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Study on the effect of roasting temperature on antioxidant activity of early-roasted Java coffee powder (Arabica and Robusta)

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Abstract. The current consumer trend on seeking more health benefits of coffee consumption, mainly due to polyphenols content has led to the increasing popularity of green coffee beans extract or green coffee products. These products include green (raw-unprocessed) coffee powder, which is directly brewed and/or consumed. There is a safety concern in relation to consumption of raw-unprocessed coffee. Meanwhile, high temperature roasting may have influence on the functional properties of coffee, particularly its polyphenols. The objective of this research is to study the effect of roasting temperature at the early roasting stage (95°C, 125°C, and 165°C) on the antioxidant activity of two coffee species, i.e. Java Arabica and Java Robusta. The non-roasted coffees were evaluated for comparison. The IC_{50} and total phenol were analysed in triplicates. The results showed that Arabica and Robusta coffee powders were significantly differ on the antioxidant activity, where Robusta showed the highest activity as compared to Arabica. The application of heating on coffee beans during roasting tends to decrease antioxidant activity. However, there was a fluctuation where antioxidant activity of coffee reached a peak at early roasting temperature of 95°C.

1. Introduction

From farm to cup, coffee experienced several processing steps that influence the quality of the finished products [1]. After harvesting, coffee fruits (cherries) are generally processed into green coffee beans that will be further processed prior to consumption. A very popular process is roasting, where green coffee beans are transformed into roasted version that is rich in flavour. However, roasting causes a significant decrease in phenolic compounds of coffee beans due to the application of high temperature heating [2].

The currently increasing popular coffee-based product includes green (raw-unprocessed) coffee powder, which is directly brewed and/or consumed. The green coffee is not roasted, and therefore it has high antioxidant content, mainly due to its phenolic compounds such as chlorogenic acid [1]. Some of reported benefits of green coffee for health are reducing obesity, preventing diabetes, heart disease and anticancer [2].

While the consumption of green coffee extracts or in form of green coffee capsules had been advertised as offering many health benefits, there is a limited research publication and information on the direct consumption/brew of green coffee beans powder. However, there is a safety concern in

relation to production and consumption of raw-unprocessed coffee beans. One reason is that it might get contaminated by mould during improper handling, processing, packaging and storage, and therefore may contain toxic produce by those moulds such as ochratoxin A (OTA) produced by *Aspergillus sp*. [3,4]. Besides producing less pleasant aroma, the absence of heating also may have effect on less destruction of the initial ochratoxins [4]. However, high temperature roasting at above 200°C had changed coffee physical, chemical and sensory characteristics. High temperature may have significant influence on the functional properties of coffee, particularly its polyphenols. While there were many scientific publications on the polyphenols of roasted coffee and high temperature roasting effect on coffee, there were limited research, to the author knowledge, on the changes occur at the early roasting stage. Therefore, this research is conducted to address those gaps.

The objective of this research is to study the effect of roasting temperature at the early roasting stage of heating temperature (95°C, 125°C, and 165°C) on the antioxidant activity of two coffee species, i.e. Java Arabica and Java Robusta. The non-roasted coffees were evaluated for comparison. The results will give important information for further development of early roasted coffee beans, or an intermediate product in-between green and roasted coffee with optimum functional properties.
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2. Materials and Methods

2.1. Materials

Green coffee beans (3 kg) used in this research were Java Arabica and Java Robusta coffee cultivated on Arjuno Mountain, UB Forest Malang, East Java, harvested in 2017. Both coffee beans were processed by local farmers following full-wash method and the green coffee beans were collected for this research. Chemicals used includes those were obtained from Sigma-Aldrich i.e. gallic acid standard, Folin Ciocalteu reagent, 1,1-diphenyl-2-pycrillhydrazyl radical, 2,2-diphenyl-1-(2,4,6-trinitrophenyl)hydrazyl, DPPH, PDA media, peptone water, and those are purchased from Merck i.e Na_2CO_3 anhydrous, methanol pa.(Merck). Sterile aquadest was purchased from local company, PT. Ikapharmindo, Jakarta, Indonesia.

2.2. Methods

There were two factors being investigated in this research. The first factor was two different coffee species (Java Arabica and Java Robusta) while the second factor, nested to the first factor, was coffee roasting treatment consisting non-roasting (the raw green coffee beans were not roasted) and coffee roasting temperature at the early stage (95°C, 125°C, and 165°C) for 15 minutes. Roasting was performed by professionals at the local coffee roastery. Samples were sealed in laminates pouch and stored at approximately -18°C prior to analysis.

Proximate analysis was performed following AOAC standards [5] for the raw coffee beans (non-roasted) to get information on initial properties. For the analysis of chemical characteristics, the frozen coffee beans were directly ground into powder. Moisture content was analyzed based on gravimetric method II using vacuum oven. Fat content was analyzed using soxhlet extraction method, protein was analysed using kjeldahl digestion method, ash content was determined based on dry method, while carbohydrate was calculated by difference [5]. For all samples, Colour (CIE L*a*b*) was measured using CR 310 photometer (Konica Minolta Imaging, Dietikon, Switzerland). Total phenols was analyzed using colorimetric method using gallic acid standards [6] as also previously used for spent ground coffee analysis [7], while antioxidant activity (IC_{50}) was measured based on Molyneux [8]. Total plate count was performed following the method modified by Maturin and Peeler [9].

Data was collected and tabulated in Microsoft Excel 2013. Analysis of Variance (ANOVA) and post-hoc analysis (Fisher's Least Significance Difference Test) at 95% confidence interval were performed using Minitab 17 Statistical Software (Minitab Inc., State College, Pennsylvania, USA).
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3. Results and Discussion

Arabica and Robusta green coffee beans were treated similarly, heated at the early roasting stage, temperature of 95°C, 125°C, and 165°C. The resulting coffee beans (samples) and the raw-unroasted

coffee beans were evaluated. Initially, the green coffee beans compositions were analysed as the background information. The results of proximate analysis can be seen in Table 1.

Paired *t*-test on the two coffee samples showed that Arabica and green Robusta coffee samples were not differ significantly on its proximate properties (α=0,05). However, green Robusta coffee was found to have less ash, less fat, and more protein than the Arabica. Considering those coffee were in different species that is commonly different in the chemical characteristics, it is expected that the coffee showed almost similar basic chemical properties since both were cultivated in the same location, i.e. the slopes of Arjuno mountain, UB Forrest, with the same environmental influence including climate, soil, etc. The difference between these two species could be potentially observed more on the non-proximate and physical properties.

Table 1. Proximate data of green arabica and robusta coffee beans.

Parameter	Arabica		Robusta	
	Current Analysis	Literature [13,14]	Current Analysis	Literature [13,14]
Water content (%)	12.04	8-13	12.17	12-13
Ash (%)	5.09	4-5	4.63	4-5
Protein (%)	9.48	11-17	10.39	11-13
Crude fat (%)	13.39	9-18	12.98	9-13
Carbohydrate	60.00	60-76	60.20	69-76

Notes: 1) Data mean of duplicate measurements

2) Ash, protein, and crude fat represented in % dry matter

Those green coffee beans were further roasted under different early roasting temperature (95°C, 125°C, and 165°C). All samples including the unroasted beans were evaluated for their colour to know differences based on species and treatment applied (roasting). Colour measurement was performed based on CIE L*a*b* colour space. The L* value shows the lightness, while a* and b* provides coordinates for red/green and yellow/blue, respectively. The results were presented in Table 2.

Table 2. Colour of arabica and robusta coffee samples, unroasted and roasted at early roasting stage.

Coffee species	Early roasting stage temperature (°C)	L*	a*	b*
Arabica	No-roasting	50.00 ± 0.10 d	-0.30 ± 0.00 c	11.13 ± 0.15 d
	95°C	53.10 ± 0.10 c	0.60 ± 0.00 b	13.86 ± 0.32 c
	125°C	54.80 ± 0.26 b	0.60 ± 0.00 b	15.63 ± 0.31 b
	165°C	55.66 ± 0.47 a	4.20 ± 0.20 a	20.33 ± 0.15 a
Robusta	No-roasting	48.17 ± 0.29 d	0.80 ± 0.10 c	11.13 ± 0.15 d
	95°C	50.10 ± 0.26 c	0.86 ± 0.15 c	13.30 ± 0.40 c
	125°C	51.67 ± 0.12 b	1.06 ± 0.06 b	14.10 ± 0.69 b
	165°C	52.73 ± 0.40 a	1.33 ± 0.06 a	15.56 ± 0.15 a

Notes: 1) Data mean ± standard deviation (n=3)

2) Data followed by different notation showed significant difference (α=0.05)

Based on Table 2, it can be seen that Arabica coffee samples was significantly different (α=0.05) from Robusta in terms of colours measured as L*, a*, and b*. Arabica coffee samples was found to be lighter with more yellowish-green colour as compared to the Robusta counterpart. The application of heating or early roasting temperature seemed to increase lightness (L* value) while also increasing redness (a*) and yellowness (b*) values. Significant different (α=0.05) was observed amongst treatments. This result indicated that heating, even though at a lower roasting temperature or early roasting temperature, may change coffee physical appearance. Along the roasting process, green

coffee beans undergo sequential transformation due to some reactions that change its chemical compositions and thus changing its physical and sensory properties. The initial process had been explained by Fiore [10] due to water evaporation and the loss of bean's cuticles resulting in the lighter beans colour. The following process was related to non-enzymatic browning reaction such as caramelization and Maillard.

The chemical reaction involved simple sugars, amino acids, and high temperature. Continuous heating would bring green coffee beans into the yellow stage and further into reddish-brown. Arabica coffee beans tend to show more yellow-reddish colour than Robusta potentially due to more sugar content it has. It has been reported that Arabica coffee contained sucrose of 6-9 g/100 g while Robusta coffee had only 0.9-4 g/100 g [2]. The more sugar content could mean potentially more Maillard reaction occurred since sugar is one important substrate for this reaction. Maillard would produce brownish pigments or intermediate products including melanoidins [11].

Further investigation was carried out to know the effect of species difference and early roasting temperature on the total phenols and antioxidant activity of coffee samples. Total phenols was expressed as milligrams Gallic acid equivalent (GAE) per gram while antioxidant activity was presented as IC_{50}, which is the inhibition concentration of antioxidant to 50% of initial DPPH radical concentration. The total phenols and IC_{50} of the coffee samples were given in Table 3.

Table 3. Total phenols and IC_{50} of Arabica and Robusta coffee samples, unroasted and roasted at early roasting stage.

Coffee species	Early roasting stage temperature (°C)	Total Phenols (mg GAE/g)	IC_{50} (ppm)
Arabika	No-roasting	52.04 ± 2.07 b	122.33 ± 5.00 bc
	95°C	56.85 ± 2.51 a	112.49 ± 10.46 c
	125°C	43.86 ± 1.59 c	134.72 ± 12.26 ab
	165°C	41.27 ± 2.87 c	149.12 ± 13.04 a
Robusta	No-roasting	68.72 ± 3.30 b	110.32 ± 12.03 b
	95°C	75.14 ± 1.34 a	85.60 ± 9.00 c
	125°C	67.24 ± 2.04 b	112.24 ± 10.99 b
	165°C	59.93 ± 0.98 c	125.19 ± 10.00 ab

Notes: 1) GAE is Gallic acid equivalent
2) Data mean ± standard deviation (n=3)
3) Data followed by different notation showed significant difference (α=0.05)

Table 3 indicated that Robusta coffee contains higher concentration of total phenols than the Arabica. Total phenols was increased at the initial heating process (95°C) on the early roasting stage, before experiencing a further decrease on the next higher early roasting temperature (125°C and 165°C). In contrast, Robusta coffee showed a lower IC_{50} value than the Arabica. The low IC_{50} means that less concentration of antioxidant required to inhibit 50% of DPPH radical, or it might refer to higher antioxidant activity. Robusta coffee was found to have higher antioxidant activity than Arabica probably due to its higher phenolic (antioxidant) contents. Early roasting temperature at 95°C was found to reduce IC_{50} value of coffee sample, which means increasing its antioxidant activity. The reason was probably due to the degradation of coffee components or the occurrence of chemical reaction induced by heating that increases availability or releases the antioxidant compounds. Priftis [12] had also stated that some compounds synthesized during roasting such as melanoidins might contribute to the increase in coffee's antioxidant activity. However, further heating or the use of higher temperature had decreased antioxidant activity due to compositional degradation and other reactions such as phenolic compounds degradation and its bond with protein that inhibit ability to react with free radicals, as that of reported by previous study [13].

The Pearson Correlation analysis showed that total phenols and IC_{50} has a negative correlation (r= -0.79). Coffee beans contain high polyphenols and amongst all coffee polyphenols, chlorogenic acids

were the most popular [14]. Chlorogenic acids are a family of esters formed between certain trans-cinnamic acids and quinic acid [14]. This potential antioxidant is one of the most abundant polyphenols found in plant and plant-based foods. However, coffee is recognised as one of the richest chlorogenic acids source in the human diet compared to other beverages [14].

During the process of roasting, chlorogenic acid might play a role in the formation of polymeric materials such as melanoidins through condensation [11]. Melanoidins has been confirmed to have strong antioxidant properties [11]. While coffee phenolic compounds was mostly contributed to antioxidative properties of coffee, there were also another contributors to consider such as kahweol and cafestol [15]. Those diterpenes were widely found in coffee beans, had the potential as an antioxidant and is resistant to high temperatures [15].

Besides physical and chemical analysis, the coffee samples were evaluated for their microbiological properties. The results showed that the unroasted Arabica coffee (green coffee beans) contains 4.21 log CFU/g microbes while Robusta has 4.19 log CFU/g. The final microbial content after early roasting stage at 165°C for 15 minutes was 2.43 log CFU/g and 2.82 log CFU/g for Arabica and Robusta, respectively. The application of heating at the early roasting stage was able to significantly reduce the microbial content for at least ±1 log CFU/g to the acceptable level based on Indonesian National Standard, SNI 0-3542-2004 for roasted coffee powder. However, further toxin identification and toxicology study would need to be carried out to ensure product safety since reduction of microbial content is the effort to minimize the risk of microbial growth but might not reduce or eliminate toxic compounds that already present.

4. Conclusion

In conclusion, early-roasted Arabica and Robusta coffee differs in their physical as well as chemical characteristics. More importantly, Robusta coffee contains higher phenols and thus shows lower IC_{50} that means higher antioxidant activity as compared to the Arabica counterpart. Heating at the early roasting stage tend to decrease antioxidant activity. However, there was a fluctuation where antioxidant activity of coffee reached a peak at early roasting temperature of 95°C before a further decline at higher roasting temperature. The low temperature roasting was found to be able to reduce microbial content to the acceptable level and reduce the risk of microbial growth during storage and distribution of coffee beans. However, should the product will be commercialize, it would need a proper packaging and handling after low temperature roasting in order to prevent contamination from the environment. Moreover, toxicology research will be beneficial to ensure that the early-roasted coffee beans are safe to be consumed. Therefore, further research might focus on this area such as in reducing acrylamide production during roasting.

Acknowledgments

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