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Effect of Superheated Steam Roasting on Radical Scavenging Activity and Phenolic Content of Robusta Coffee Beans

Ooi Ee Shan[#], Wahidu Zzaman[#,*], Tajul A. Yang[#,1]

[#] *Food Technology Division, School of Industrial Technology, Universiti Sains Malaysia, 11800 Pulau Pinang, Malaysia.*
E-mail: [1]taris@usm.my

**Food Engineering and Tea Technology, Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh.*
E-mail: wahidanft@yahoo.com

***Abstract*— Robusta coffee is one of the coffee species grown in Malaysia. However, there is little research conducted on Robusta coffee beans as Arabica coffee is more popular among the consumers. Coffee is a rich source of antioxidants, therefore research on antioxidant properties of Robusta coffee beans is important to explore its market value. Nowadays, most of coffee analysis is on conventional roasted coffee which reduces their antioxidant properties. In this study, Robusta coffee beans (Coffea canephora) were subjected to superheated steam roasting at 200, 220 and 240 ˚C for 20-40 min to obtain light, medium and dark roast. The effect of different roasting temperature and time on the total phenolic content (TPC) and radical scavenging activity (RSA) of Robusta coffee bean was investigated. Total phenolic content of coffee brews decreased with the increase of roasting degree due to the degradation of phenolic compounds. The highest phenolic content was found at 220 ˚C for 20 min. Meanwhile, brews extracted from light roasted coffee and medium roasted at 220 ˚C for 20 min showed a maximum scavenging activity than those from green coffee. Brews from dark roasted coffee showed lowest radical scavenging activity and total phenol content. Hence, based on the results from this study, the best superheated steam roasting condition is at 220 ˚C for 20 min (medium roast) to achieve a maximum antioxidant activity and highest phenolic content.**

***Keywords*— Superheated steam roasting; Total phenolic content; Radical scavenging activity; Robusta coffee**

I. INTRODUCTION

Demand for better quality coffee beverage is growing rapidly. Recently, different coffee origins are being sourced and new preparation methods are being devised. Coffee, prepared from the roasted coffee beans, is one of the most widely consumed beverages in the world for their physiological effects and attractive aroma and taste [34]. The green beans are, in fact, characterized by a flavourless, green-earthy aroma and exhibiting exceptional hardness due to the thick cell walls and lack of intracellular spaces, which impede them to be used as food. All the chemical, physical, structural and sensorial properties of green beans are changed remarkably by the intense thermal treatment of roasting, which include thermal degradation of natural phenolic antioxidants and generation of the flavour compounds [2]. Hence, the pleasant flavour of coffee originates from the roasting process, where the sensation of bitter quality and volatile aroma compounds are formed [37].

In recent years, there has been much interest in the health-enhancing roles of specific foods or physiologically functional foods [17]. Great attention has been paid to those foods that have the potential to exert its antioxidant activity. Antioxidants are substances which inhibit or delay oxidation of a substrate although present in minute amounts [13]. It can quench reactive oxygen species (ROS), such as free radicals, prevent the oxidation of other molecules and therefore, have health promoting effects in the diseases prevention [27], [14]. Scientific studies showed that moderate coffee consumption has health-promoting effect. Coffee contains rich source of compounds possessing antioxidant and radical scavenging activities [10], [32].

Coffee stands out for its antioxidant potential compared to other beverages and this may be due to its high content of polyphenols that contributes to its strong antioxidant activity [10]. Green coffee beans contain several polyphenolic antioxidants, such as chlorogenic acid, caffeic acid, ferulic acid and n-coumarinic acid [8]. The concentration of highly active polyphenols in green bean is influenced by the species and its origin [10], whereas in coffee beverages it is mostly dependent on the roasting conditions, much more than the brewing methods and source of coffee beans [36], [16]. The major antioxidant compounds in coffee is the polyphenol chlorogenic acid. Chlorogenic acids mainly include

caffeoylquinic acids (CQA), dicaffeoylquinic acids (diCQA), and feruloylquinic acids (FQA) [19]. They are phenolic compounds formed by esterification of hydroxycinnamic acids, such as caffeic acid, ferulic acid and p-coumaric acid with quinic acid [23], [4]. Chlorogenic acids give astringency, bitterness and final acidity to the coffee brew. Chlorogenic acids are responsible for the bitterness of coffee due to release of caffeic acid as well as formation of lactones and phenolic derivatives during roasting [3]. Furthermore, it gives the roasted coffee flavor which determines the final coffee brew quality [5].

The impact of roasting on antioxidant activity of coffee brew has been studied by many researchers but the results are largely inconsistent. Some studies reported that higher roasting degree will increase the antioxidant activity of the coffee brew while others found that there is a progressive reduction in antioxidant activity at higher roasting degree. For example, [17] reported that during intense heat treatment of coffee, the antioxidant activity was found to be reduced by the formation of Maillard reaction products (MRPs). The overall antioxidant capacity of roasted coffee may be enhanced or maintained as the development of Maillard reaction during roasting seems to play a counter balancing role in the thermal degradation of naturally occurring phenolic compounds. In contrast, [10] reported that antioxidant activity increased up to the medium roasting degree but decreased at higher (dark) roasting degree.

Thus, the antioxidant activity of coffee brew is greatly influenced by the roasting process. In this study, the superheated steam roasting process will be introduced and its roasting condition on antioxidant activity of green and roasted coffee will be evaluated. During roasting, coffee beans are roasted at 200 – 240 °C depending on the degree of roasting (light, medium and dark roasted coffee). No experimental research has been performed in this area.

II. Material and Methods

A. Sample Collection

Robusta (Coffea canephora) green coffee beans were obtained from local Hang Tuah Coffee factory, Tasek Gelugor Seberang Prai, Malaysia. The beans were then subjected to selection processes manually at the laboratory of the Food Technology in the School of Industrial Technology of Universiti Sains Malaysia (USM). The defective beans (black, partly black, broken, infested) were discarded.

B. Roasting

A superheated steam oven (Healsio, AV-1500V, SHARP, Japan) with the superheated steam roast mode was used to roast all the coffee samples. The oven was preheated to the roasting temperature before roast. Bean (100 g) was roasted separately at the roasting temperature of 200 (light), 220 (medium), 240 °C (dark) for 20 to 40 minutes. The roasted beans were each ground into fine powder using a laboratory grinder and fractions of each were stored in the air-tight container for subsequent analyses.

C. Preparation of Coffee Brews

Ground coffee was prepared by solid-liquid extraction with distilled water. The ground coffee (1 g) was mixed with 50 ml of boiling distilled water and extracted for 15 minutes. After being cooled down to room temperature, the coffee brew was then centrifuged at 3500 rpm for 5 minutes. The supernatant layer was used for analysis. All analyses were performed with freshly prepared coffee brews.

D. Determination of Total Phenolic Content

A spectrophotometric method [33] with slightly modifications was adopted for the determination of total polyphenols in the prepared coffee brews. Folin-ciocalteu reagent was used and a standard calibration curve was prepared using different concentrations of Gallic acid (0.5 – 0.1 $mg.ml^{-1}$). A volume of 1 ml of coffee brews was mixed with 10 ml of 10 % Folin-Ciocalteu (FC) reagent and 10 ml of 7 % sodium carbonate (Na_2CO_3) solution. Then, 4 ml of distilled water was added up to a final volume of 25 ml. Solutions were maintained in dark, at room temperature for 90 minutes and total polyphenol content was determined at 750 nm using UV-Vis 1240 Shimadzu spectrophotometer. The total phenolic content was calculated as Gallic acid equivalent (GAE) by the following equation: $T = C \times V/M$. T is the total phenolic content in $mg.g^{-1}$ of the coffee brew as GAE, C is the concentration of Gallic acid established from the calibration curve in $mg.g^{-1}$, V is the volume of the extract solution in ml and M is the weight of the extract in g [38].

E. Determination of Antioxidant Activity by DPPH-Scavenging Assay

The free radical scavenging activity of the coffee brew was investigated using 1, 1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging according to the method of [15] with slight modification. Briefly, the sample contained 0.1 ml of coffee brew and 3.9 ml of DPPH solution (5 mg per 100 ml of methanol). A_{517} was measured immediately after the mixture was prepared. The control sample contained 3.9 ml of DPPH solution and 0.1 ml of water. The activity in DPPH scavenging was expressed as a percentage and calculated from the following equation:

$$\% \text{ Inhibition} = \frac{A_{control} - A_{sample}}{A_{control}} \times 100 \qquad (1)$$

F. Statistical Analysis

All measurements and analyses were carried out in triplicate. The results were analyzed statistically using two way analysis of variance method (ANOVA) to determine the effect of temperature and time on these responses. The ANOVA tests were performed using SPSS 13.0 (SPSS Inc., Chicago, IL, USA).

III. Results and Discussion

A. Total Phenolic Content

Coffee is a beverage that is rich in antioxidant compounds which are usually in the phenolic form [20], [11]. Phenolic compounds are the main class of natural antioxidants present in plants and make a significant contribution to the total water-soluble antioxidant activity [11], [7]. The phenolic content of Robusta coffee beans were extracted with hot water in order to determine the amount of polyphenol

content present in coffee brew as prepared by consumers. Folin-Ciocalteu method was used to assess the amount of phenolic compounds present in Robusta coffee and results were expressed as Gallic acid equivalents.

In general, a decreased in phenolic content was observed when the roasting temperature-time increased is shown in Figure 1. These results are in accordance with the study conducted by [22], which have shown that the total phenolic content of coffee brews decreased with the increase of roasting degree, at all temperature. Changes in the antioxidative capacity of coffee are related to the chlorogenic acids (CGAs) that present in green coffee bean. CGAs are the major source of antioxidant capacity in green coffee beans [30], [6]. Roasted beans contain less phenolic content than green beans as chlorogenic acid present in the green coffee was degraded upon roasting [24].

Green coffee has 18.75 mg GAE/g of phenolic content. Meanwhile, at the first 20 min of roasting, light- and medium roasted coffee gave the highest phenolic content compared to the green coffee, 18.8 mg GAE/g and 19.3 mg GAE/g respectively. According to [21], chlorogenic acid content increased during the beginning stage of roasting due to the decomposition of phenolic acids. Heat treatment caused the cell wall disruption and thus soluble polyphenolic compounds released from insoluble ester bonds, leading to an increase in antioxidant capacity in the beginning stage of the roasting [1], [18], [35]. Besides, [25] also reported that formation of melanoidins and other Maillard reaction products during the early phases of coffee roasting may attributed to the higher antioxidant capacity at the first 20 min of light- and medium roasted coffee.

Polyphenolic contents decrease with an increase in the degree of roasting, hence dark roast coffee has the lowest phenolic content. Polyphenolic compounds are highly thermolabile compounds. Degradation of polyphenols caused by the oxidative condensation and decomposition of thermolabile compounds induced during the prolonged heat treatment [28], [31], [12].

However, our study has demonstrated that at 20 min of medium-roasted coffee (220 °C) gave the highest phenolic content compared to the other roasting condition. It is believed that upon application of a sufficient amount of heat, polyphenolic compounds in coffee are produced [9].

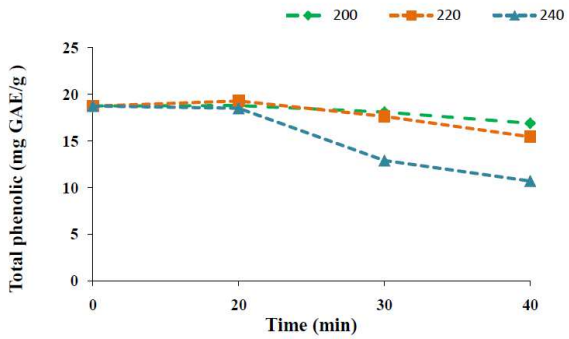

Fig. 1 The changes in total phenolic content (mg GAE/g) of Robusta coffee during superheated steam roasting

B. Radical Scavenging Activity

The free radical scavenging activities of the coffee beans were determined by the DPPH assay. It is widely used to investigate the antioxidant potential of a sample. DPPH is a stable, nitrogen centered free radical with a maximum absorption at 517 nm. As the antioxidants donate protons to this radical, the absorption decreases. The principle behind this assay is that the antioxidants react with the stable free radical i.e. α,α-diphenyl-β-picrylhydrazyl (deep violet colour) and convert to α,α-diphenyl-β-picrylhydrazine with discoloration. The degree of discoloration indicates the scavenging potential of the sample [29]. The free radical scavenging activity of coffee brew was evaluated using DPPH method, and the results are shown in Figure 2.

The scavenging activity of superheated steam roasted coffee brew was in the order of light roasted > unroasted > medium roasted > dark roasted. Our study was in accordance with the result from [11]. However, the scavenging activity at the first 20 min of medium roasted (91.78 %) in our study was observed to be higher than the unroasted coffee (91.28 %). It was reported by [26] that polyphenols are the major compounds that responsible for the free radical scavenging activity of coffee brew under mild roasting conditions, while Maillard reaction products (MRPs) are mainly responsible for the scavenging activity of medium and dark roasted coffee.

According to [16], medium roasted coffee brews have higher radical scavenging activity than unroasted coffee due to an increase of the radical scavenging activity of the non-phenolic fraction (NPF) upon roasting. On the other hand, dark roasted coffee exhibited lower radical scavenging activity due to the degradation of polyphenol during roasting process. Radical scavenging activity (RSA) of the non-phenolic fraction (NPF) increased gradually with the roasting intensity, while the RSA of the phenolic fraction (PF) decreased due to the thermal degradation of phenolic compounds [25].

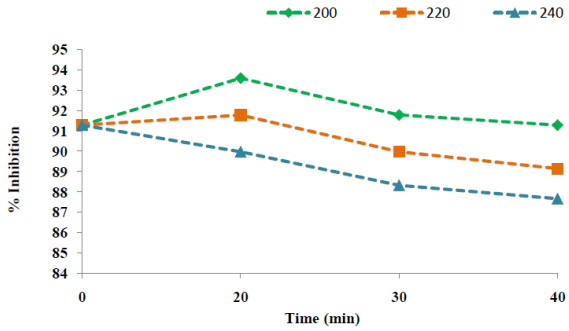

Fig. 2 Free radical scavenging activity of the Robusta coffee roasted using superheated steam at 200-240 °C for different time.

IV. Conclusions

The results indicated that roasting degree (light, medium and dark) significantly influenced the total phenolic content and radical scavenging activity of the coffee beans. Total phenolic content of the coffee brew decreased as the roasting temperature and time increased. However, it is interesting to note that phenolic content at 220 °C for 20 min (medium-roast) is higher than unroasted (green) bean, light- and dark-roasted coffee. This is very likely due to the production of polyphenolic compounds in coffee upon application of a sufficient amount of heat. DPPH assay has been widely used to determine the free radical scavenging activity due to its ease and convenience. Light- (200 °C for 20-40 min) and

medium-roasted (220 °C for 20 min) gave higher radical scavenging activity than unroasted (green) bean and dark-roasted coffee. Based on the results generated in this study, the authors conclude that superheated steam roasting can actually increase the antioxidant properties of coffee beans. Result showed that maximum antioxidant activity and phenolic compounds can be achieved at 220 ˚C for 20 min (medium roast) which is higher than the unroasted (green) bean.

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