Antioxidant and sensory properties of ready to drink coffee-ginger made from decaffeinated and non-decaffeinated robusta coffee beans

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Abstract. In this research, Robusta coffee bean was used in the making of ready to drink coffee-ginger. This research was conducted to know the influence of different formulas on the content of total polyphenols, melanoidin brown pigments, antioxidant activity and sensory properties in decaffeinated and non-decaffeinated coffee-ginger drink. The coffee-ginger drinks were made with 50 ml and 40 ml of decaffeinated and non-decaffeinated Robusta coffee extracts, added with 20, 15 and 10 ml ginger extract respectively. The results showed the formulation of coffee: ginger (50ml: 20ml) with non-decaffeinated coffee beans had total polyphenol (2.69 mg GAE/ml), melanoidin brown pigment (1.31 AU) and antioxidant activity (0.43 mmol TE/ml) contents; which is the highest compared to other formulations. The coffee-ginger drink that favored the most by panelists is the formulation of coffee: ginger (40ml : 10ml) with non-decaffeinated coffee bean. The decaffeinated coffee-ginger has a faded brown color and strong flavor, so it is less preferred. The high addition of ginger extract is also less preferred because it has a too strong flavor and pungent taste.

1. Introduction
Coffee is a type of beverage that is popular throughout the world. Coffee production in Indonesia in 2019 reached 760,963 tons, and in 2020 it is estimated at 773,409 tons [1]. In Indonesia, there are two varieties of coffee, namely Robusta, and Arabica. Indonesian coffee production was dominated by Robusta coffee as much as 72.66% in 2019 [1].

The chemical composition of Robusta coffee consisted of 0.9-4% sucrose; reducing sugar 0.4%; polysaccharides 48-55%; lignin 5%; pectin 2%; protein 10-11%; free amino acids 0.8-1%; caffeine from 1.5 to 2.5%; trigonelline 0.6-0.7%; fat 7-10%; diterpenes 0.2-0.8%; minerals 4.4-4.5%; chlorogenic acid 6.1-11.3%; 1% aliphatic acid; and quinic-acid 0.4% [2]. Coffee contains essential polyphenol elements such as chlorogenic acid, ferulic acid, caffeine, coumaric acid [3], and melanoidin [4]. The chlorogenic acid and caffeine are the secondary metabolites of coffee.

The caffeine content in coffee ranges from 1-4% (db) [5]. Robusta coffee is known to have higher caffeine compared to Arabica coffee [6]. Robusta bean coffee contains 1.5-2.5% caffeine, and after roasting, it becomes 2.4-2.5% [2]. Caffeine has beneficial effects, such as stimulating the central
nervous system, relaxation of smooth muscle, especially bronchial smooth muscle, and stimulation of the heart muscle. Consuming caffeine will make the body fresher and warmer for the people who have a high tolerance for caffeine. While for those having a low tolerance for caffeine, it will cause adverse effects, such as insomnia; worry; increased blood pressure; and heart rate that is too fast [7]. The majority of coffee drinkers in Indonesia have not realized the negative effect of caffeine. Therefore, it is necessary to make an effort to diversify the processed coffee products, which can be an alternative in consuming processed coffee drinks with lower caffeine content. Decaffeination reduces the total amount of caffeine in agricultural materials [8]. Decaffeination can be done with organic solvents, extraction with water, and supercritical carbon dioxide [5].

In this study, adding ginger extract as diversification of the coffee bean process was the method to decaffeinate and non-decaffeinated coffee drinks. Ginger contains the oleoresin, which consists of oxy methyl phenols such as gingerol, shogaol, and zingerone, as antioxidants [9]. The addition of ginger extract will enrich the flavor and functional properties by increasing antioxidant activity in coffee drinks. Coffee-ginger drink as a commercial functional drink is still not widely available. Therefore, this research was conducted to determine the effect of decaffeination treatment and the addition of ginger extract on antioxidant properties, characteristics and the level of panelists’ preference on coffee-ginger drink products.

2. Materials and methods

2.1. Materials and chemicals
This research’s main ingredient for the beverage was Robusta bean coffee obtained from Argopuro mountains, Jember, followed by sugar and large ginger obtained from traditional markets in Jember. The chemicals used were ethanol, methanol; distilled water; Follin-ciocalteu; Na₂CO₃; gallic acid, Trolox, and DPPH (2,2-diphenyl-1-picrylhydrazyl).

2.2. Tools
The tools used in coffee-ginger drinks production were a pot, oven, coffee roaster, grinder, knife, cutting board, filter, scale, grated coconut, measuring cup, beaker glass, and spatula. Analytical tools are vortex mixer VM-300, spectrophotometer UV-1800, micropipette, stirrer rod, centrifuge, centrifuge bottle, and glass tools.

2.3. Decaffeinated coffee beans preparation
The decaffeination of coffee beans was carried out using the water solvent [10]. Coffee beans were heated by steaming at 80°C for 4 hours, then boiled at 100°C with a volume of 5 times the coffee beans (1: 5, w / v) for 3 hours to dissolve the caffeine. The coffee beans dried at 100°C for 21 hours until produced decaffeinated coffee beans.

2.4. Coffee extraction
Decaffeinated and non-decaffeinated coffee beans were roasted at 180°C for 10 minutes. Grind roasted coffee using a grinder. One hundred grams of coffee powder was brewed using 300 ml of boiling water (1: 3, w / v) at a temperature of 80°C for 45 minutes and then stirred using a stirrer. The brewed coffee was filtered using a 100 mesh sieve to obtain coffee extract [11].

2.5. Ginger extraction
Fresh ginger rhizomes were peeled and washed. One hundred grams of unpeeled ginger was crushed by shredding and boiling water (T = 100°C) was added as much as 50 ml (1: 0.5, w / v). After that, the ginger solution was extracted for 15 minutes and deposited for 1-2 hours, then filtered to get the ginger extract.
2.6. Coffee-ginger drink preparation
The coffee-ginger drinks are made by mixing coffee extract from decaffeinated and non-decaffeinated coffee beans with ginger extract, sugar solution, and water. The formulation of ginger coffee drink was shown in Table 1.

| Coffee types | Formulas | Coffee extract (ml) | Ginger extract (ml) | Sugar solution (ml) | Water (ml) |
|--------------|----------|---------------------|---------------------|---------------------|------------|
| Non-decaffeinated Robusta coffee | N0 | 50 | - | 30 | 20 |
| | N1 | 50 | 20 | 30 | - |
| | N2 | 50 | 15 | 30 | 5 |
| | N3 | 50 | 10 | 30 | 10 |
| | N4 | 40 | 20 | 30 | 10 |
| | N5 | 40 | 15 | 30 | 15 |
| | N6 | 40 | 10 | 30 | 20 |
| Decaffeinated Robusta coffee | D0 | 50 | - | 30 | 20 |
| | D1 | 50 | 20 | 30 | - |
| | D2 | 50 | 15 | 30 | 5 |
| | D3 | 50 | 10 | 30 | 10 |
| | D4 | 40 | 20 | 30 | 10 |
| | D5 | 40 | 15 | 30 | 15 |
| | D6 | 40 | 10 | 30 | 20 |

2.7. Determination of total polyphenol content
The content of total polyphenol was determined using the Folin-Ciocalteau method [12]. Coffee-ginger drink (0.05 ml), distilled water (4.95 ml) and 0.5 ml of folin-ciocalteau solution (0.5 ml) were mixed in a test tube. Samples were vortexed and let stand for 5 minutes, and then 1 ml of Na₂CO₃ 7% was added to the solution. Samples were vortexed and left to stand for 60 minutes in dark conditions then read the absorbance value of the sample using a spectrophotometer (λ=765 nm). The total polyphenol content of coffee-ginger drink was obtained from data processing of absorbance values. The results were compared to standard curves that made from several series of gallic acid concentrations. The total polyphenol content was expressed as mg Gallic Acid Equivalent (GAE) / ml.

2.8. Determination of melanoidin brown pigment content
The melanoindin brown pigment was determined using spectrophotometer [13]. The coffee-ginger drink sample (0.5 ml) was diluted 13 times with water. The sample was then read the absorbance value using a spectrophotometer (λ=420 nm). The brown pigment content of melanoidin in coffee-ginger drinks was expressed as an absorbance value (AU).

2.9. Determination of antioxidant activity
The antioxidant activity was determined on the basis of ability of antioxidant compound to scavenge the stable radical DPPH, DPPH method [14]. Samples of coffee-ginger drink (0.05 ml), ethanol (2.95 ml), and 300 μM (3ml) of DPPH (2,2-diphenil-1-pichylhydazyl) solution were added to the test tube. The sample was vortexed and left to stand for 30 minutes, then read the absorbance value with a spectrophotometer (λ= 517 nm). The antioxidant activity of coffee-ginger drink was obtained from absorbance value data processing with equations obtained from standard curves made from several trolox concentration series. The antioxidant activity was expressed in units of mmol Trolox Equivalent (TE) / ml.

2.10. Sensory Analysis
The coffee extract, ginger extract, sugar solution, and water are heated and then poured into small glasses given a code, then presented for the hedonic sensory analysis with a total of 50 panelists.
Sensory analysis on coffee-ginger drinks was carried out on the attributes of color, aroma, taste, and overall on a scale of 1) very dislike, 2) dislike, 3) rather like, 4) like, and 5) very like.

3. Results and discussion

3.1. Total polyphenol content

The analysis of the total polyphenol content of decaffeinated and non-decaffeinated coffee-ginger drinks is presented in Table 2. The total polyphenol content in decaffeinated coffee-ginger drinks ranges from 0.61 to 0.77 mg GAE / ml, whereas non-decaffeinated coffee-ginger drinks ranged from 2.16 to 2.69 mg GAE / ml. Non-decaffeinated coffee-ginger drinks have a higher total polyphenol content than decaffeinated coffee-ginger drinks. The total polyphenol content decreased due to heating treatment in the decaffeination process. Hydrolysis of coffee beans occurred during heat treatment [15]. It results in the decomposition of chlorogenic acid compounds that are easily soluble in water. Chlorogenic acid is the most polyphenol compound in coffee, reaching 90% of the total phenol [16].

Higher additional ginger extract on coffee-ginger drinks increases in the total polyphenol content of the drink. Ginger contains polyphenolic compounds represented by flavonoids, gingerol, and shogaol compounds [17]. The total polyphenol content in coffee-ginger drinks with 50 ml coffee extract (N1, N2, N3, and D1, D2, D3) was higher than 40 ml of coffee extract (N4, N5, N6 and D4, D5, D6). Similarly, less in the addition of coffee extract resulted in a decrease in the total polyphenol content. It showed that coffee extract contributes to polyphenols content compare to ginger extract. The total polyphenol content in Robusta bean coffee is 915 mg GAE / g extract [18], while it was 181.41 mg GAE / g extract of ginger [17].

Table 2. Polyphenol and melanoidin brown pigment contents of coffee-ginger drink on various formulas

| Coffee types                      | Formulas | Total polyphenol (mg GAE / mL) | Melanoidin brown pigment (AU) |
|-----------------------------------|----------|--------------------------------|--------------------------------|
| Non-decaffeinated robusta coffee  | N0       | 2.61 ± 0.045                   | 1.17 ± 0.009                   |
|                                   | N1       | 2.69 ± 0.035                   | 1.31 ± 0.012                   |
|                                   | N2       | 2.67 ± 0.057                   | 1.27 ± 0.011                   |
|                                   | N3       | 2.62 ± 0.039                   | 1.23 ± 0.008                   |
|                                   | N4       | 2.27 ± 0.082                   | 1.05 ± 0.004                   |
|                                   | N5       | 2.18 ± 0.029                   | 1.03 ± 0.006                   |
|                                   | N6       | 2.16 ± 0.033                   | 1.02 ± 0.004                   |
| Decaffeinated robusta coffee      | D0       | 0.72 ± 0.023                   | 0.42 ± 0.012                   |
|                                   | D1       | 0.77 ± 0.010                   | 0.49 ± 0.008                   |
|                                   | D2       | 0.76 ± 0.008                   | 0.48 ± 0.011                   |
|                                   | D3       | 0.73 ± 0.006                   | 0.47 ± 0.005                   |
|                                   | D4       | 0.64 ± 0.023                   | 0.42 ± 0.004                   |
|                                   | D5       | 0.62 ± 0.016                   | 0.40 ± 0.005                   |
|                                   | D6       | 0.61 ± 0.009                   | 0.38 ± 0.007                   |

3.2. Total melanoidin brown pigment content

The analysis of melanoidin brown pigment content in decaffeinated coffee-ginger drinks showed an absorbance value varied from 0.38 to 0.49 AU; whereas non-decaffeinated coffee-ginger drinks ranged 1.02-1.31 AU. The results of the analysis of melanoidin brown pigment content were shown in Table 2. The absorbance value of decaffeinated coffee-ginger drinks was lower than non-decaffeinated coffee-ginger drinks. It was due to the organic compound precursor for brown pigments might degrade and dissolve in water during the decaffeination process, so that the precursor brown pigment is less than in non-decaffeinated coffee beans.
The additional ginger extract with several formulations can affect the melanoidin brown pigments in coffee-ginger drinks. The higher extra ginger extract acts on increasing the brown pigment content of melanoidin. It was the effect of enzymatic and non-enzymatic browning. Enzymatic browning begins with the oxidation of phenol by polyphenol oxidase to quinone with two types of reactions: monophenol hydroxylation to O-diphenol and oxidation O-diphenol to quinones [19]. Non-enzymatic browning occurs due to the maillard reaction. In this research, the Maillard reaction might be caused by two melanoidin pigment precursor compounds in ginger (1.82% protein and 17.77% carbohydrates) [20].

The melanoidin brown pigment content of coffee-ginger drinks with 50 ml coffee extract (N1, N2, N3 and D1, D2, D3) was higher than the addition of 40 ml of coffee extract (N4, N5, N6 and D4, D5, D6). The decrease in the additional coffee extract resulted in a reduction of the content of melanoidin brown pigment. It shows that coffee extract contains more melanoidin brown pigment than ginger extract. Robusta bean coffee contains precursor compounds of melanoidin pigments such as protein and free amino acids of 10.8-12% and carbohydrates (sucrose, reducing sugars, polysaccharides, lignin, and pectin) of 54.3-64.4% [2]. These precursor compounds will experience a Maillard reaction when exposed to heat to form melanoidin [21]. Twenty-five percent of melanoidin occurred after roasting in Robusta coffee beans [2].

3.3. Antioxidant activity
The analysis of the antioxidant activity of decaffeinated and non-decaffeinated coffee-ginger drinks is presented in Figure 1. The values of antioxidant activity in decaffeinated coffee-ginger drinks ranged from 0.06 to 0.17 mmol TE / ml, whereas in the non-decaffeinated coffee-ginger drink, it was 0.28-0.43 mmol TE / ml. Decaffeinated coffee-ginger drinks have lower antioxidant activity values than non-decaffeinated coffee-ginger drinks. It happens because heating during the decaffeination process results in releasing several phenolic compounds in the coffee beans. Chlorogenic acid is the dominant phenolic compound in beans. The content of chlorogenic acid in coffee serves as a source of antioxidants [2].

![Figure 1. Antioxidant activity of coffee-ginger drink on various formulas](image)

The addition of higher ginger extract results in increased antioxidant activity in coffee-ginger drinks. It shows that ginger can influence antioxidant activity in coffee-ginger drink. The antioxidant compounds in ginger, such as gingerol and shogaol could ward off strong free radicals in vitro [17].

The value of antioxidant activity in coffee-ginger drinks with 50 ml coffee extract (N1, N2, N3 and D1, D2, D3) was higher than the addition of 40 ml of coffee extract (N4, N5, N6 and D4, D5, D6).
The addition of less and less coffee extract resulted in a decrease in the value of antioxidant activity in coffee-ginger drinks. It indicated that coffee has a higher antioxidant compound than ginger. Coffee contains many antioxidant compounds, including chlorogenic acid, flavonoids, melanoidin, furans, pyrrole, and maltol [22].

The highest value of antioxidant activity in coffee-ginger drinks found in non-decaffeinated coffee beans with ratio the coffee: ginger formulation (50 ml: 20ml, N1), which is 0.43 mmol TE/ml. The analysis of the value of antioxidant activity in these drinks correlated positively with the study of total polyphenols and melanoidin brown pigments. The total polyphenol content and melanoidin brown pigment in the drink also showed the highest values, 2.69 mg GAE / ml, and 1.31 AU, respectively. Polyphenols are powerful antioxidants in coffee [23]. The higher the total polyphenol content, the higher the resulting antioxidant activity [24]. Melanoidin content contributed to antioxidant activity. Melanoidin, which is formed during the roasting process, was 25% (db) and significantly showed antioxidant activity [25].

3.4. Sensory preference

3.4.1. Color. The results of the coffee-ginger drink color preference assessment were presented in Table 3. The coffee-ginger drink color preference's average value ranges from 2.82 to 3.50 (dislike to rather). The highest value (3.50) was obtained by the coffee-ginger drink made from non-decaffeinated coffee beans with the coffee: ginger formulation (40 ml: 10 ml, N6). Coffee-ginger drinks made from decaffeinated coffee beans had a lower average color preference value than ginger-coffee drinks made from non-decaffeinated coffee beans. Decaffeinated ginger coffee drinks have a lighter color due to lower melanoidin brown pigment. Maillard reaction between free amino acids and reducing sugars formed melanoidin [21]. The organic compound precursor for brown pigment might degrade and dissolve in water during the decaffeination process, so the brown pigment precursor is less than in non-decaffeinated coffee beans. In the decaffeination process, the caffeine content and other compounds in coffee beans dissolve easily. Hence, it affects less brown pigment precursors than non-decaffeinated coffee beans [26].

3.4.2. Flavor. The value of preference for the flavor of coffee-ginger drinks ranged from 3.2-3.36. The results of the assessment of the coffee-ginger flavor preference can be seen in Table 3. The most preferred coffee-ginger drink was the coffee formulation: ginger (50 ml: 10 ml, N3) made from non-decaffeinated coffee beans with a value of 3.34; however, these results were still lower than the coffee formulation: ginger (50 ml: 0 ml, N0). The coffee-ginger drink formulated N3 had the right flavor between coffee and ginger. The flavor of coffee-ginger brewing process arose from the evaporation of volatile compounds from coffee and ginger spices captured by the human sense of taste (smell). The flavor of coffee-ginger drinks was also influenced by the amount of ginger added. The flavor characteristics of ginger come from a mixture of zingerone, shogaol, and essential oils with a range of 1-3% in fresh ginger [27].

Non-decaffeinated coffee-ginger drinks had a higher average value than decaffeinated coffee-ginger drinks. According to the panelists, the non-decaffeinated coffee-ginger drink had a flavor like herbs, while the decaffeinated coffee-ginger drink had a natural flavor of the coffee. The decaffeination process causes trigonelline compounds and other flavor precursor compounds to evaporate or dissolve during heating easily. Volatile compounds that affect coffee's flavor include aldehyde, ketone, and alcohol class compounds, while non-volatile compounds including chlorogenic acid, sugar, and trigonelline. When there is an increase in temperature, the volatile compounds will quickly evaporate [28].
Table 3. Hedonic sensory properties of coffee-ginger drink on various formulas

| Coffee types         | Formulas | Color | Flavor | Taste | Overall |
|----------------------|----------|-------|--------|-------|---------|
| Non-decaffeinated    | N0       | 3.50  | 3.36   | 3.16  | 3.42    |
|                      | N1       | 3.20  | 3.30   | 3.28  | 3.30    |
|                      | N2       | 3.14  | 3.32   | 2.96  | 3.16    |
|                      | N3       | 3.38  | 3.34   | 3.08  | 3.10    |
|                      | N4       | 3.30  | 3.30   | 3.12  | 3.24    |
|                      | N5       | 3.30  | 3.28   | 3.34  | 3.36    |
|                      | N6       | 3.50  | 3.32   | 3.38  | 3.50    |
| Decaffeinated        | D0       | 3.24  | 3.26   | 3.00  | 3.18    |
|                      | D1       | 3.08  | 3.24   | 2.58  | 2.78    |
|                      | D2       | 2.98  | 3.24   | 2.62  | 2.80    |
|                      | D3       | 3.08  | 3.26   | 2.76  | 2.92    |
|                      | D4       | 2.82  | 3.20   | 2.68  | 3.02    |
|                      | D5       | 3.02  | 3.20   | 2.90  | 3.10    |
|                      | D6       | 2.96  | 3.24   | 2.96  | 3.26    |

3.4.3. Taste. The results of the sensory test assessment of the taste of coffee-ginger drinks ranged from 2.58 to 3.38 (dislike - rather like). The average value of taste preference in ginger coffee drinks was shown in Table 3. The coffee-ginger drink with the highest taste preference value was the coffee: ginger formulation (40 ml: 10 ml, N6) made from non-decaffeinated coffee beans (3.38). Decaffeinated coffee-ginger drinks had an average lower taste preference value than non-decaffeinated coffee-ginger drinks. In the decaffeination process, there is a dissolution of compounds that play a role in taste, caffeine. Caffeine contributes between 10-30% of the bitter taste of brewed coffee. The bitterness value tends to decrease with the more prolonged the decaffeination process and the higher the temperature of the solvent used [8]. The decaffeination process resulted in a reduction in several flavors of coffee, which tended to be more bitter [5].

The addition of ginger extract also affects the taste of the drink. The oleoresin content in ginger gives a spicy taste. By adding more ginger extract, it will increase the pungent taste of the ginger coffee drink. Ginger's spicy taste is due to the presence of non-volatile phenylpropanoid compound derivatives such as gingerol and shogaol. Meanwhile, zingerone has a lower pungent taste and gives a sweet taste [27].

3.4.4. Overall. The results of the average value of the favorite of all drinks are presented in Table 3. Based on the results, the most preferred coffee-ginger drink was the coffee: ginger formulation (40 ml: 10 ml, N6) made from non-caffeinated coffee beans with an average value of 3.50. Panelists prefer non-decaffeinated coffee-ginger drinks due to the panelists' taste, which tends to select bitter and less pungent ginger flavor. The coffee-ginger drink decaffeinated with the highest ginger extract (D1) had the lowest preference value because less bitter and too strong of pungent ginger flavor.

4. Conclusion
Decaffeinated coffee-ginger drinks have a lower total content of polyphenols, melanoidin brown pigment, and antioxidant activity than non-decaffeinated coffee-ginger drinks. The addition of more ginger extract resulted in an increased total polyphenol content, melanoidin chocolate pigment, and antioxidant activity in the product. The ratio non-decaffeinated coffee: ginger; 50 ml: 20 ml, has the highest total polyphenol content, melanoidin brown pigment, and antioxidant activity. The most preferable coffee-ginger drink was found in formulas with ratio non-decaffeinated coffee: ginger 40 ml: 10 ml.
References

[1] Direktorat Jenderal Perkebunan (Dirjen Perkebunan) 2019 *Statistik Perkebunan Indonesia: Kopi Tahun 2018-2020* (Jakarta: Kementerian Pertanian)

[2] Farhaty N, dan Muchtaridi 2017 *Jurnal Farmaka* 14 214–227

[3] Hecimovic I, Cvitanovic A B, Horzic D and Komes D 2011 *Food Chemistry* 129 991–1000

[4] Yashin A, Yashin Y, Wang J Y and Nemzer B 2013 *Journal Antioxidants* 2 230–245

[5] Butter M S, Ahmeda A, Sultan M T, Imran A, Yasin M and Imran M 2011 *Inter. Journal of Food Safety* 13 198–207

[6] Erdiansyah N P and Yusianto 2012 *Jurnal Pelita Perkebunan* 28 184–200

[7] Yashin A, Yashin Y, Wang J Y and Nemzer B 2013 *Journal Antioxidants* 2 230–245

[8] Widyowati E 2010 *Evaluasi Mutu Kimia Kopi Dekaf-Inul Instan Berbahan Baku Biji Kopi Hasil Dekafeinasi Berbagai Pelarut Skripsi* (Jember: Universitas Jember)

[9] Nwaoha I E M, Okafor G I and Apochi O V 2013 *African Journal of Microbiology Research* 7(42) 4981–4989

[10] Slinkard K, and Singleton V L 1977 *American Journal of Enology and Viticulture* 28 49–55

[11] Bartel C, Mesias M and Morales F J 2015 *Food Research International* 67 356–365

[12] Yamaguchi T, Takamura H, Mahtoba T and Terao J 1998 *Bioscience Biotechnology Biochemistry* 62 1201–1204

[13] Kuncoro S, Sutiarso L, Nugroho J and Masithoh R E 2018 *Jurnal Agritech* 38 105–111

[14] Wigati E I, Pratiwi E, Nissa T F and Utami N F 2018 *Fitofarmaka Jurnal Ilmiah Farmasi* 8 59–66

[15] Mošovská S, Nováková D and Kaliňák M 2015 *Acta Chimica Slovaca* 8 115–119

[16] United States Department of Agriculture (USDA) 2020 *Food Composition Databases: Ginger Root, Raw* https://ndb.nal.usda.gov/fdc-app.html#/food-details/169231/nutrients [Diakses pada tanggal 6 Oktober 2020]

[17] Toledo R T 1999 *Fundamental of Food Process Engineering, 2nd Edition* (Maryland: Aspen Publisher Inc)

[18] Putri A R, Poku M S, Yani S and Wiyani L 2016 *Journal of Chemical Process Engineering* 13 1–9