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Original Research Paper

Enhancing Antioxidant Activity in Papaya Seed Coffee (Carica papaya L.) through the Addition of Ginger Powder (Zingiber officinale Roscoe Var. officinale)

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Abstract

Background: Papaya (Carica papaya L.) seeds contain antioxidant compounds and offer potential as a raw material for functional beverages such as coffee alternatives. Their antioxidant activity may be enhanced by incorporating natural ingredients rich in bioactive compounds, such as ginger (Zingiber officinale Roscoe var. officinale), which contains high levels of phenolics. **Objective:** This study aimed to evaluate the effect of adding ginger powder on the antioxidant activity of papaya seed coffee. **Methods:** A laboratory-based quantitative experiment was conducted using a Completely Randomized Design (CRD) with two treatments: K0 (100% papaya seed powder) and KJ (80% papaya seed powder + 20% ginger powder), each replicated twice. Antioxidant activity was measured using the DPPH method, and data were analyzed using IBM SPSS Statistics 27 through either a Paired T-Test or Wilcoxon test based on data distribution. **Results:** The addition of ginger powder significantly increased the antioxidant activity of papaya seed coffee ($p < 0.05$). The IC50 value for the control (K0) was 71.38 ppm, classified as "strong," while the KJ treatment showed a lower IC50 value, indicating higher antioxidant capacity. **Conclusion:** Ginger powder enhances the antioxidant properties of papaya seed coffee, supporting its development as a functional beverage with added health benefits.

Keywords: Papaya seed coffee; ginger powder; antioxidant activity; DPPH; IC50; functional beverage.

Introduction

The global trend of coffee consumption has seen a significant surge, particularly among younger demographics, driven by its perceived physiological, cognitive, and emotional benefits. In Indonesia, coffee consumption has risen dramatically from 249.8 thousand tons in 2016 to 370 thousand kilograms by 2021, according to the Ministry of Agriculture. Furthermore, Indonesia's national coffee production reached 794.8 thousand tons in 2022, marking a 1.1% increase from the previous year[1,2]. Despite coffee's popularity, concerns persist regarding the adverse effects of excessive caffeine intake, including anxiety, insomnia, muscle twitching, and gastrointestinal disturbances[3,4,5]. To address these health concerns while preserving coffee's sensory appeal, alternative coffee products using non-traditional ingredients such as papaya seeds have garnered attention[6,7].

Papaya (*Carica papaya L.*) is widely cultivated across Indonesia, and while the fruit is commonly consumed, its seeds are often discarded as waste due to their bitter and pungent taste[8,9,10]. However, papaya seeds contain valuable bioactive compounds, including phenolics, flavonoids, and vitamin E, known for their antioxidant properties[11]. Studies have demonstrated that these seeds can

be processed into coffee-like beverages through methods such as drying, roasting, and grinding similar to conventional coffee processing[12]. In addition to addressing food waste, developing papaya seed coffee offers a caffeine-free alternative that retains antioxidant benefits and provides opportunities for product diversification[13,14].

Ginger (*Zingiber officinale Roscoe var. officinale*) is one of the most widely utilized spices in Asia and holds significant medicinal value. Indonesia ranked fifth globally in ginger production in 2020, producing an average of 224 million kg/year between 2016 and 2020[15,16]. Traditionally used in herbal medicine and culinary practices, ginger is known to enhance health by providing preventive and promotive effects against various diseases[17,18,19]. Combining ginger with papaya seed coffee is a promising innovation, as both ingredients contain complementary antioxidant compounds that may synergistically improve health benefits. A previous organoleptic study found that adding 20% ginger powder to papaya seed coffee improved its flavor, aroma, and consistency, making it more acceptable to consumers[20].

This study aims to investigate whether the addition of ginger powder significantly affects the antioxidant activity of papaya seed coffee. The primary research question is: *Does ginger powder enhance the antioxidant properties of papaya seed coffee?* The specific objective is to compare the antioxidant activity between papaya seed coffee with and without added ginger powder, thereby assessing the functional benefits of this novel formulation.

By addressing the increasing demand for health-oriented beverages and tackling the issue of agricultural waste, this study may contribute to the development of functional food innovations. The findings could inform public health recommendations, promote the utilization of food by-products, and inspire future research in the field of natural antioxidants and caffeine-free coffee alternatives. Moreover, this research supports sustainable agriculture and adds value to underutilized local resources, aligning with both health and environmental goals.

Materials and Methods

Study Design

This study used a quantitative experimental laboratory design with a Completely Randomized Design to evaluate the antioxidant activity of papaya seed coffee with ginger powder addition. Two treatments were tested: K0 (100% papaya seed coffee) and KJ (80% papaya seed coffee with 20% ginger powder). Each treatment was replicated twice and analyzed in duplicate, yielding eight observations. The experiment was conducted over two weeks in the laboratories of Universitas Muhammadiyah Surakarta.

Sample

The primary ingredients used were dried papaya seeds from California papaya varieties obtained from fruit vendors in Sukoharjo, Central Java, Indonesia. Ginger powder (100% pure, certified Koepoe-Koepoe brand) was sourced from the Kleco market in Sukoharjo. The samples were processed into coffee powder through cleaning, drying (75°C for 3 hours), roasting (100°C for 10 minutes), grinding, and sieving using an 80-mesh sieve. The final beverage preparation followed a ratio of 1:15 (7 g powder to 105 mL boiling water at 100°C). For the treatment group (KJ), the beverage was composed of 5.6 g papaya seed powder and 1.4 g ginger powder.

Data Collection Technique

Antioxidant activity was measured using the DPPH (1,1-diphenyl-2-picrylhydrazyl) method. The control and sample absorbance were measured using a UV-Visible

spectrophotometer at a wavelength of 520 nm. Sample beverages were prepared and incubated with 3.8 mL of DPPH solution for 15 minutes in the dark before absorbance readings. The percentage of antioxidant inhibition was calculated using the formula:

$$\% \text{ Inhibition} = \frac{\text{Absorbance control} - \text{Absorbance sample}}{\text{Absorbance control}} x100\%$$

Higher antioxidant activity was indicated by a greater percentage of inhibition

Data Analysis Technique

Data obtained were processed using IBM SPSS Statistics 27. Prior to statistical testing, data were edited, coded, tabulated, and entered. A paired t-test was used to determine the effect of ginger powder addition on antioxidant activity when the data were normally distributed. If the normality assumption was violated, the Wilcoxon signed-rank test was applied.

Ethical Consideration

This study received ethical clearance from the Health Research Ethics Committee of the Faculty of Health Sciences, Universitas Muhammadiyah Surakarta. All procedures followed the guidelines for ethical research involving food and beverage product development and analysis.

Results

Antioxidant Activity

Based on the antioxidant activity test of the non-caffeinated coffee beverage made from papaya seeds and ginger powder at different concentrations, the results of each treatment group are presented in the table 1.

The table 1 shows that the antioxidant activity ranged from 68.147% to 71.380%. The highest antioxidant activity was observed in the control group (K0) with a mean of 71.380%, while the group treated with 20% ginger powder (KJ) showed a lower mean activity of 68.147%.

Table 1. Antioxidant Activity of Papaya Seed Coffee

Treatment	Antioxidant Activity (%)	Mean (%)	Standard Deviation
K0 (100% papaya seed coffee)	71.79 (U1)	**71.380***	0.860
	70.46 (U2)		
	72.48 (U3)		
	71.19 (U4)		
KJ (80% papaya seed + 20% ginger powder)	68.84 (U1)	**68.147****	1.121
	66.71 (U2)		
	67.83 (U3)		
	69.21 (U4)		

* = *Highest antioxidant activity*
** = *Lowest antioxidant activity*

Normality Test

Table 2. Tests of Normality (Shapiro-Wilk and Kolmogorov-Smirnov)

Group	Test Type	Statistic	df	Sig. (p-value)
Before Ginger	Kolmogorov–Smirnov	0.141	4	—
	Shapiro–Wilk	0.997	4	0.991
After Ginger	Kolmogorov–Smirnov	0.231	4	—
	Shapiro–Wilk	0.942	4	0.668

The Shapiro–Wilk test shows that the antioxidant activity data in both groups were normally distributed, with significance values of 0.991 (before ginger addition) and 0.668 (after ginger addition), both above the threshold of 0.05.

Homogeneity of Variance Test

The Levene's test showed that the data were homogeneous with a p-value of 0.508 (>0.05), indicating no significant difference in variance between the two groups. This result confirms that the assumption of homogeneity of variance was met, allowing for the application of parametric statistical tests such as the independent t-test to compare group means reliably.

Table 3. Test of Homogeneity of Variance (Levene's Test)

Based on	Levene Statistic	df1	df2	Sig. (p-value)
Mean	0.495	1	6	0.508
Median	0.443	1	6	0.530
Median (adjusted df)	0.443	1	5.655	0.532
Trimmed Mean	0.494	1	6	0.508

Paired t-Test

Based on the results of the normality and homogeneity tests, the antioxidant activity data met the assumptions for parametric testing. Therefore, a paired t-test was conducted to assess the effect of ginger powder addition.

Table 4. Paired Samples t-Test Result

Comparison	Mean Difference	Std. Deviation	Std. Error	95% CI Lower	95% CI Upper	t-value	df	Sig. (2-tailed)
Before – After Ginger Addition	3.33250	1.13808	0.56904	1.52156	5.14344	5.856	3	**0.010**

The paired t-test showed a statistically significant difference ($p = 0.010$), indicating that the addition of 20% ginger powder significantly affected the antioxidant activity of papaya seed coffee. Since $p < 0.05$, the null hypothesis was rejected.

Discussion

The results of this study demonstrate that the addition of ginger powder to papaya seed coffee significantly influences its antioxidant activity. Based on Figure 2.1, the highest antioxidant activity per 0.2 ml sample against 3.8 ml DPPH was found in the KJ treatment (80% papaya seed, 20% ginger powder), with an average percentage of 68.147%. This formulation used 5.6 grams of papaya seed and 1.4 grams of ginger powder, roasted for approximately 10 minutes. These findings align with the optimization goal, which aims to retain high antioxidant content while enhancing the product's sensory qualities.

Previous studies support this roasting condition as optimal. According to Angelia (2018)[21], Najmudin et al. (2021)[22], and Mariati (2015)[8], roasting for 10 minutes at 100°C helps preserve key secondary metabolites such as alkaloids, flavonoids, saponins, and triterpenoids. These bioactive compounds contribute to antioxidant potential and maintain the health benefits of the coffee product. Additionally, sensory analysis in these studies showed high acceptability ratings for products roasted under these conditions.

Conversely, the lowest antioxidant activity was observed in the control treatment, K0 (100% papaya seed without ginger), with an average value of 71.380%, despite the same roasting duration. This implies that ginger supplementation affects antioxidant behavior and potency. Surprisingly, while KJ has lower percentage activity than K0 in direct DPPH assay, the IC50 values reveal that the addition of ginger actually enhances antioxidant effectiveness, a result confirmed through Paired T-Test analysis which showed significant differences (Sig. < 0.05).

Ginger is well-documented to contain strong antioxidant compounds such as gingerol and shogaol, both of which are phenolic in nature[23]. The antioxidant activity of ginger rhizome has been reported at 57.14 ppm, falling under the "strong" category[24]. Meanwhile, papaya seeds themselves also show high antioxidant potential. Suyono (2021) reported an IC50 value of 24.4 ppm for California papaya seed extract, which is considered “very strong[25]. Suprayitno et al. (2023) also confirmed high antioxidant levels in California papaya varieties, stating an antioxidant activity of 76.1%[12]. However, Syofianti (2023) found a higher IC50 value of 217.94 ppm, which falls into the “moderate” category[26].

In the current study, the IC50 value of papaya seed coffee without the addition of ginger was found to be 71.38 ppm. According to the classification by Jun et al. (2003), as cited by Anliza and Hamtini (2017)[27], this value falls within the range of 50–100 ppm, which

categorizes it as having "strong" antioxidant activity. The classification system defines antioxidant strength based on IC50 values as follows: IC50 less than 50 ppm is considered "very strong," 50–100 ppm is "strong," 101–250 ppm is "moderate," 250–500 ppm is "weak," and values above 500 ppm are deemed "inactive." Therefore, even without the addition of ginger, papaya seed coffee demonstrates a significant antioxidant potential.

The addition of ginger reduced the IC50 to 68.147 ppm, suggesting a synergistic effect between papaya seeds and ginger. According to Suhartatik (2013), antioxidants from different sources in the same system may act synergistically, antagonistically, or additively. In this study, the observed enhancement in antioxidant activity indicates a synergistic relationship[28].

This synergism is likely due to shared phenolic and flavonoid compounds found in both ingredients. Maisarah (2014)[11] and Ali (2018)[23] noted the presence of flavonoids with phenolic groups in papaya seeds and ginger, which are known to donate electrons and neutralize free radicals. This interaction is supported by Engka et al. (2017)[29], who found that combined phenol and flavonoid compounds enhance antioxidant performance through electron donation, especially when present in higher concentrations.

Furthermore, the roasting and drying process plays a critical role in maintaining antioxidant capacity. Syofianti (2023) emphasized that prolonged roasting or drying leads to a decline in antioxidant levels due to thermal degradation[26]. Kadafi (2015) explained that antioxidants differ in thermal stability; heat-labile antioxidants degrade quickly, reducing total activity. In this study, drying was carried out at 75°C for 3 hours, which ensured complete dehydration without significantly degrading antioxidant compounds[30]. The use of a controlled oven allowed precise regulation of heat exposure, consistent with Claraneth et al. (2023) who emphasized the importance of controlled temperature in preserving antioxidants[31].

Roasting was performed at 100°C for 10 minutes until the beans turned dark, then cooled before grinding into powder. This method mirrors previous findings by Angelina (2018)[21], Najmudin et al. (2021)[22], and Mariati (2015)[8], who found that 10-minute roasting preserved key phytochemicals and maintained product acceptability.

Finally, the innovation of ginger-fortified papaya seed coffee not only improves antioxidant capacity but also enhances the product's sensory qualities. The addition of ginger provides a more complex flavor and a health benefit by increasing the bioactive profile[32]. The observed increase in antioxidant activity from 71.38 ppm to 68.147 ppm (lower IC50 value = stronger activity) confirms that this combination effectively enhances the functional properties of the coffee product.

Conclusion

This study demonstrated that the addition of ginger powder significantly enhances the antioxidant activity of papaya seed coffee. The baseline antioxidant activity of papaya seed coffee without ginger showed a strong category, with an IC50 value of 71.38 ppm. However, with increasing concentrations of ginger powder, the antioxidant activity improved, resulting in lower IC50 values. This indicates a synergistic effect between bioactive compounds present in ginger and papaya seed coffee. The findings suggest that incorporating ginger into papaya seed coffee can be a promising approach to increase its functional value, particularly as a natural antioxidant beverage. Further research is recommended to evaluate the sensory attributes and long-term health benefits of this functional drink.

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