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REVIEW

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Antioxidant activity of fermented green coffee beans

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Abstract: A green coffee bean contains phenolic compounds with strong antioxidant activity, such as chlorogenic acid. Fermentation is one of the ways to increase the antioxidant activity of coffee beans by using microorganisms. This review aims to study the antioxidant activity of fermented green coffee beans and the factors involved in the fermentation process. We selected original research articles providing data on the antioxidant activity of fermented green coffee beans published from 2015 to 2021. Fermented green coffee beans shows stronger antioxidant activity compared to the controls. The amount of substrate, yeast (as a starter), and fermentation time influence the antioxidant activity of the fermented green coffee beans. The fermented green coffee beans with yeast had significantly higher antioxidant activity than those in unfermented coffee.

Keywords: fermentation, green coffee bean, chlorogenic acid, antioxidant activity

Introduction

The coffee plant (*Coffea* sp.) is one of the commodities in Indonesia. The chemical composition of green coffee beans depends on the species, variety, environment, maturity level, and storage conditions. The major acid content in coffee beans is chlorogenic acid (8% in unprocessed coffee beans and 4.5% in roasted coffee) [1]. Chlorogenic acid, a phenolic compound and ester group, is formed from quinic acid and several trans-cinnamic acids, generally caffeine, p-coumaric acid, and ferulic acid (Figure 1) [2]. One of the benefits of chlorogenic acid for humans is an antioxidant [3].

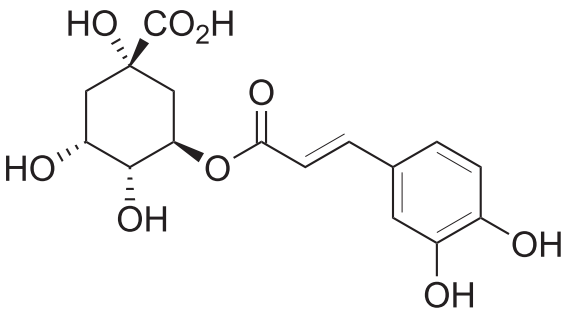

Figure 1. Chemical structure of chlorogenic acid

Some studies reported various methods to process coffee beans [4,5]; one method is fermentation. Some factors affect the fermentation such as type and amount of substrate, type and amount of starter, temperature, pH, and fermentation duration [6]. Coffee bean fermentation is part of the post-harvest process, that can increase the antioxidant activity of green beans. Fermentation can increase antioxidant activity, phenolic and flavonoid content in soybeans [7], okra seeds [8], nuts [9,10], and fermented coffee [11]. However, green coffee bean fermentation has not been widely studied as a second processing step to increase the activity of antioxidants and phenolic compounds. This review article aims to analyze the antioxidant activity of fermented green coffee beans and the factors affected the fermentation process.

Methods

This review was constructed by articles published in 2015-2021 from national and international journals through scientific databases such as PubMed, Google Scholar, and Science Direct, with the keywords *fermentation, green bean, antioxidants, chlorogenic acid,* and *optimization fermentation*. The inclusion criteria are articles containing coffee fermentation with antioxidant activity, while the exclusion criteria are articles only discussing coffee fermentation without antioxidant activity. The articles were collected and combined to study the antioxidant activity of fermented green coffee beans and the factors in the fermentation process affecting the antioxidant activity.

Coffee bean fermentation process

Fermentation can be carried out using bacteria, fungi, yeast, or a mixture of various microorganisms. The mucilage layer of coffee beans rich in sugar and pectin is a source of nutrition for the microorganism [12]. Sugar and pectin will be converted into alcohols and organic acids during fermentation, yielding lower acidity and changing the texture of the mucilage layer that is easier to wash and remove [13].

Most phenolic compounds in the green coffee bean are present as glycosides. These glycosides contain organic acids such as chlorogenic, ferulic, and caffeic acids [14,15]. The high molecular weight and hydrophilicity of these acid glycosides limit their bioavailability contrast to their free forms with several hydroxyl groups [15,16]. Fermentation using appropriate microorganisms can break the acid glycosides into their phenolic compounds and consequently their functional properties [15]. The summary of fermentation condition and the antioxidant activity is presented in Table 1.

Table 1. Fermentation condition and the antioxidant of coffee bean

Type of yeast	Fermentation condition	Results	Reference
Saccharomyces cerevisiae	Wet fermentation Time: 79.09, 120, 180, 240, and 280.90 h Temperature: 25, 31, and 37°C Substrate: 1 kg Sugar: 3.18%, 10%, 20%, 30%, 36.81% Starter: 0.3%, 1.5%, 3.25%, 5%, 6.19%	Optimum composition: yeast 3.25%; sugar 21.38%; 124.73 h of fermentation time resulted in a total phenol of 10.22 mg GAE/g.	[17]
Wickerhamomyces anomalus (strain KNU18Y3)	Time: 0-24 h Temperature: 30°C Substrate: 300 g Starter: 1.0×10^4 CFU/g coffee beans	Method: ORAC Antioxidant activity of control: 48.31 μM TE/mL Antioxidant activity of fermented green coffee bean: 47.82 μM TE/mL Method: SOD Antioxidant activity of control: 89.54% Antioxidant activity of fermented green coffee bean: 89.05%	[18]
Acetobacter xylinum and *S. cerevisiae*	Wet fermentation Time: 6, 12, and 18 days Temperature: 25, 31, dan 37°C Substrate: 0.375 g Sugar: 5; 7.5; dan 10% ($^w/_v$) Starter: 20 g (1.0×10^8 CFU/mL)	Optimum composition: sugar 6.77%, temperature 25°C, and 18 days of fermentation resulted in 138.78% chlorogenic acid.	[19]
S. cerevisiae (strain KNU18Y13), *Saccharomycopsis fibuligera* (strain KNU18Y4), and *S. cerevisiae* (strain KNU18Y12)	Time: 0-48 h Temperature: 30°C Substrate: 250 g Starter: 1.0×10^4 CFU/g coffee beans	Method: ORAC Antioxidant activity of control: 30.37 μM TE/mL Antioxidant activity of fermented green coffee bean using KNU18Y13 yeast strain: 42.42 μM TE/mL Antioxidant activity of fermented green coffee bean using KNU18Y4 yeast strain: 42.09 μM TE/mL Antioxidant activity of fermented green coffee bean using KNU18Y12 yeast strain: 48.83 μM TE/mL Method: SOD Antioxidant activity of control: 70.23% Antioxidant activity of fermented green coffee bean using KNU18Y13 yeast strain: 82.12% Antioxidant activity of fermented green coffee bean using KNU18Y4 yeast strain: 82.15% Antioxidant activity of fermented green coffee bean using KNU18Y12 yeast strain: 88.62%	[20]

Type of yeast	Fermentation condition	Results	Reference
S. cerevisiae	Solid-state fermentation Time: 24 h Temperature: 28°C Substrate: 400 g Starter: 1.0×10^7 CFU/g	The final concentration of chlorogenic acid is 30 mg/L	[21]
Three commercial yeasts (*S. cerevisiae*)	Time: 0-24 h Temperature: 30°C Substrate: 300 g Starter: 1.0×10^7 CFU/mL	Method: ORAC Antioxidant activity of control: 14.11 μM TE/mL Antioxidant activity of fermented green coffee bean: 34.95 μM TE/mL; 37.44 μM TE/mL; 34.09 μM TE/mL Method: SOD Antioxidant activity of control: 29.63% Antioxidant activity of fermented green coffee bean: 82.76%; 79.79%; 69.58%	[11]
Yeast mixtures	Spontaneous fermentation Time: 48 h Substrate: 75 kg	Yeast population increased from 6.60 to 7.89 log CFU/g^{-1}; yeast population mainly represented by *Saccharomyces* sp.; organic acids production (mainly lactic (3.35 g/L) and acetic (1.27 g/L) acids). SPME-GC-MS analysis revealed a total of 25 volatile organic compounds with predominance of hydrocarbons (9 compounds) and higher alcohols (6 compounds).	[22]
S. cerevisiae (Four strains, coded as L1, L2, L5, and L7)	Wet fermentation Time: 12 and 36 h Substrate: 50 kg Sugar: 3.18%, 10%, 20%, 30%, and 36.81% Starter: 1 g/kg of depulped coffee	Concentration of chlorogenic acid Control: 9.66% L1 (12 h): 10.47% L1 (36 h): 10.02% L2 (12 h): 9.88% L2 (36 h): 9.55% L5 (12 h): 9.22% L5 (36 h): 9.73% L7 (12 h): 9.33% L7 (36 h): 8.74%	[23]

CFU: colony forming unit; GAE: gallic acid equivalent; ORAC: oxygen radical absorbance capacity; TE: Trolox equivalent; SOD: superoxide dismutase-like activity

Effect of fermentation on antioxidant activity

The articles in Table 1 reporting antioxidant activity of fermented green coffee bean then selected and further analyzed by counting the increase of antioxidant activity compared to control and displayed in Table 2.

Haile and Kang (2019) reported the increase of antioxidant activity of fermented green coffee bean with total phenolic contents (TPC) of the extracts (1.11-1.30 GAE mg/mL) significantly higher than the control (0.72 GAE mg/mL) [20]. The fermented green coffee bean using *S. cerevisiae* (strain KNU18Y13) and *S. fibuligera* (strain KNU18Y4) produced higher antioxidant activity as evaluated by ORAC and SOD methods. The ORAC quantifies the antioxidant capacity based on a probe's fluorescent signal, which is quenched in the presence of reactive oxygen species (ROS). The SOD activity uses a xanthine/xanthine oxidase (XOD) system to generate superoxide anions and a chromagen to produce a water-soluble formazan dye upon reduction by superoxide anions. The SOD activity is determined as the inhibition or reduction of chromagen. The antioxidant activity of fermented green coffee bean with *W. anomalus* (KNU18Y3 strain) was not significantly different from the control, while the TPC of the control was 0.70 GAE mg/mL and of the fermented green coffee bean was 0.91 GAE mg/mL [18].

In the wet processing method, *W. anomalus* and *S. cerevisiae* can produce a pectinase enzyme, so they are selected as a starter culture for coffee bean fermentation. However, *S. cerevisiae* has a higher ethanol tolerance and

Table 2. Antioxidant activity of fermented green coffee bean

Antioxidant activity method	Antioxidant activity of fermented green bean coffee	Antioxidant activity of control	The increase amount of antioxidant activity	Reference
ORAC	42.42 μM TE/mL		12.05 μM TE/mL	[20]
	42.09 μM TE/mL	30.37 μM TE/mL	11.72 μM TE/mL	
	48.83 μM TE/mL		18.46 μM TE/mL	
SOD	82.12%		11.89%	
	82.15%	70.23%	11.92%	
	88.62%		18.39%	
ORAC	34.95 μM TE/mL		20.84 μM TE/mL	[11]
	37.44 μM TE/mL	14.11 μM TE/mL	23.33 μM TE/mL	
	34.09 μM TE/mL		19.98 μM TE/mL	
SOD	82.76%		53.13%	
	79.79%	29.63%	50.16%	
	69.58%		39.95%	
ORAC	47.82 μM TE/mL	48.31 μM TE/mL	- 0.49 μM TE/mL	[18]
SOD	89.05%	89.54%	- 0.49%	

maintains fermentation activity than *W. anomalus* [24]. Therefore, the type of yeast for the fermentation process significantly affects the yield of secondary metabolites and the antioxidant activity of the fermented green coffee bean. The fermentation time of green coffee beans disturbs the antioxidant activity. A similar profile was also noted for the amount of starter used in the fermentation process.

Green coffee beans contain phenolic compounds involved in the scavenging activity of ROS. Chlorogenic acid is the main phenolic component of green coffee beans, which exhibit antimutagenic, anticarcinogenic, antibacterial, and antioxidant activities [25]. Besides, green coffee bean phytochemicals reduce visceral fat and have been added to skin cosmetics to prevent skin aging [26].

Conclusion and future direction

The fermentation process can increase the antioxidant activity of green coffee beans. The antioxidant activity was affected by the amount of starter, fermentation time, and the amount of substrate. Optimizing fermentation conditions for producing optimal antioxidant activity is needed to utilize and develop fermented green coffee beans.

Declaration of interest

None.

Author contributions

JJ, PSY conceptualized the review article and search literature for the data, JJ wrote the original draft, JJ reviewed and edited the final version, PSY supervised the review process.

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