Chemical profiling of western Indonesian single origin robusta coffee

O N Marsilani, Wagiman, and A C Sukartiko*  
Department of Agro-Industrial Technology, Faculty of Agricultural Technology,  
Universitas Gadjah Mada, Jl. Flora 1 Bulaksumur Yogyakarta 55281, INDONESIA  
*Corresponding Author’s E-mail: cahyos@ugm.ac.id

Abstract. The majority of coffee plantations in Indonesia is dominated by Robusta coffee. Some of them have a distinctive quality with a strong relation to their origin, in which the coffee has been cultivated. These are known as single-origin coffee. Most of the coffees are produced in the western part of the country. This study aimed to profile the chemical quality parameters of robusta single-origin coffee in the western part of Indonesia. Green coffee bean from various regions of the western part of the country, namely Empat Lawang, Menoreh, and Gunung Kelir, which were cultivated at various elevation ranges, were collected and analyzed in their chemical quality parameters such as caffeine, sucrose, total fat, and fatty acids. ANOVA was then performed on the collected data, and the results are discussed in this paper.

1. Introduction  
Coffee is the most widely traded agricultural commodity in the world [1]. In Indonesia, the country with the fourth largest production [2] after Brazil, Vietnam and Colombia [3], the commodity has contributed to the national economy as well as the country's largest source of foreign exchange from agricultural products, with an export number of 467,800 tons in 2017 and a value reaching US $1,187,157,000 [4].

The majority of Indonesia’s coffee plantations are dominated by Robusta coffee (81.96%) [2]. Similar to the area of coffee plantations, most of Indonesia's coffee production is also dominated by Robusta. This is due to the fact that most of the available coffee plantations in Indonesia are at an altitude of 700 to 900 m a.s.l. which is good for Robusta growth, while Arabica grows well at an altitude of more than 1,000 m a.s.l. [5]. Besides, Robusta coffee is also more resistant to pests and diseases [6].

Robusta coffee production areas are spread across various regions in Indonesia, including South Sumatra, Special Region of Yogyakarta, and Central Java. From 2013 to 2017, South Sumatra was the province with the highest Robusta coffee production in the country, amounting to 26.84% [2]. Robusta coffee production areas in South Sumatra are spread over five districts, namely South Ogan Komering Ulu, Empat Lawang, Muara Enim, Lahat, and Ogan Komering Ulu. These districts contributed 24.76%, 19.42%, 18.59%, 15.33%, and 11.82%, respectively, from the total Robusta coffee produced in the South Sumatera [4].

Among the various types of coffee cultivated in Indonesia, some have strong links with the area in which the product originates, both due to natural factors, human factors, or a combination of the two. Because of its strong association, the origin area of the product is used as part of the product name and known as a geographical indication. When applied to coffee commodities, the use of this origin area in
the product name is known as single-origin coffee. This type of coffee generally has a distinct flavor and provides added value compared to non-single origin coffee. The existence of plant genetic diversity, variation in climatic and environmental conditions, as well as the cultivation and processing techniques used in the production of coffee by each producer, these may cause the quality and flavor of the coffee produced to be varied and unique [7]. Furthermore, in the last few decades, more and more consumers choose food products based on local attributes and product specificities as well as environmental and ethical issues. This trend reflects public concern for safety, health, sustainability, and social problems in food production practices [8]. The author [9] highlights the growing consumer segment pays attention to food safety and food quality issues and assesses its origin as a sign of quality.

According to [7], the characteristics of coffee flavor are influenced since the cultivation process. During the development process of the coffee cherry, there is an accumulation of biochemical compounds, which are precursors of coffee flavor. After coffee cherry is harvested, the biochemical compound can react and interact at the processing stages to become a final product that has flavor complexity. The importance of the parameters is consistent with [10] that the biochemical composition plays a great role in determining the taste of the coffee. Looking at the potential of Indonesia Robusta single-origin coffees and the role of biochemical composition in determining the quality of coffee as mentioned previously, therefore, this study was aimed at profiling the chemical quality of a single-origin coffee from the western region of Indonesia, that needs to be carried out.

2. Material and methods

2.1. Samples geographical origin
To ensure the authenticity of the coffee origin, green coffee samples were taken directly from coffee plantations in Empat Lawang South Sumatra Province, Kulon Progo in Yogyakarta Special Region, and Semarang in Central Java Province with various elevation ranges of planting areas. Determination of the ranges was referred to [11]. Menoreh and Empat Lawang coffee sampling locations were carried out at four stratifications of altitudes, i.e., 300 to 500 m.a.s.l., 500 to 600 m.a.s.l., 600 to 700 m.a.s.l., and > 700 m.a.s.l.

Meanwhile, because Gunung Kelir Coffee is only grown in areas with elevations >700 m.a.s.l., the used elevation ranges were different from the other two previous coffees, which are in the range 700 to 900; 900 to 1,100; 1,100 to 1,300; and more than 1,300 m.a.s.l. Each sampling location coordinates and its altitude were determined using Google Maps/Earth (Empat Lawang Coffee) and Global Positioning System equipment (Menoreh and Gunung Kelir Coffees). Profile of the samples' geographical origin is depicted in Table 1.

| Districts | Range of elevation (m a.s.l.) | Elevation (m a.s.l.) | Latitude coordinates | Longitude coordinates |
|-----------|-----------------------------|--------------------|----------------------|----------------------|
| Semarang  | 700−900                     | 741                | 7°19' 26.40" S      | 110°22' 3.9" E      |
|           | 900−1,100                   | 1,047              | 7°19' 48.00" S      | 110°22' 22.3" E     |
|           | 1,100−1,300                 | 1,192              | 7°19' 54.90" S      | 110°22' 29.8" E     |
|           | >1,300                      | 1,332              | 7°20' 3.60" S       | 110°22' 45.3" E     |
| Kulon     | 300−500                     | 417                | 7°40' 189.00" S     | 110°12' 36.3" E     |
| Progo     | 500−600                     | 515                | 7°39' 43.10" S      | 110°12' 19.9" E     |
|           | 600−700                     | 688                | 7°39' 30.70" S      | 110°11' 57.0" E     |
|           | >700                        | 842                | 7°38' 51.10" S      | 110°11' 18.0" E     |
| Empat     | 300−500                     | 309                | 3°42' 2.20" S       | 102°56' 47.2" E     |
| Lawang    | 500−600                     | 410                | 3° 7' 6.00" S       | 102°46' 36.2" E     |
|           | 600−700                     | 478                | 3°45' 11.90" S      | 102°54' 11.8" E     |
|           | >700                        | 754                | 4° 4' 37.00" S      | 103°21' 0.2" E      |
2.2. Analysis of chemical quality

2.2.1. Caffeine, sucrose, and total fat contents. Caffeine content was determined using the Bailey-Andrew method. Caffeine extraction was carried out on 3 g pulverized sample using water and other alkaloids deposition with the addition of 5 ml KOH 1%. Sucrose content was determined as the difference between total and reducing sugars. Reducing sugar was determined based on the Nelson-Somogyi method. Total fat was analyzed based on the Soxhlet method. A total of 1 g of the pulverized sample was put into a soxhlet extraction tube in a thimble with 15 ml of petroleum ether solvent to be distilled for four hours. Petroleum ether containing fat extract was transferred into a clean weighing bottle with a known weight and then evaporated with a water bath until it was slightly concentrated and continued drying in a 100°C oven until a constant weight was achieved. The weight of the residue in the weighing bottle is expressed as the weight of the oil. All three analyses were carried out based on the procedure explained by [12].

2.2.2. Fatty Acids. Fatty acids content of the samples were analyzed with Gas Chromatography (Shimadzu GC 2010 Plus, Flame Ionisation Detector (FID), 240°C, RTX-Wax, P=30 m, d=0.25 mm, Helium/0.80 ml.minute⁻¹). The initial column temperature was 150°C, raised to 200°C, with an increase in temperature of 8°C/minute. The temperature of 200°C was maintained for 30 minutes, then was raised to 220°C with an increase 8°C/minute. The temperature of 220°C was maintained for 25 minutes, then the temperature was allowed back to the initial temperature. The procedure of the analysis was based on [13]. Four saturated fatty acids (myristic (C14:0), palmitic (C16:0), stearic (C18:0), and arachidic(C20:0)) and three unsaturated fatty acids (oleic (C18:1), linoleic (C18:2), and linolenic (C18:3)) were analyzed.

2.3. Statistical analysis

One way ANOVA was used to determine and explain the different levels of coffee quality characteristics based on origin and elevation using IBM SPSS Statistics 22. The output was used as a determination of the hypothesis to be accepted or rejected. Hypothesis testing can be done using probability or significance. If \( p >0.05 \), then \( H_0 \) is accepted and if \( p <0.05 \), then \( H_0 \) is rejected. If the ANOVA output shows that \( H_0 \) is rejected, then a post hoc test can be performed to determine which quality parameters have significant differences. Data that did not meet the assumption of heteroscedasticity were further tested using the Brown-Forsythe test [14].

3. Results and discussion

The caffeine content of coffee beans in this study is shown in Table 2, ranged from 1.11-1.76% on a dry basis (db), mostly in accordance with Robusta Coffee caffeine levels according to [15]. The highest caffeine levels were found on Gunung Kelir sample at high altitude level (1,100-1,300 m a.s.l.), while the lowest caffeine levels were also found on Gunung Kelir sample but at lower altitude, namely medium-altitude levels (900-1,100 m a.s.l.). It was known from the table that the caffeine content of the samples from various regions was not significantly different in each region of origin ([15]) but had a significant difference in several levels of altitude ([15]).

Caffeine is a type of purine methylxanthine (1,3,7-trimethylxanthine) alkaloid compound derived from xanthosine with the chemical formula \( \text{C}_8\text{H}_{10}\text{N}_4\text{O}_2 \). Caffeine is a secondary metabolite in coffee because it has an impact on the quality of coffee, where the accumulation of its contents increases bitter taste and affects health, including causing the body to stay awake [16]. The caffeine content in Robusta ranges from 1.5 to 2.5% (db), causing the taste of the coffee bitter [15]. No trend was found for caffeine content at various elevation ranges in this study. On the contrary, [1] and [17] reported that altitude has significantly affected the caffeine content of Arabica coffee beans, the higher the cultivation location, the higher the caffeine content is. However, in a study conducted by [18] and
[19], Arabica coffee samples showed inversely proportional results, i.e., if the height increases by 500 m, the caffeine content of coffee beans will also increase by 15%.

Fat is a significant component in coffee and has a vital role in determining its sensory quality. Triacylglycerol is the aroma carrier in roasted coffee. The fatty acid fraction from triacylglycerol releases side products from oxidation results when roasted, which consists mainly of aldehyde compounds that play a role in giving flavor and aroma to coffee [20]. The total fat content of coffee beans in this study (Table 2) ranged from 7.92 to 9.93% (db), which are in accordance with [15]. The highest total fat content was observed on Gunung Kelir coffee at low altitude levels (700-900 m a.s.l.), while the lowest total fat content was found on the same coffee at high altitude levels (1,100-1,300 m a.s.l.). It was also known from the table that based on the area of origin, the total fat content of all the samples ($p>0.05$). However, based on the location’s altitude of coffee growth, all samples have significant differences ($p<0.05$).

According to [18], site altitude is positively correlated with fat content. The higher the location of coffee growth, the higher the fat content. The altitude of the location is related to the temperature of the air, where the higher the location, the temperature will be lower. Coffee beans that grow in low-temperature environments can cause the fruit maturation process to slow down, specifically, this may result in the formation of more complex biochemical compounds and the accumulation of sugars and fats [1]. However, in our study, we also did not found of such a trend.

**Table 2. Caffeine, total fat, and sucrose contents.**

| Geographical origin | Elevation (m a.s.l.) | Caffeine (%) | Total fat (%) | Sucrose (%) |
|---------------------|---------------------|--------------|--------------|------------|
| **Kopi Kelir Semarang** | 700−900 | 1.62 ± 0.14$^{bc}$ | 9.93 ± 0.05$^{d}$ | 2.91 ± 0.06$^{c}$ |
| | 900−1,100 | 1.11 ± 0.01$^{a}$ | 9.05 ± 0.20$^{f}$ | 4.07 ± 0.08$^{f}$ |
| | 1,100−1,300 | 1.76 ± 0.01$^{c}$ | 7.92 ± 0.08$^{e}$ | 2.88 ± 0.07$^{c}$ |
| | >1,300 | 1.74 ± 0.00$^{e}$ | 7.98 ± 0.10$^{e}$ | 3.14 ± 0.01$^{d}$ |
| Pooled | | 1.55 ± 0.28$^{*}$ | 8.73 ± 0.87$^{*}$ | 3.25 ± 0.51$^{†}$ |
| **Kopi Menoreh Kulon Progo** | 300−500 | 1.66 ± 0.02$^{bc}$ | 8.46 ± 0.07$^{e}$ | 0.83 ± 0.04$^{a}$ |
| | 500−600 | 1.57 ± 0.01$^{bc}$ | 9.69 ± 0.29$^{f}$ | 2.44 ± 0.03$^{b}$ |
| | 600−700 | 1.75 ± 0.04$^{c}$ | 9.04 ± 0.11$^{e}$ | 3.35 ± 0.03$^{c}$ |
| | >700 | 1.40 ± 0.35$^{bc}$ | 8.50 ± 0.03$^{b}$ | 2.50 ± 0.04$^{b}$ |
| Pooled | | 1.58 ± 0.22$^{*}$ | 8.97 ± 0.60$^{*}$ | 2.28 ± 0.93$^{b}$ |
| **Kopi Empat Lawang** | 300−500 | 1.58 ± 0.02$^{bc}$ | 8.75 ± 0.02$^{d}$ | 4.08 ± 0.04$^{d}$ |
| | 500−600 | 1.48 ± 0.01$^{bc}$ | 9.14 ± 0.06$^{e}$ | 4.24 ± 0.03$^{e}$ |
| | 600−700 | 1.66 ± 0.01$^{bc}$ | 9.08 ± 0.08$^{e}$ | 4.32 ± 0.03$^{e}$ |
| | >700 | 1.33 ± 0.02$^{b}$ | 8.95 ± 0.11$^{d}$ | 3.20 ± 0.07$^{e}$ |
| Pooled | | 1.52 ± 0.22$^{*}$ | 8.98 ± 0.62$^{*}$ | 3.96 ± 0.46$^{b}$ |

Different letters or symbol within a column indicate significant difference within the corresponding group ($p<0.05$). Mean and standard deviation of each location was pooled from all elevation ranges at the same location.

Sucrose is a disaccharide formed from its monomers in the form of glucose and fructose units, with the molecular formula C$_{12}$H$_{22}$O$_{11}$. The disaccharide is the main constituent of sugar content (around 90%), so that its presence represents the general sugar composition in coffee beans [21]. Sucrose plays an essential role in influencing the taste and aroma of the coffee so that its presence is always expected to be in high amounts in coffee [20]. The value of sucrose content in coffee beans from various regions is shown in Table 2. The sucrose content in coffee samples from various regions and various altitude was significantly different ($p<0.05$). The sucrose content of coffee beans in this study ranged from 0.83 to 4.82% (db), slightly lower and higher than the reference level of Robusta Coffee sucrose according to [15]. The lowest sucrose content was found on Menoreh Kulon Progo Coffee at a low altitude level (300 to 500 m a.s.l.), while the highest sucrose content was observed on Empat Lawang coffee at a high altitude level (600 to 700 m a.s.l.). The content variation can be caused by differences
in the height of the coffee cultivation area [18], the average temperature [22], and the presence of shade plants [17]. Site altitude is positively correlated with sucrose content [18]. The higher the location of the coffee growing region, the higher the sucrose content is. Besides, coffee beans that grow in low-temperature environments can cause a slow process of fruit ripening, which leads to the formation of more complex biochemical compounds and the accumulation of sugars and fats [1]. According to [22], the low temperature can also be created by giving more shade plants so that it can reduce the intensity of incoming sunlight on the coffee plant. However, [17] gave different results, coffee plants with sufficient shade experienced a process of increasing.

The composition of fatty acids detected in our samples were myristic acid (C14:0) 0.25%, palmitic acid (C16:0) 33.90%, stearic acid (C18:0) 10.22%, oleic acid (C18:1) 8.16%, linoleic acid (C18:2) 43.42%, linolenic acid (C18:3) 0.80%, and arachidic acid (C20:0) 2.89%, as shown in Table 3 and Table 4. From these results, it can be seen that the most fatty acids contained in coffee beans were linoleic acid (43.42%), and the lowest amount of fatty acids was myristic acid (0.25%). These results were consistent with the finding that linoleic acid is the most dominant fatty acid in plants including coffee, followed by palmitic acid and several other types of fatty acids contained in smaller amounts such as oleic, stearic, arachidic, and linolenic acids [23]. No significant difference was found on myristic and stearic acids, for both elevation and area origin. However, significant differences in palmitic and arachidic acid contents were observed based on the geographical origin of Empat Lawang coffee, allowing the two parameters as potential discriminating parameters. Empat Lawang coffee is the only coffee in this study that already certified as geographical indication products [24].

Author [25] also reported that linoleic acid is the primary fatty acid contained in coffee beans, which is about 44%, followed by palmitic acid as much as 33.3%. Author [15] also observed similar results, in which the fatty acids in coffee beans consisted of linoleic acid as much as 43% to 54%, oleic acid as much as 7 to 14%, and linolenic acid as much as 1 to 2.6%. Fatty acids are not only beneficial for the body but are also useful for keeping coffee fresh and preventing loss of aroma and flavor caused by the hydrolysis and oxidation of triacylglycerol. According to [26] and [15], most of the fatty acids in coffee beans are unsaturated fatty acids. The condition is in accordance with the

| Geographical origin | Elevation ranges (m a.s.l.) | Myristic C14:0 (%) | Palmitic C:16:0 (%) | Stearic C18:0 (%) | Arachidic C20:0 (%) |
|---------------------|-----------------------------|------------------|-------------------|------------------|-------------------|
| Kopi Kelir Semarang | 700–900                     | 0.20 ± 0.78 a    | 36.76 ± 2.58 ab   | 6.52 ± 0.98     | 2.60 ± 0.06 a     |
|                     | 900–1,100                   | 0.15 ± 0.03 a    | 38.53 ± 2.89 ab   | 6.45 ± 0.91 a   | 2.48 ± 0.42 a     |
|                     | 1,100–1,300                 | 0.14 ± 0.00 a    | 37.72 ± 0.35 ab   | 6.72 ± 0.56 a   | 2.75 ± 0.28 a     |
|                     | >1,300                      | 0.13 ± 0.02 a    | 39.55 ± 1.69 ab   | 6.99 ± 0.40 a   | 2.38 ± 0.11 a     |
|                     | Pooled                      | 0.16 ± 0.04     | 38.14 ± 1.95      | 6.67 ± 0.40 a   | 2.55 ± 0.25       |
| Kopi Menoreh Kulon Progo | 300–500                   | 0.15 ± 0.06 a    | 37.11 ± 0.44 ab   | 5.83 ± 0.32     | 2.68 ± 0.04 a     |
|                     | 500–600                     | 0.39 ± 0.39 a    | 36.58 ± 0.43 ab   | 6.02 ± 0.27 a   | 2.93 ± 0.35 a     |
|                     | 600–700                     | 0.15 ± 0.01 a    | 36.38 ± 0.51 ab   | 6.42 ± 0.57 a   | 2.63 ± 0.33 a     |
|                     | >700                        | 0.16 ± 0.02 a    | 37.37 ± 0.95 ab   | 6.08 ± 0.13     | 2.75 ± 0.40 a     |
|                     | Pooled                      | 0.21 ± 0.18      | 36.86 ± 0.63      | 6.09 ± 0.36     | 2.74 ± 0.23       |
| Kopi Empat Lawang   | 300–500                     | 0.55 ± 0.54 a    | 31.91 ± 2.48 ab   | 7.29 ± 0.63 a   | 4.48 ± 1.60 a     |
|                     | 500–600                     | 0.62 ± 0.66 a    | 32.97 ± 2.88 ab   | 6.59 ± 0.29 a   | 3.79 ± 0.54 a     |
|                     | 600–700                     | 0.43 ± 0.47 a    | 32.84 ± 1.70 ab   | 3.96 ± 4.88 a   | 4.16 ± 0.32 a     |
|                     | >700                        | 0.12 ± 0.01 a    | 34.96 ± 0.02 ab   | 6.94 ± 0.38 a   | 3.32 ± 0.54 a     |
|                     | Pooled                      | 0.22 ± 0.22      | 33.17 ± 1.98      | 6.19 ± 2.34     | 3.94 ± 0.83       |

Different letters or symbol within a column indicate significant difference within the corresponding group (p<0.05). Mean and standard deviation of each location was pooled from all elevation ranges at the same location.
results of this study where unsaturated fatty acids dominate the detected fatty acid composition, which is 52.38% composed of linoleic acid (43.42%), oleic acid (8.16%) and linolenic acid (0.80%).

Linoleic acid is an unsaturated fatty acid dominating the types of fatty acids contained in Robusta Coffee Beans from several regions in China [27]. Linoleic acid is an essential fatty acid that is needed by humans from external sources (from outside the body). Linoleic acid functions to launch lipoprotein metabolism. The composition of the detected fatty acids was also largely the same as the fatty acids detected in this study, i.e., linoleic acid, palmitic acid, oleic acid, arachidic acid, linolenic acid, and myristic acid.

Among studied unsaturated fatty acids, only oleic acid has shown significant difference based on the independent variables of the area of origin (Semarang, Kulon Progo and Empat Lawang). Palmitic and arachidic acid of coffee samples originating from the Empat Lawang District were significantly different from coffee from Semarang Regency and Kulon Progo Regency. Meanwhile, palmitic acid and arachidic acid coffee samples from Semarang were not significantly different from other studied coffee.

### Table 4. Unsaturated fatty acid contents.

| Geographical origin | Elevation ranges (m a.s.l.) | Oleic C18:1 (%) | Linoleic C18:2 (%) | Linolenic C18:3 (%) |
|---------------------|----------------------------|----------------|-------------------|-------------------|
| Kopi Kelir Semarang | 700–900                    | 8.38 ± 0.79a   | 40.70 ± 1.60a     | 0.91 ± 0.11a     |
|                     | 900–1,100                  | 9.10 ± 0.35ab  | 39.21 ± 1.93a     | 0.90 ± 0.19a     |
|                     | 1,100–1,300                | 9.78 ± 0.96abc | 41.07 ± 0.28a     | 0.81 ± 0.15a     |
|                     | >1,300                     | 9.83 ± 0.11abcd| 38.99 ± 0.09a     | 0.71 ± 0.02a     |
| Pooled              | 9.28 ± 0.79 *              | 39.99 ± 1.35 * | 0.83 ± 0.13 *†    |
| Kopi Menoreh Kulon Progo | 300–500                  | 10.26 ± 0.35bcd | 40.45 ± 1.21 *     | 0.67 ± 0.01 *     |
|                     | 500–600                    | 10.45 ± 0.23bcd | 41.42 ± 0.83 *     | 0.68 ± 0.01 *     |
|                     | 600–700                    | 10.81 ± 0.25bcd | 41.66 ± 0.51 *     | 0.75 ± 0.28 *     |
|                     | >700                       | 10.55 ± 0.02bcd | 41.43 ± 0.97 *     | 0.75 ± 0.07 *     |
| Pooled              | 10.52 ± 0.28 *             | 41.24 ± 0.85 * | 0.71 ± 0.05 *      |
| Kopi Empat Lawang   | 300–500                    | 11.39 ± 0.54cd | 39.21 ± 4.18 *     | 1.12 ± 0.54 *     |
|                     | 500–600                    | 11.08 ± 0.47cd | 39.53 ± 3.61 *     | 1.23 ± 0.47 *     |
|                     | 600–700                    | 11.58 ± 0.23cd | 39.53 ± 1.67 *     | 0.99 ± 0.37 *     |
|                     | >700                       | 11.05 ± 0.04cd | 42.07 ± 1.17 *     | 0.73 ± 0.06 *     |
| Pooled              | 11.28 ± 0.37 *             | 40.08 ± 2.55 * | 1.02 ± 0.37 *      |

Different letters or symbol within a column indicate significant difference within the corresponding group (p<0.05). Mean and standard deviation of each location was pooled from all elevation ranges at the same location.

### 4. Conclusion

A chemical profile of robusta coffee samples from the western part of Indonesia has been presented in this study. Differences in caffeine and total fat contents were more influenced by altitude, not the geographical origin. On the contrary, fatty acids, especially in oleic, palmitic, arachidic, and linolenic, were more influenced by geographical origin. Sucrose content was influenced by both altitude and geographical origin.

### Acknowledgements

Authors wishing to acknowledge assistance from Sulistio Eko Prasetyo and farmers for providing the green coffee bean samples. The authors also gratefully acknowledge the Indonesian Endowment Fund for Education (LPDP) for the scholarship and financial support to this work.
References

[1] Tolessa K, D’heer J, Duchateau L and Boeckx P 2017 Influence of growing altitude, shade and harvest period on quality and biochemical composition of Ethiopian specialty coffee J. Sci. Food Agric. 97 2849–57

[2] Pusat Data dan Sistem Informasi Pertanian Sekretariat Jenderal Kementerian Pertanian 2017 Outlook 2017 Komoditas Pertanian Sub Sektor Perkebunan Kopi

[3] International Coffee Organization 2019 Total production by all exporting countries

[4] BPS - Statistics Indonesia 2017 Statistik Kopi Indonesia 2017 (Statistics Indonesia)

[5] Prastowo B, Karmawati E, Rubijo, Siswanto, Indrawanto C and Munarso S J 2010 Budidaya dan Pasca Panen Kopi (Bogor: Pusat Penelitian dan Pengembangan Perkebunan)

[6] Purwanto E heri, Rubiyono and Towaha J 2015 Karakteristik Mutu Dan Citarasa Kopi Robusta Kلون BP 42,BP 385 Dan 308 Asal Bali Dan Lampung Sirinov 3 67–74

[7] Sunarharum W B, Williams D J and Smyth H E 2014 Complexity of coffee flavor: A compositional and sensory perspective Food Res. Int. 62 315–25

[8] Kos Skubic M, Erjavec K and Klopčič M 2018 Consumer preferences regarding national and EU quality labels for cheese, ham and honey: The case of Slovenia Br. Food J. 120 650–64

[9] Teuber R 2011 Consumers’ and producers’ expectations towards geographical indications: Empirical evidence for a German case study Br. Food J. 113 900–18

[10] Gichuru E K, Mamati G E and Nyende A B 2014 Biochemical Composition Within Coffea arabica cv. Ruiru 11 and Its Relationship With Cup Quality J. Food Res. 3 31–44

[11] Kementerian Pertanian Republik Indonesia 2014 Pedoman teknis budidaya kopi yang baik (GOOD AGRICULTURE PRACTICES /GAP ON COFFEE)

[12] Sudarmadji S, Haryono B and Suhardi 1984 Prosedur Analisa untuk Bahan Makanan dan Pertanian (Yogyakarta: Liberty)

[13] PARK P W and GOINS R E 1994 In Situ Preparation of Fatty Acid Methyl Esters for Analysis of Fatty Acid Composition in Foods J. Food Sci. 59 1262–6

[14] Field A 2009 Discovering Statistics using SPSS: and Sexx and Drugs and Rock “n” Roll (3rd Edition) (London: SAGE)

[15] Farah A 2012 Coffee Constituents

[16] Campa C, Doulbeau S, Dussert S, Hamon S and Noiroit M 2005 Diversity in bean Caffeine content among Wild Coffea Species: Evidence of a Discontinuous Distribution Food Chem. 91 633–7

[17] Worku M, de Meulenaer B, Duchateau L and Boeckx P 2018 Effect of Altitude on Biochemical Composition and Quality of Green Arabica Coffee Beans can be Affected by Shade and Postharvest Processing Method Food Res. Int. 105 278–85

[18] Avelino J, Barboza B, Araya J C, Fonseca C, Davieux F, Guyot B and Cilas C 2005 Effects of Slope Exposure, Altitude and Yield on Coffee Quality in Two Altitude Terroirs of Costa Rica, Orosi and Santa Maria de Dota J. Sci. Food Agric. 85 1869–76

[19] Bertrand B, Villarreal D, Laffargue A, Posada H, Lashermes P and Dussert S 2008 Comparison of the effectiveness of fatty acids, chlorogenic acids, and elements for the chemometric discrimination of coffee (Coffea arabica L.) varieties and growing origins J. Agric. Food Chem. 56 2273–80

[20] Cheng B, Furtado A, Smyth H E and Henry R J 2016 Influence of Genotype and Environment on Coffee Quality Trends Food Sci. Technol. 57 20–30

[21] Wintgens J N 2004 Coffee: Growing, Processing, Sustainable Production (Weinheim: WILEY-VCH)
[23] Rustan A C and Drevon C A 2005 Fatty Acids: Structures and Properties Encycl. Life Sci. 1–7
[24] Direktorat Jenderal Kekayaan Intelektual 2017 Indikasi Geografis Terdaftar
[25] Martín M J, Pablos F, González A G, Valdenegro M S and León-Camacho M 2001 Fatty acid profiles as discriminant parameters for coffee varieties differentiation Talanta 54 291–7
[26] Speer K and Kölling-Speer I 2006 The Lipid Fraction of The Coffee Bean Brazilian J. Plant Physiol. 18 201–16
[27] Dong W, Tan L, Zhao J, Hu R and Lu M 2015 Characterization of fatty acid, amino acid and volatile compound compositions and bioactive components of seven coffee (Coffea robusta) cultivars grown in Hainan Province, China Molecules 20 16687–708