06 ± 0.020
The mix of Robusta and 10% of Soybeans	195	0.823 ± 0.001	2.67 ± 0.012
	215	0.832 ± 0.002	2.74 ± 0.019
	225	0.913 ± 0.005	3.42 ± 0.044
	230	1.117 ± 0.003	5.12 ± 0.025
	240	0.941 ± 0.004	3.66 ± 0.035
The mix of Robusta and 20% of Soybeans	195	1.616 ± 0.003	9.28 ± 0.025
	215	1.556 ± 0.004	8.78 ± 0.030
	225	1.529 ± 0.002	8.55 ± 0.016
	230	1.424 ± 0.001	7.68 ± 0.009
	240	1.613 ± 0006	9.26 ± 0.053

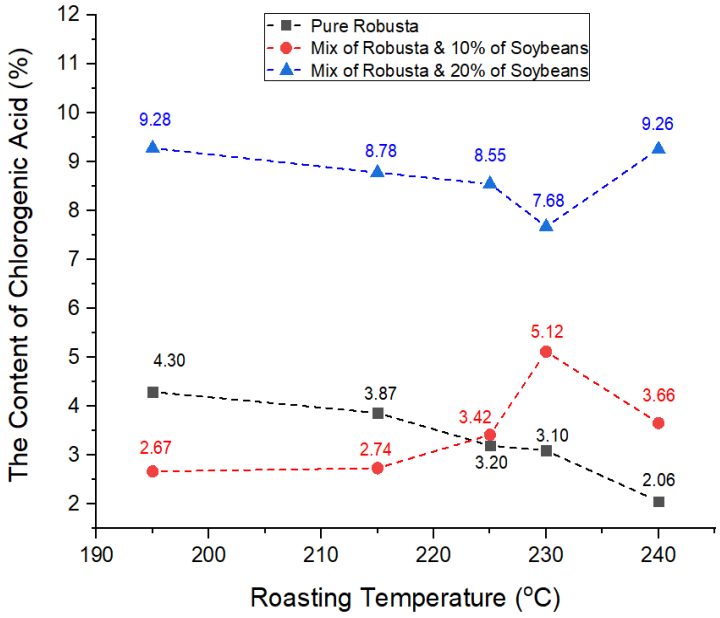

Figure 3. The Content of Chlorogenic Acid of Pure Robusta, The Mix of Robusta and 10% of Soybeans and Mix of Robusta and 20% of Soybeans at Variation of Roasting Temperatures

Based on the data presented, there is a decrease in the absorbance when the roasting temperature of pure Robusta coffee is lowered. The decrease in absorbance indicates that there is a decrease in the content of chlorogenic acid. Perrone et al. (2012) gave the same result when measuring the chlorogenic acid content in Arabica and Canephora Coffee, where the samples roasted at higher roasting temperatures presented more pronounced chlorogenic acid losses.

The opposite happened when 10% soybean (0.2 g) was added to pure Robusta coffee which resulted in an increase in the absorption of the material to electromagnetic waves up to a temperature of 230oC. If the composition of soybeans in Robusta coffee is increased to 20%, the material undergoes a change in absorption sensitivity to electromagnetic waves so that the absorbance of chlorogenic acid in this sample decreases when the roasting temperature is increased to 230oC. The absorbance value of each coffee sample is then substituted into equation (7), to obtain chlorogenic acid levels for the three types of coffee samples at 5 variations of roasting temperature as shown in Figure 3.

In general, the data shows that at a roasting temperature of 195°C-240°C, chlorogenic acid levels decrease as the roasting temperature increases. The longer the roasting process causes the chlorogenic acid levels decrease. Some of the chlorogenic acids turn into melanoidin compounds, which are one color-forming compound. The darker the color of the roasted coffee beans, the more melanoidin formed during the roasting process, so that when the roasting temperature is increased, the chlorogenic acid levels decrease due to the formation of melanoidin compounds (Vignoli, Bassoli, & Benassi, 2011). The levels of chlorogenic acid for pure Robusta coffee in this study ranged from 2.06 to 4.30 %.

The presence of soybeans given in this study affected the levels of chlorogenic acid in coffee. The chlorogenic acid content for 10% mixed robusta coffee ranged from 2.67 to 5.12 %. The addition of soybeans as much as 10% reduced the levels of chlorogenic acid at temperatures below 225oC. The increase in the content/levels of chlorogenic acid occurred at roasting temperatures of 225oC and 230oC with levels of 3.42% and 5.12%, respectively. It is suspected that other compounds have the potential to increase the absorption of electromagnetic waves at a wavelength of 290 nm.

Figure 3 also shows that the addition of soybeans with a mass fraction of 20% of the total amount of coffee, can increase the chlorogenic acid of pure robusta coffee by more than two times at all roasting temperatures. The data shows that the chlorogenic acid content of Robusta coffee with a mixture of soybeans as much as 20% ranges from 7.68 to 9.28 %. This is obtained from the calculation of chlorogenic acid content which is a function of the absorbance variable (equation 7). Absorbance data shows that there is an increase in the absorption of electromagnetic waves at a wavelength of 290 nm. However, because of the amount of robusta coffee extracted, the content of chlorogenic acid decreased to 80%, there may be other compounds that cause an increase in absorbance. Soybeans contain flavonoids which are also antioxidant compounds such as chlorogenic acid. Therefore, the absorbance from the extraction may contain other antioxidant compounds bound by methanol, thus causing the absorbance measurement results to increase and have implications for increasing levels of chlorogenic acid. The other compound is thought to be the result of the Maillard reaction formed by roasting (Rahayu and Astuti, 2017).

CONCLUSION

Observations on the absorbance of chlorogenic acid in pure Robusta coffee and a mixture of 10% and 20% Robusta-soybean were carried out using a UV-Vis Spectrophotometer at a wavelength of 290 nm. The roasting temperature treatment is given to samples of pure Robusta coffee of the local variety Argopuro, Jember Regency, ranging from 195oC to 240oC, has reduced chlorogenic acid levels up to 2.06%. The addition of soybeans with a mass fraction of 10% further reduced the chlorogenic acid content of mixed Robusta coffee until it was heated to 215oC. On the other hand, 20% soybean mass fraction added to pure Robusta coffee allows the formation of other antioxidant compounds, thereby increasing the value of the absorbance measurement results. Based on the measurement of the absorbance value, it was found that pure Robusta coffee with a temperature of 195oC was the best quality coffee in terms of the amount of chlorogenic acid content with a level of 4.30%.

ACKNOWLEDGEMENT

We thank LP2M University of Jember for providing financial support through the Hibah Keris 2020 with Research Contract Number 3508/UN25.3.1/LT/2020 October 22, 2020.

REFERENCES

Belay, A. dan A. V. Gholap. 2009. Characterization and determination of chlorogenic acids (CGA) in coffee beans by UV-Vis spectroscopy. *African Journal of Pure and Applied Chemistry* 3 (11), 234–240.

Cammerer, B. dan L. W. Kroh. 2006. Antioxidant activity of coffee brews. *European Food Research and Technology* 223 (4), 469–474.

Choiron, M. 2010. Penerapan GMP pada penanganan pasca panen kopi rakyat untuk menurunkan okratoksin produk kopi (studi kasus di Sidomulyo, Jember). *Agrointek* 4 (2), 114-120.

Ciptaningsih, E. 2012. Uji Aktivitas Antioksidan dan Karakteristik Fitokimia pada Kopi Luwak Arabika dan Pengaruhnya terhadap Tekanan Darah Tikus Normal dan Tikus Hipertensi. Tesis, Jakarta, Universitas Indonesia.

Fadri, R. A., K. Sayuti, N. Nazir dan I. Suliansyah. 2019. Review proses penyangraian kopi dan terbentuknya akrilamida yang berhubungan dengan kesehatan. *Journal of Applied Agricultural Science and Technology* 3 (1), 129–145.

Grace, H. A. 2017. Inventarisasi Organoleptik, Kandungan Kafein, dan Asam Klorogenat pada Kopi Bubuk Robusta (*Coffea canephora* L.) di Kabupaten Tanggamus. *Skripsi*, Bandar Lampung, Universitas Lampung

Mangiwa, S., A. Futwembun dan P. M. Awak. 2015. Kadar asam klorogenat (CGA) dalam biji kopi arabika (*Coffea arabica*) asal Wamena, Papua. *Jurnal Kependidikan Kimia Hydrogen* 3 (2), 313–317.

Moon, J.K., H. S. Yoo dan T. Shibamoto. 2009. Role of roasting conditions in the level of chlorogenic acid content in coffee beans: correlation with coffee acidity. *Journal of Agriculture and Food Chemistry* 57 (12): 5365–5369.

Mulato, S., S. Widyotomo dan H. Lestari. 2001. Pelarut Kafein Biji Kopi Robusta dengan Kolom Tetap Menguunakan Pelarut Air. Pelita Perkebunan 17 (2): 97–109.

Neldawati, Ratnawulan dan Gusnedi. 2013. Analisis nilai absorbansi dalam penentuan kadar

flavonoid untuk berbagai jenis daun tanaman obat. *Pillar of Physics*. *Oktober 2013*. 76-83

Perrone, D., R. Donangelo, C. M. Donangelo dan A. Farah. 2012. Modeling weight loss and chlorogenic acid content in coffee during roasting. *Journal of Agricultural and Food Chemistry* 58 (23), 12238-12243.

Rahayu, W. M. dan E. Astuti. 2017. Pengaruh proses pengolahan dan penyangraian biji terhadap aktivitas dan kandungan senyawa antioksidan sari kedelai hitam malika (*Glycine max*). *Journal Chemica* 4 (2), 59-65.

Ridwansyah. 2003. *Pengolahan Kopi*. Sumatra Utara: Jurusan Teknologi Pertanian Fakultas Pertanian Universitas Sumatra Utara.

Sartika. 2011. Analisis Kadar Glukosa dan Fruktosa pada Beberapa Madu Murni yang Beredar di Pasaran Menggunakan Metode Spektrofotometer Visible. *Skripsi*, Makassar, UIN Alaudin

Singh, R., M. Maithani, S. K. Saraf, S. Saraf dan R. C. Gupta. 2008. *Simultaneous estimation of ciprofloxacin hydrochloride, ofloxacin, tinidazole, and ornidazole by reverse phase-high performance liquid chromatography*. *Eurasian J Anal Chem* 4 (2), 161-167.

Triyanti, D. R. 2016. *Outlook Kopi Komoditas Pertanian Subsektor Perkebunan*. Jakarta: Kementerian Pertanian

Vignoli, J. A., D. G. Bassoli dan M. T. Benassi. 2011. Antioxidant activity, polyphenols, caffeine and melanoidins in soluble coffee: The influence of processing conditions and raw material. *Journal of Food Chemistry* 124 (3), 863-868.

Yulian, N. F., N. Kusardhani, dan W. Amilia. 2019. Identifikasi dan analisis struktur rantai pasok kopi rakyat robusta Kecamatan Bangsalsari, Jember. *Jurnal Agroteknologi* 13 (1), 10-15.