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Effect Of Coffee Processing To Antioxidant Activity And Sensory Profile

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ABSTRACT: *Coffee is described as the world's most popular beverage because of health properties of coffee. Coffee treatment processes affect the bioactive composition contents of green coffee beans, affecting the quality and final products directly or indirectly. Dry processing (DP), semi-dry processing (SDP), and wet processing (WP) are the three most prevalent methods of coffee processing (WP). Coffee fermentation is a process in which microorganisms, such as yeast, mold and even bacteria break down the mucilage layer from the parchment coffee. Coffee roasting is one of the main steps, resulting in important changes in the coffee bioactive composition and flavor characteristics. Currently, researches indicate that coffee processing effects to coffee quality as chemical compositions typically antioxidant compounds as well as sensory profile. This review will provide a clear understanding of effects of processing methods to antioxidant compounds of coffee and sensory profile.*

Keywords: *Coffee processing methods, antioxidant properties, sensory profile, coffee fermentation, coffee roasting*

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I. INTRODUCTION

Coffee is described as the world's most popular beverage. Coffee is mainly grown in more than 70 countries by farmers, especially in tropical developing countries, including Vietnam, where the countries are mostly concentrated. Moreover, coffee consumption is distributed across the globe, with a significant percentage kept by developing countries. Nowadays, because of its stimulant effect and exquisite taste, coffee is commonly consumed [1]. Coffee beans are rich in bioactive compounds such as caffeine, free amino groups, polyphenols, antioxidants, and chlorogenic acids. They contain a number of functional biological properties such as stimulation of the central nervous system, myocardial stimulation and peripheral vasoconstriction [2].

As the coffee cherries mature, the coffee fruits contain various chemical compositions which are responsible for the best quality [3]. Coffee treatment processes affect the bioactive composition contents of green coffee beans, affecting the quality and final products directly or indirectly [3, 4]. Dry processing (DP), semi-dry processing (SDP), and wet processing (WP) are the three most prevalent methods of coffee processing (WP). Dry processing is the simplest way of processing methods, which is used sunshine for drying the coffee beans [5]. Coffee beans in semi-processing are fermented but not washed [6]. Wet processing (WP) is the common methods which requires huge amount of water and some special facilities for washing and fermentation processes, being used by many coffee producers to meet market demands for green coffee beans with higher quality [5, 7]. In addition, there is a unique coffee processing method call digestive bioprocessing which uses the animal's gastrointestinal tract, for example weasel coffee, elephant coffee [7, 8]. It is currently believed that post-harvest can affect the chemical compositions of coffee beans in which the antioxidant activity of coffee comes from various bioactive compounds in the bean, most well-known ones are caffeine, trigonelline, and chlorogenic acid, etc. [9, 10], which displays an important antioxidant capacity and was favorable appreciated by its sensory characteristics [9, 11].

Fermentation is a metabolism in which organic substances (mostly sugar) were transformed to other molecules, such as alcohol, acids, gas, or other secondary metabolites by microorganism activities in the absence (anaerobic) or presence (aerobic) of oxygen. Coffee fermentation is a process in which microorganisms, such as yeast, mold and even bacteria break down the mucilage layer from the parchment coffee [12]. During fermentation, it is critical for removing mucilage from coffee parchment and reduce water content. Moreover, it is currently reported that the fermentation effect on the antioxidant activity of green coffee beans and sensory profile [13]. Enzymes found naturally in the coffee berry, as well as microorganisms obtained from the environment, aid in the fermentation process which help to produce a variety of metabolites [1, 14].

Current research indicates that coffee processing especially coffee fermentation effects to coffee quality in chemical compositions typically antioxidant compounds as well as aroma and favour of coffee. Therefore, the purpose of this review is to briefly explain that different processing methods cause different metabolic reactions in coffee, changing of antioxidant activity, and sensory profile of the beans. This review will provide a clear understanding of effects of processing methods to antioxidant compounds of coffee and sensory profile.

II. EFFECT OF COFFEE PROCESSING TO ANTIOXIDANT COMPUNDS OF COFFEE

2.1. Coffee Components with Antioxidant Activity

Coffee as a functional food with antioxidant properties, which includes caffeine, chlorogenic acid, trigonelline, cafestol and kahweol of green coffee beans, reduces the incidence of cancer, diabetes, and liver disease, protects against Parkinson’s disease, and reduces mortality risk [9, 15-17]. In addition, roasting processing of coffee produces melanoidins through non-enzymatic browning exhibit antioxidant activity [9].

a. Caffeine

Caffeine (1,3,7 – trimethylxanthine) is an alkaloid with a bitterness, which is known to have positive health effects, for instance, increased mental alertness, faster information processing, wakefulness, reduction of fatigue, etc. [11, 18, 19]. There is evidence regarding the contribution of caffeine which prevent oxidative stress damage in hypoxia-induced pulmonary epithelial cells to the antioxidant capacity of coffee [16, 20-23]. The caffeine content is highly dependent on the genotype as well as the environment in which coffee is grown. Among the commonly cultivated Coffea species, that is, Arabica and Robusta, the content of caffeine in the Robusta beans is approximately double that found in Arabica (19–21 mg/g and 10 - 12 mg/g, respectively) [19, 24, 25]. Other than the genotype, the processing methods also significantly influence the caffeine concentration in the beans [6, 26].

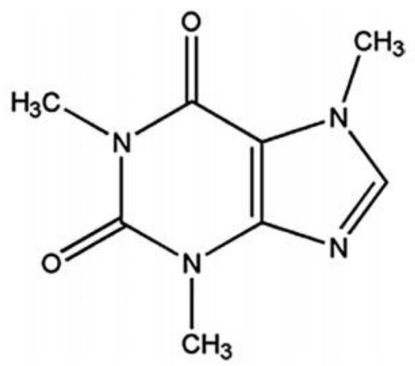

Figure 2.1. Chemical structures of Caffeine (1,3,7 – trimethylxanthine). *From Komes, D., & Bušić, A. (2014)* [18]

b. Chlorogenic acids

Chlorogenic acids, the ester of caffeic acid and quinic acid, that found in coffee beans, possessing strong antioxidant activity [16, 27] which induced oxidative stress by scavenge free radicals because of reactive nitrogen species and reactive oxygen species, as well as strongly influencing the taste and colour of coffee [28-33]. In coffee beans, three major sub-classes of CGA includes caffeoylquinic (CQA), feruloylquinic (FQA) and dicaffeoylquinic (diCQA) acids with the isomer 5-caffeoylquinic acid (5-CQA) recording the highest amounts compared to other chlorogenic acids that were identified [32, 34, 35]. Generally, the total content of chlorogenic acids in coffee beans not only depending on variety, containing in Robusta coffee bean to be 19.42 %, which was higher than one recorded for Arabica coffee (15.72 %), but also depending on the processing methods [6].

c. Trigonelline

Trigonelline (1-methylpyridinium-3-carboxylate) is the second most abundant alkaloid after caffeine in green coffee bean, which formed by the methylation of the nitrogen atom of niacin [18]. According to Arlt, A., et al. (2013) and Zhou, J., et al., (2012 and 2013), trigonelline was attributed to its antioxidant potential because it has been shown to reduce oxidative stress in diabetic rats through insulin secretion, activities of enzymes related to glucose metabolism, reactive oxygen species as well as a significant quenching effect on the lipid peroxidation extent and improvement of antioxidant defence systems in rat pancreatic tissue [36-38]. The content of trigonelline in coffee varies greatly depending on the species, with Robusta coffee having 0.7–1.24% compared to Arabica coffee having 0.80–1.82% [39, 40]. Moreover, it also effects on the post-harvest processing methods [6, 26, 41].

d. Cafestol and Kahweol

Cafestol and kahweol are two natural diterpenes exclusively found in coffee, which mainly present as fatty esters [42]. Their structure is nearly identical, differing only in kahweol has an extra double bond [43]. Both have shown antioxidant activity through their effectiveness in protecting neuronal cells, against damage of DNA and hydrogen peroxide (H_2O_2)-induced oxidative stress by scavenging free oxygen radicals [44, 45].

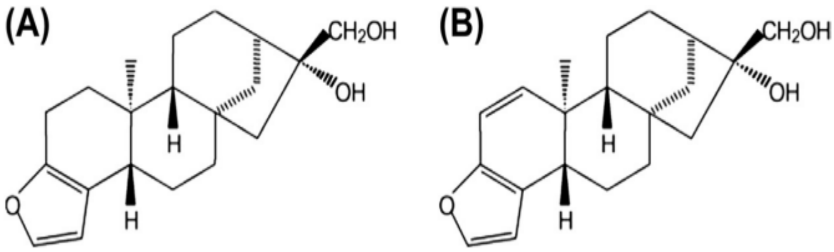

Figure 2.2. Chemical structures of cafestol (A) and kahweol (B). *From Komes, D., & Bušić, A. (2014)* [18]

e. Melanoidins

Melanoidins are a type of phenolic compound, that are formed during the Maillard reaction with coffee roasting with contribution to the antioxidant activity [46]. The structure of coffee melanoidins is still poorly described, because of containing many constituents such as sucrose, arabinogalactans, galactomannans, amino acids, proteins, and chlorogenic acids (CGA) as well as changing according to the degree of roasting [47-49].

2.2. Effect of coffee processing to antioxidant activity of coffee

Antioxidant activity of coffee is affected by the bioactive composition such as caffeine, chlorogenic acids, trigonelline, cafestol, kahweol, and melanoidins [36-38, 46, 50], which are influenced by coffee processing, especially in coffee fermentation and roasting [6, 26, 50].

Rodriguez, Y. F., et al., (2020) observed that the caffeine content in green coffee beans utilizing the semi-dry processing were higher than in it utilizing the wet processing [6]. Mintesnot, A., et al., (2018) reported the influence of processing methods (dry processing and wet processing) on the differences bioactive composition in terms of caffeine, chlorogenic acids, and trigonelline. The wet processing method resulted in an increase in chlorogenic acids [51]. According to Santos Scholz, M. B., et al. (2018), reported similar observations which were differences in the content of phenolic compounds, caffeine, and lipid on coffees processed by semi-dry and dry methods [26]. In another study, changes antioxidant activities of coffee beans processed with different methods (wet processing and dry processing), and even using the digestive bioprocessing of animals (elephant dung coffee) could be attributed to the available of both naturally existing constituent and the compounds produced during processing [52]. Wet-processed beans and elephant dung coffee recorded high antioxidant activities as opposed to dry-processed beans [53]. Bioactive composition significantly effected by each type of post-harvest treatment with the dry processing had low level content may be due to the drying period, which is linked to lower rate of water removal, can expose the beans to a high risk of fungal attract and even undesirable fermentation. These conditions can influence to bioactive composition compared to wet-processed beans [54].

Another hypothesis for the variation in the antioxidant compounds of the coffee beans is fermentation. According to Kwak, H. S., et al. (2018), coffee fermentation with different yeasts (*Saccharomyces* species) at 30^{o}C for 24 hours improved the functionally of coffee by significantly increasing antioxidant properties [13]. Haile, M., et al. (2019) reported similar observations on coffee fermentation with yeast has positive impacts which increasing antioxidant activity compared to non-fermented coffee beans [55]. Additionally, the fermentation of coffee beans with *Wickerhamomyces anomalus* for 24 hours noted the similar observations on an increase in antioxidant properties when compared to non-fermented coffee [53]. This is because esters bound of phenolic compounds which are attached to the cell wall can be broken by fermentation, leading to increase their concentration and consequently their functional properties [56, 57] and making them easier to extract after roasting [13].

In addition, the roasting of coffee is controlled by temperature and duration, and usually qualified by the color of roasted beans. It is classified as light, medium or dark roasted coffee. The process of coffee roasting is one of the main steps, resulting in significant changes in the coffee bioactive composition which correlation to antioxidant properties and flavor characteristics. Coffee roasting includes some complex chemical reaction such as Maillard reaction, caramelization reaction which result in formation of melanoidins, reduction in amino acids, protein, caffeine, chlorogenic acids, trigonelline, reducing sugars, sucrose [58]. Odžaković, B., et al. (2016) noted that the antioxidant activity of coffee is influenced by roasting temperatures due to different compounds with antioxidant properties were formed during heat treatment, with the greatest antioxidant activity shown in coffee roasted at 171°C. Total polyphenol content decreases when the roasting temperature increases, while total flavonoid content and flavonol content also increase [59]. Sunarharum, W. B., et al. (2019) reported that roasting temperature at early roasted stage effected on antioxidant activity which tends to decrease when heating at the early roasting stage. However, there was a variation in antioxidant activity of coffee, with a peak at 95°C before a further decline at higher roasting temperature [60]. In another study, coffee roasting parameters (light roasting, medium roasting, and dark roasting) influences the quality and quantity of bioactive compounds present in coffee, and medium roasting is the best level of roasting [61]. Similar findings were observed by Bobková, A., et al. (2011) who reported roasting process affects both the oxidative activity as well as polyphenolic content. After reaching the light roast stage, total antioxidant capacity increased, then declined as the roast progressed to the dark roast stage. From a nutritional standpoint, the best coffees are those that have been roasted to a light or medium stage, which ensures the maximum level of antioxidant properties [62].

Roasting process may lead to the loss of some antioxidants, such as CGA or other phenolic compounds. However, it also creates other compounds, including Maillard reaction products (melanoidins), hydroxymethylfurfural (HMF – an intermediate compound forming during Maillard reaction), some volatile heterocyclic compounds which are reported in potential antioxidant activity. In the research of Alessandra et al. in 2014, the caffeine, trigonelline, 5-CQA and Maillard reaction products (melanoidins, furfural, HMF) was evaluated during the roasting process of both Arabica and Robusta coffee. Especially, this research was done in an industrial pilot scale, and had three replications. The antioxidant activity of roasted coffee was measured by Folin – Ciocalteau and FRAP methods and considering the scavenging of free radicals. The gallic acid standard was used to calibrate and the results were expressed in g of gallic acid/ 100g of the soluble solids of original coffee. By FRAP methodology, solution with known concentration of Trolox was used to calibrate, the results were expressed in g of Trolox/ 100g of the soluble solids of original coffee. The color of roasted coffee bean was based on the Index of Reflectance (IR). There were 12 types of roasted coffee, vary from 25 IR (dark roasted) to 80 IR (light roasted) with the interval of 5 IR. As the results, the antioxidant activity of Robusta was higher than Arabica coffee and the antioxidant activity was decreased as the roasting level increased. As the increasing of roasting level, the formation of Maillard reaction products were not enough to make up for the destruction of phenolic compounds. The antioxidant activity of coffee, therefore, decreased as the roasting level increased. The antioxidant Figure 2. AA in Arabica and Robusta coffees during roasting, evaluated by the Folin–Ciocalteau (A), gallic acis ABTS (B) activity of Robusta coffee was higher than Arabica's due to the larger amount of caffeine that played a role as antioxidant in coffee [63].

In Vietnam, commercial (Viscozyme®L) and microbial enzymes from yeast and bacteria such as *Saccharomyces cerevisiae, Bacillus subtilis*… were treated on green and germinated coffee to enhance the extraction of antioxidants from coffee [64,65,66]. The improvement of antioxidants from green coffee fermentation by using *Saccharomyces cerevisiae* and *Bacillus subtilis*. In this study, antioxidant properties were determined by Folin -Ciocalteau reagent for determination of total phenolic content (TPC), DPPH assay for determination of antioxidant activity (AA), and Aluminium Chloride colorimetric method for determination of total flavonoid content (TFC). The results of TPC, antioxidant activity, TFC were calculated by Galic acid standard curve (expressed in mg GAE/g DW), Trolox standard curve (expressed in µmol TE/g DW), and Quercetine standard curve (expressed in mg QE/g DW), respectively. As the results, there was no significant differences between fermented coffee extracts and unfermented coffee extracts on TPC and AA.

However, the fermented coffee extracts had a significantly higher TFC than the unfermented coffee extracts. [65]

III. EFFECT OF COFFEE PROCESSING ON SENSORY PROFILE

Coffee content various complex chemical composition including carbohydrates, proteins, lipids, amino acids, peptides, alkaloids, and phenolic compounds which is a wide range of non-volatile and volatile compounds that have diverse functionalities [67, 68]. These compounds are essential precursors which are responsible for flavour and aroma that are either naturally present in green coffee beans or produced from coffee processing (fermentation, roasting) [8, 51].

According to Elmacı, İ., & Gok, I. (2021), different post-harvest and roasting methods influence on sensory profile of Turkish coffee. It was observed that Turkish coffee flavour characteristics were shown to be strongly impacted by roasting process, and no significant influences from postharvest method [69]. Haile, M., et al. (2020) compared the total concentration of volatile compounds by each processing method (dry processing, wet processing, and digestive bioprocessing), resulting these compounds are significantly affected by processing method. In general, when compared to other types of coffee, the overall concentration of most functional classes of volatile chemicals was lower in dry processing coffee [7]. Santos Scholz, M. B., et al. (2018) reported coffee and sweet aromas and sweet and acid tastes presented significant differences between the processes (dry processing and semi-dry processing) in the sensory evaluation. Each post-harvest procedure produces various precursors in the green coffee beans, and diverse aromatic constituents are produced during roasting through Maillard reactions and caramelization reactions. The aromatic profile and sensory characteristics of dry and semi-dry processing are determined by the mixture of these volatile compounds [26]. Similar findings were observed by Mintesnot, A., & Dechassa, N. (2018), dry processing had better values for primary defect, secondary defect, odour, total-point, and preliminary grade, whereas wet processing had better scores for acidity, body, and flavour attributes, all of which have a distinguishing affect on the ultimate taste profile of coffee origins [51]. Rodriguez, Y. F., et al. (2020) found that although the coffee postharvest processing method had no effect on the total cup score, the results for the attributes of fragrance/aroma, aftertaste, acidity, and body obtained from the wet processing method were, on average, higher than those obtained from the semi-dry processing method [6].

Roasting coffee process is a complex series of Maillard reactions, caramelization reactions and other thermal reactions involving aroma precursors that are present in green coffee beans [58]. Hu, G., Peng, X., et al. (2020) noted that the medium roasting samples had higher cupping scores in terms of aroma, flavor, aftertaste, acidity, balance, and overall than light roasting and dark roasting [70]. Alstrup, J., et al. (2020) provided evidence for supporting the effect of roasting process on coffee sensory. A short roasting time increases the fruity, sweet, and acidic characteristics of the coffee, whereas a longer development time shifts the balance towards a more roasty, nutty, and bitter profile. The medium roasting was the best sensory evaluation than other roasting [71]. Bolka, M., & Emire, S. (2020) reported that the highest cupping scores were obtained by roasting them using drum roaster [72].

Additionally, Muzaifa, M., et al. (2019) showed the coffee fermentation with inoculation of *Bacillus subtilis* isolated from civet as starter culture, resulting in increase the total cupping score from 82.83 to 84.33 as well as improvement in the aroma, flavour, aftertaste, body, balance, and overall [1]. Analysis by Afriliana, A., et al. (2018) found evidence of fermentation using starter culture (Lactic acid bacteria and *Saccharomyces cerevisiae*) has effect on the cupping test as well as the volatile compounds of coffee produced, resulting in enhance cup test value and increase volatile compounds. Sensory profiles are derived from enzymatic products, microbial activity results, bioactive composition, and thermal reaction compounds through processing with microbial fermentation and roasting process [73]. Lee, L. W., et al. (2016) also proposed that *Rhizopus oligosporus* fermentation of green coffee beans might influence the aroma and flavor precursors in green coffee. Coffee fermentation by *Rhizopus oligosporus* significantly changes of volatile profile such as 2,3-butanediol, ethyl 3-hydroxybutanoate, another ester compound characterized with fruity notes, were significantly higher in the fermented beans compared to unfermented green coffee beans. *R. oligosporus* fermentation also showed changes of non-volatile profile which effects to concentrations of sugars, organic and phenolic acids present within green coffee beans [74]. Mota, M. C. B., et al. (2020) described a process of fermentation with yeast (*Saccharomyces cerevisiae* and *Torulaspora delbrueckii*) effect on the sensorial quality of coffee [75]. On the other hand, over-fermentation results in the development of spoilage microorganisms that production of black or ‘‘stinker’’ beans and undesirable chemical compounds as well as creation optimum condition for the growth of filamentous fungi and mycotoxins with poor flavour and aroma characteristics [76,77].

In Vietnam, there are various researches on the application of microbial enzymes on the fermentation of coffee to enhance flavors of coffee products and using advanced techniques to improve sensory properties of coffee after fermentation [78,79,80].

IV. CONCLUSION

In conclusion, bioactive composition, that contributed to both antioxidant properties and sensory profile, was significant effected by various post-harvest processing of coffee. Based on the reviewed literature, different processing methods in term of dry-processing, wet-processing, semi-dry processing, coffee fermentation and even roasting processing affects the content of phytochemicals differently. According to recent studies, the biological reactions of the phytochemicals found in coffee which has a high antioxidant capacity that can help prevent diabetes, cancer, and cardiovascular disease as well as are degraded to produce compounds that contribute to the colour, taste, aroma and flavour of the beverage. Therefore, the contribution of phytochemicals to the functional and sensory characteristics of coffee is dependent on mainly processes of coffee, which should consider factors of the processing to produce beverages with better health benefits and good sensory characteristics.

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