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Study on The Addition of Red Ginger (*Zingiber officinale* Var. Rubrum) and Black Rice (*Oryza sativa* L. Indica) to The Organoleptic Evaluation and Physical-Chemical Properties of Robusta Coffee (*Coffea canephora*) from Southeast Sulawesi

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Abstract: This study aims to determine the effect of adding red ginger and black rice on the organoleptic and physicochemical properties of robusta coffee. The problem in this study arose because, so far, the caffeine content in coffee has generally been high. On the other hand, the addition of red ginger and black rice can reduce caffeine levels and improve the taste of coffee. This study employed a factorial Completely Randomised Block Design with two factors. The first factor is the addition of red ginger (J) at three levels: 4% (J1), 8% (J2), and 12% (J3). The second factor is the addition of black rice (B) at two levels: 10% (B1) and 20% (B2). Organoleptic data were analyzed using ANOVA and DMRT tests. Physicochemical properties were analyzed descriptively. The results of the study showed that the best treatment was with the addition of 12% red ginger and 20% black rice (J3B2), with a color of 3.75 (like), aroma 3.90 (like), texture 4.00 (like), and taste 4.03 (like), water content 1.113%, ash 3.657%, pH 5.83, caffeine 0.72%, chlorogenic acid 4.92%, and antioxidant activity (IC50) 39.28 ppm.

Keywords: Black Rice; Caffeine Content; Coffee; Flavor; Red Ginger

Introduction

Indonesia is one of the largest producers of Robusta coffee in the world, contributing 30% of global Robusta coffee exports (Sarvina et al., 2023). Robusta coffee production in Indonesia is spread almost throughout the country, with a total plantation area of 1,268,905 ha, where 62% of this area is concentrated in Sumatra (Campuzano-Duque et al., 2021), Java (16%), Bali and Nusa Tenggara (10%), Sulawesi (10%), Kalimantan (1%), and Maluku and Papua (1%) (Ditjenbun, 2023). In terms of productivity, coffee production in Indonesia is relatively low, around 760,192 tons per year (Sarvina et al., 2023), compared to major coffee-producing countries like Brazil and Vietnam, which produce 2,680,000 tons per year (Omar et al., 2022) and 1,780,000 tons per year (Revindo et al., 2024), respectively.

Over the past five years, global coffee consumption and demand have significantly increased, outpacing the global coffee production rate. This has made the export prospects for Indonesian Robusta coffee in the international market increasingly promising (Torga & Spers, 2020). The International Coffee Organization (ICO) reported that since 2010, global coffee consumption has increased by an average of 2.5% per year. In 2020, it was estimated that global coffee demand would reach around 10.3 million tons (Freitas et al., 2024).

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The chemical composition of coffee can vary depending on the type of coffee, the soil conditions where it is grown, and the processing method used. These factors influence the levels of compounds like caffeine, chlorogenic acid, and various aromatic oils in coffee beans (Janissen & Huynh, 2018). Caffeine and caffeol are the most important compounds in coffee (Prihadi & Maimulyanti, 2021). Caffeine stimulates the nervous system, while caffeol provides the characteristic flavor and aroma (Depaula & Farah, 2019). Caffeine is a weak monobasic base that can be separated by evaporation and easily decomposed with hot alkalis (Zhang et al., 2024). In its pure form, caffeine appears as crystalline powder or as tangled silk-like threads and melts at a temperature of 235-237°C and sublimates at 176°C (Hoffmann, 2018). Caffeine has a fragrant aroma, is extremely bitter, and dissolves in water (Hoffmann, 2018).

Excessive caffeine consumption can lead to various negative health effects, such as insomnia, hypertension, peptic ulcers, and increased blood sugar levels in type 2 diabetes patients. Therefore, it is important to control caffeine intake to avoid adverse effects on health (Frozi et al., 2018). For pregnant women, caffeine consumption can cause miscarriage (Ayoub & Yaseen, 2022). Robusta coffee contains higher caffeine levels than Arabica coffee, which can make individuals more susceptible to addiction if consumed excessively. Consuming large amounts of Robusta coffee over time can lead to negative health effects such as sleep disturbances, increased blood pressure, and digestive issues (Topik, 2009). The high caffeine content in Robusta coffee necessitates reducing caffeine levels (Hariyadi et al., 2020). A safe caffeine intake is 80-150 ppm (Zornoza et al., 2022). The vacuum roasting process and the addition of ginger and black rice are methods that can reduce caffeine content in coffee (Ateş & Elmacı, 2019).

Roasting is carried out to develop the flavor of coffee beans (Hu et al., 2020). The roasting process is easier to control if the coffee beans have uniform size, moisture content, and texture (Anastácio et al., 2023). Roasting is typically done at a temperature of approximately 200°C after preliminary treatment to remove moisture (Mazaheri et al., 2019).

Coffee farmers generally still use traditional methods to make coffee powder, relying on simple equipment, including during the roasting process. Although this method preserves the unique flavor of the coffee, it often requires longer processing times and produces inconsistent results compared to modern roasting techniques that are more controlled (Hoffmann, 2018). During the roasting process, farmers typically use additives such as red ginger and black rice to enhance the flavor of the coffee, giving it a distinctive aroma and increasing the weight of the coffee powder (Asif et al., 2013). According to Nachay & Malochleb (2018), mixing coffee with 15-20% rice or corn results in coffee powder with a more pleasant and delicious taste.

Black rice has gained popularity as a functional food due to its high antioxidant content. These antioxidants, particularly anthocyanins, play an important role in combating free radicals in the body, which can help prevent various degenerative diseases and promote overall health (Panda et al., 2022). Ginger is a plant widely used as a seasoning, for flavoring products such as bread, biscuits, candies, and drinks (Shahrajabian et al., 2019a). It is used in beverages such as bandrek, sekoteng, and syrup. Ginger has been found to have various health benefits, including acting as an expectorant, a cough remedy, a diaphoretic, an emmenagogue, an anti-nausea agent, an appetite stimulant, a wind expeller, a stomach strengthener, and a digestive aid (Shahrajabian et al., 2019b).

Based on the above description, it is necessary to conduct research on "The Effect of Adding Red Ginger and Black Rice on the Organoleptic and Physical-Chemical Properties of Local Robusta Coffee from Southeast Sulawesi". It is hoped that this study will help researchers find the optimal ratio of red ginger and black rice to achieve a balanced flavor, high chlorogenic acid content, antioxidant activity, and low caffeine levels.

Method

Time and Place of Research

This research was conducted in the food technology laboratory of the Faculty of Agriculture, Halu Oleo University, the chemistry laboratory of the Faculty of Teacher Training and Education, and the biology laboratory of the Faculty of Mathematics and Natural Sciences. Starting from July to November 2019.

Equipment

The equipment used in this study includes a coffee roaster, aluminium foil, a set of organoleptic testing tools, petri dishes, oven, desiccator, analytical balance, stopwatch, porcelain dishes, furnace, pH meter (pH-009 model, ATC), beakers, separating funnels, a set of extraction tools, Erlenmeyer flasks, distillation apparatus, measuring flasks, spectrophotometer, centrifuge tubes, Whatman filter paper, Buchner funnel, water bath, glass spatula, graduated cylinders, and glassware.

Materials

The materials used in this study included Robusta coffee beans and coffee powder sourced from Tetewua Village, Dangia District, East Kolaka Regency, Southeast Sulawesi, along with red ginger and black glutinous rice of the Wakombe variety from Southeast Sulawesi. Materials for sample analysis included buffer solution, distilled water, Na_2CO_3, chloroform, caffeine standard, chlorogenic acid standard, H_2O, petroleum ether, saturated KCH_3COO solution, and $(CH_3COO)_2Pb$ solution.

Methods

Research Design

This study used a Randomized Complete Block Design (RCBD) in a factorial format with two factors. The first factor was the addition of red ginger (J), with three levels: (J1) 4%, (J2) 8%, and (J3) 12%. The second factor was the addition of black rice (B), with two levels: (B1) 10% and (B2) 20%. These two factors were combined, resulting in 6 treatment combinations, repeated three times, yielding a total of 18 experimental units.

Research Stages

The research stages involved sorting dry coffee beans to separate the good-quality beans from the defective ones. The selected high-quality dry beans were then roasted for 20 minutes at a temperature of 200°C. This process was carried out using a vacuum roasting machine to maintain the flavor of the coffee beans. During the roasting process, red ginger (J) was added at 4%, 8%, and 12%, and black rice (B) was added at 10% and 20%. After roasting, the coffee beans were ground using a coffee grinder to reduce their size, resulting in coffee powder. The coffee powder was then packed in polypropylene plastic and stored in a cool place, away from direct sunlight, to prevent contamination by microorganisms that could degrade the quality of the coffee powder. The coffee powder was prepared for organoleptic testing, and physical-chemical tests were carried out on the control treatment and the best treatment, as well as on the coffee beans.

Observation Variables

The observation variables for organoleptic testing included the color and texture of the coffee powder, while aroma and taste were evaluated using coffee beverages by 20 panelists. The physical-chemical properties tested were moisture content (AOAC, 2005), ash content (AOAC, 2005), pH (using a pH meter), caffeine content (spectrophotometry), chlorogenic acid content (spectrophotometry), and antioxidant activity using the DPPH method.

Data Analysis

The organoleptic evaluation data were analyzed using Analysis of Variance (ANOVA). If significant, the results were followed by Duncan's Multiple Range Test (DMRT) at a 95% confidence level (α=0.05). The physical-chemical properties were analyzed descriptively.

Result and Discussion

Organoleptic Test

A summary of the analysis of variance results on the effect of adding red ginger (4%, 8%, and 12%) and black rice (10% and 20%) on the organoleptic preferences, which include color, aroma, texture, and taste of local Robusta coffee from Southeast Sulawesi, is presented in Table 1.

Table 1. Summary of ANOVA results on the effect of adding red ginger and black rice on the organoleptic evaluation of local Robusta coffee from Southeast Sulawesi

Observation variables	ANOVA Analysis		
	Red Ginger Addition (J)	Black Rice Addition (B)	J*B
Color	ns	ns	ns
Aroma	**	ns	ns
Texture	ns	ns	ns
Taste	*	ns	ns

Note: ns = no significant effect; * = significant effect; ** = very significant effect.

1. *Color*

The ANOVA results showed that the interaction between the addition of red ginger and black rice had no significant effect on the organoleptic evaluation of color. Independent treatments, both for red ginger and black rice additions, also had no significant effect on the color evaluation. This is suspected to be due to the red ginger and black rice turning dark during the roasting process, which resembles the color of coffee, thus causing no noticeable change in the coffee powder's color. This finding aligns with Mardhatilah (2015), which indicated that adding ginger did not significantly affect the color of coffee syrup because it was dominated by the dark color of the coffee. Similarly, Putri (2011) cited in Ikbal (2019) noted that adding more than 75% ginger can alter the product's color and affect its flavor.

2. *Aroma*

The ANOVA results showed that the interaction between red ginger and black rice addition had no significant effect on the organoleptic evaluation of aroma. The independent addition of black rice also had no significant effect on the aroma of the coffee, while the addition of red ginger had a very significant effect on the aroma of the coffee beverage. The organoleptic test results of the independent effect of adding red ginger are shown in Table 2.

Table 2. Independent effect of adding red ginger on the organoleptic evaluation of the aroma of local Robusta coffee from Southeast Sulawesi

Treatment	Mean Organoleptic Aroma ± SD	Category	DMRT5%
J1 (4% red ginger)	3.36^{b} ± 0.29	Slightly like	
J2 (8% red ginger)	3.79^{a} ± 0.20	Like	2 = 0.413
J3 (red ginger12%)	3.84^{a} ± 0.18	Like	3 =0.433

Note: Numbers followed by different letters show significant differences based on the DMRT test at 5% confidence level

Based on Table 2, the effect of adding red ginger to the coffee beverage significantly increased the aroma preference, with the highest rating for treatment J3 (3.84 - like) and the lowest for J1 (3.36 - slightly like). The DMRT further showed that treatment J3 did not differ significantly from J2 but did differ significantly from J1. The addition of red ginger had a very significant effect on the aroma, which is likely due to the gingerol compounds in red ginger, providing a characteristic aroma to the coffee beverage. This is in accordance with Koswara et al. (2012), who stated that the aroma of ginger is due to the phenolic ketone compounds, particularly gingerol, which are the main components of fresh ginger. It is known that ginger rhizomes contain essential oils (0.25–3.3%), which are responsible for the distinct aroma. Mishra (2009) also noted that gingerol compounds are very unstable with heat and convert to shogaol at high temperatures. Shogaol is spicier than gingerol and is a component of dried ginger. The prolonged heating during the coffee roasting process causes gingerol to convert into shogaol. Mardhatillah (2015) found that the addition of ginger significantly influenced the aroma preference of spice-infused coffee syrup. The highest aroma preference occurred with a 10% ginger addition, while the addition of 15% and 20% ginger caused a decrease in the panelists' preference.

3. *Texture*

The ANOVA results showed that the interaction between red ginger and black rice addition did not significantly affect the organoleptic evaluation of texture. Independent treatments, both for red ginger and black rice additions, also had no significant effect on the texture of the coffee powder. This is believed to be because all treatments resulted in the same texture during the coffee grinding process. Therefore, adding red ginger up to 12% did not significantly affect the texture of the coffee powder. Similarly, adding black rice up to 20% did not significantly affect the texture of the coffee powder, as it resulted in the same texture.

4. *Taste*

The ANOVA results showed that the interaction between red ginger and black rice addition had no significant effect on the organoleptic evaluation of taste. The independent addition of black rice also had no significant effect on the taste evaluation, while the independent addition of red ginger had a significant effect on the taste of the coffee beverage. The organoleptic test results of the independent effect of adding red ginger are shown in Table 3

Table 3. Independent effect of adding red ginger on the organoleptic evaluation of the taste of local Robusta coffee from Southeast Sulawesi

Treatment	Mean Organoleptic Taste ± SD	Category	DMRT 5%
J1 (4% red ginger)	3.39^{b} ± 0.37	Slightly like	
J2 (8% red ginger)	3.47^{b} ± 0.21	Slightly like suka	2 = 0.534
J3 (12% red ginger)	3.94^{a} ± 0.25	like	3 =0.560

Note: Numbers followed by different letters show significant differences based on the DMRT test 5% confidence level

Based on Table 3, the effect of adding red ginger to the coffee beverage significantly influenced the taste evaluation, with the highest rating for treatment J3 (3.94 - like) and the lowest for treatment J1 (3.39 - slightly like). The DMRT showed that treatment J3 differed significantly from J1 and J2. The addition of red ginger had a significant effect on the taste, likely due to the increasing spiciness as the percentage of red ginger added increased. This is probably due to the shogaol compounds resulting from the degradation of gingerol. Mardhatillah (2015) also found that the addition of ginger influenced the taste by creating a characteristic ginger-coffee flavor, composed of gingerol, zingerone, and shogaol, which contributed to the spicy taste of the spice-infused coffee syrup. Similarly, Ferry (1999) in Ikbal (2019) mentioned that ginger should not exceed 10% in coffee products, as excessive amounts can cause an overwhelmingly spicy taste due to the increased oleoresin content.

Analysis of the Physical-Chemical Properties of Local Robusta Coffee from Southeast Sulawesi

The results of the physical-chemical properties of the best treatment (J3B2) and the control treatment, as well as the coffee beans, are presented in Table 4.

Table 4. Results of the analysis of physical-chemical properties of local Robusta coffee from Southeast Sulawesi

Observation Variables	Treatment		
	Control (J_0B_0)	Best (J_3B_2)	Coffee Beans
Moisture content (%)	1.694 $\pm$ 0.229	1.113 $\pm$ 0.075	8.534 $\pm$ 0.260
Ash content (%)	3.848 $\pm$ 0.083	3.657 $\pm$ 0.331	4.465 $\pm$ 0.331
pH	5.73 $\pm$ 0.06	5.83 $\pm$ 0.12	6.07 $\pm$ 0.06
Caffeine content (%)	1.27 $\pm$ 0.02	0.72 $\pm$ 0.02	1.20 $\pm$ 0.00
Chlorogenic acid content (%)	3.94 $\pm$ 0.03	4.29 $\pm$ 0.08	7.46 $\pm$ 0.03
Antioxidant activity IC_{50} (ppm)	48.10 $\pm$ 1.47	39.28 $\pm$ 0.64	36.63

Note : J_0B_0 = treatment without the additional of reg ginger and black rice; J_3B_2 = treatment with the addition of 12% red ginger and 20% black rice

1. Moisture Content

The analysis of moisture content for the best treatment (J3B2) and the control treatment, as well as the coffee beans, is shown in Figure 1

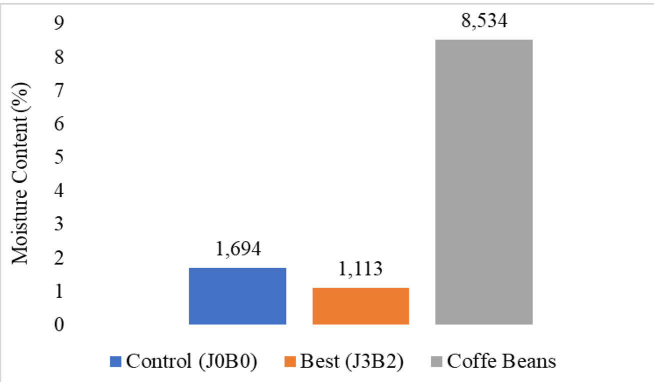

Figure 1. Analysis result graph of moisture content

Figure 1 shows that the lowest moisture content was found in the best treatment (J3B2) at 1.113%. The moisture content for the control treatment (J0B0) was 1.694%, and the moisture content for the coffee beans was 8.534%. The difference in moisture content is suspected to be due to the roasting process, which evaporates the moisture in the coffee beans. The coffee beans were roasted first, followed by the addition of red ginger and black rice, which caused more moisture to evaporate from the coffee beans compared to the ginger and black rice. This is consistent with Yusdiali (2013) in Muharram et al. (2017), who mentioned that roasting temperature and duration greatly affect moisture content. The higher the temperature, the more moisture evaporates, and the longer the roasting duration, the more the moisture decreases. The moisture content of the coffee powder in the best treatment and control met the standard for coffee powder quality (SNI Kopi Bubuk 01-3542-2004), which allows a maximum of 7% moisture (BSN, 2004).

2. Ash Content

The analysis of ash content for the best treatment (J3B2) and the control treatment, as well as the coffee beans, is shown in Figure 2.

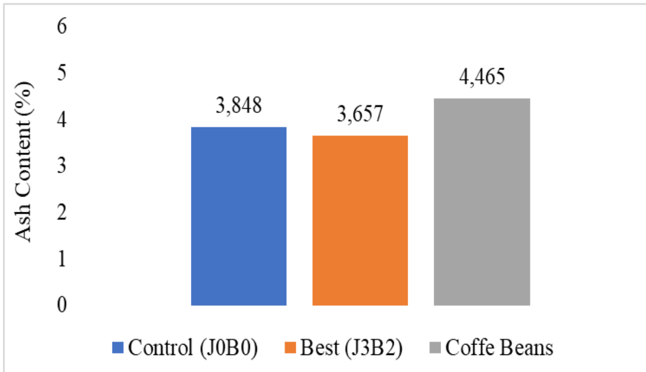

Figure 2. Analysis result graph of ash content

Figure 2 shows that the best treatment (J3B2) had the lowest ash content at 3.657% compared to the control treatment (3.848%) and the coffee beans (4.465%). This is suspected to be due to the use of different base materials, with 20% black rice in the J3B2 treatment. This is consistent with Muharram (2017), who noted that increasing the amount of black rice (40%) resulted in a decrease in ash content in the coffee powder. The difference is due to the higher mineral content in the coffee beans compared to black rice. Coffee beans contain minerals such as Na 4.0%, Fe 3.7%, and F 0.45% (Najiyati and Danarti, 2004), whereas black rice has an ash content of around 0.9% (Brilia et al., 2015). The ash content in the best treatment (J3B2) and the control treatment, as well as the Robusta coffee beans from Southeast Sulawesi, met the quality standard for coffee powder (SNI Kopi Bubuk 01-3542-2004), which allows a maximum of 5% ash content (BSN, 2004)

3. pH

The analysis of pH for the best treatment (J3B2) and the control treatment, as well as the coffee beans, is shown in Figure 3.

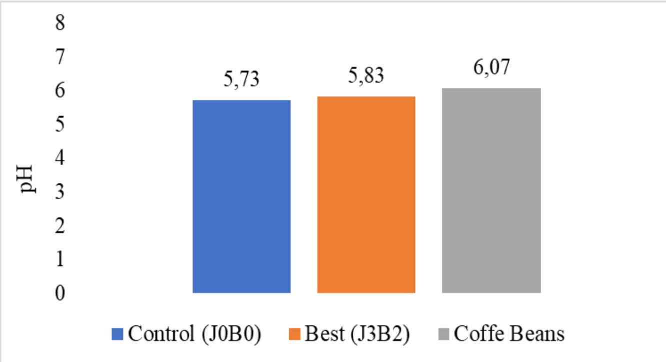

Figure 3. Analysis result graph of pH content

Figure 3 shows that the pH of the best treatment (J3B2) was 5.83, slightly higher than the pH of the control treatment (J0B0), which was 5.73, but lower than the pH of the coffee beans, which was 6.07. The difference in pH between the best treatment and the control treatment is due to the addition of 12% red ginger and 20% black rice, which increased the pH in the best treatment. Compared to the pH of the coffee beans, the best treatment had a lower pH due to the roasting process, which develops the characteristic acidic flavor of coffee. This is in accordance with Kustiyah (1985), who stated that coffee beverages with a pH between 4.9 and 5.2 are more preferred due to the desirable aroma.

4. *Caffeine Content*

The analysis of caffeine content for the best treatment (J3B2) and the control treatment, as well as the coffee beans, is shown in Figure 4

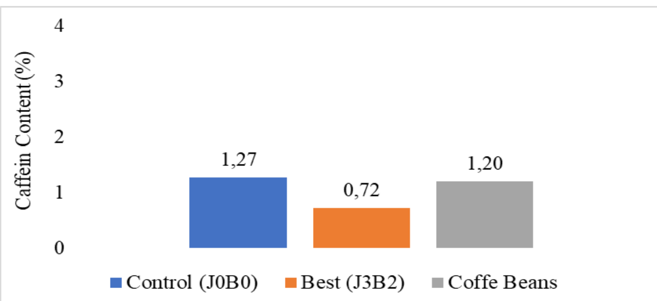

Figure 4. Analysis result graph of caffein content

Figure 4 shows that the best treatment (J3B2) had the lowest caffeine content at 0.72%, compared to the control treatment (1.27%) and the coffee beans (1.20%). The addition of 12% red ginger and 20% black rice likely reduced the caffeine content since black rice does not contain caffeine, but it has a high antioxidant content (Muharram, 2017). The caffeine content in the coffee powder from this study ranged from 0.72% to 1.27%, which is consistent with Fauzi et al. (2017), who stated that the lower the caffeine content, the better the quality of the coffee.

5. *Chlorogenic Acid Content*

The analysis of chlorogenic acid content for the best treatment (J3B2) and the control treatment, as well as the coffee beans, is shown in Figure 5.

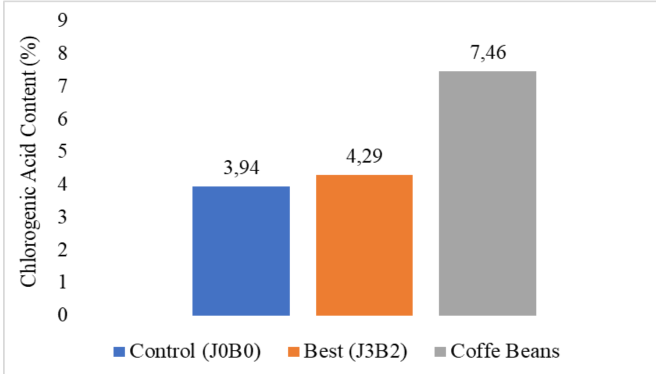

Figure 5. Analysis result graph of chlorogenic acid content

Figure 5 shows that the best treatment (J3B2) had a higher chlorogenic acid content compared to the control treatment (J0B0). The addition of 12% red ginger and 20% black rice increased the chlorogenic acid content. Red ginger contains chlorogenic acid, which contributes to the higher chlorogenic acid content in the best treatment. The chlorogenic acid content in the coffee beans was higher than in both treatments. This is suspected because during the roasting process, chlorogenic acid in coffee undergoes thermal degradation. Setyani et al. (2017) reported that during coffee roasting, most chlorogenic acid is hydrolyzed into caffeic acid and quinic acid.

6. *Antioxidant Activity*

The analysis of antioxidant activity for the best treatment (J3B2) and the control treatment, as well as the coffee beans, is shown in Figure 6.

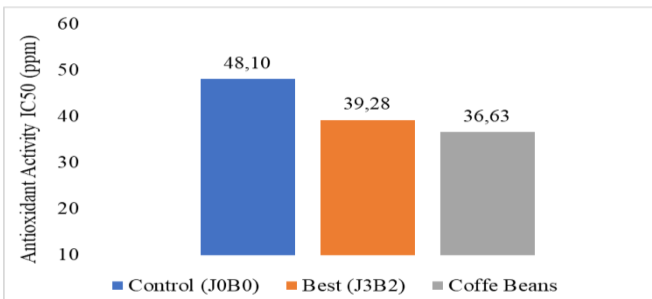

Figure 6. Analysis result graph of antioxidant activity IC50 (ppm)

Figure 6 shows that the antioxidant activity of the best treatment (J3B2), measured as IC50, was 39.28 ppm, which is higher compared to the control treatment (48.10 ppm). IC50 is the concentration of antioxidants (ppm) capable of neutralizing 50% of free radicals. The addition of 12% red ginger and 20% black rice increased the antioxidant activity in the best treatment compared to the control treatment. When compared to the antioxidant activity of the Robusta coffee beans from Southeast Sulawesi, the best treatment showed a lower antioxidant activity. This is because the roasting process reduces the antioxidant activity of coffee (chlorogenic acid), red ginger (gingerol and shogaol), and black rice (anthocyanin) due to the high heat. Belay et al. (2009) in Mangiwa et al. (2015) stated that a strong aroma is released when coffee is roasted at temperatures above 200°C, but the roasting process decreases the chlorogenic acid (antioxidant) content in the coffee. The darker the roasted coffee beans, the lower the chlorogenic acid content (Cammerer et al., 2006 in Mangiwa et al., 2015), and the higher the roasting temperature, the lower the antioxidant activity

Conclusion

The interaction between the addition of red ginger and black rice, as well as the independent addition of black rice, did not significantly affect the organoleptic evaluation of color, aroma, texture, and taste. However, the independent addition of red ginger had no significant effect on color and texture, but had a very significant effect on aroma and a significant effect on the taste of coffee. The best treatment was the addition of 12% red ginger and 20% black rice (J3B2), with organoleptic evaluations of color 3.75 (like), aroma 3.90 (like), texture 4.00 (like), and taste 4.03 (like).

The physical-chemical properties of the best treatment (J3B2) were: moisture content 1.113%, ash content 3.657%, pH 5.83, caffeine 0.72%, chlorogenic acid 4.29%, and antioxidant activity (IC50) 39.28 ppm. The moisture content and ash content of the coffee powder in the best treatment (J3B2) and control treatment met the coffee powder quality standards (SNI Kopi Bubuk 01-3542-2004)

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Author Contributions

Contributing scientific knowledge related to the development of coffee beverage products by adding red ginger and black rice to reduce caffeine levels and improve the taste of coffee products

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Conflicts of Interest

The author has no conflict of interest during the publication of this scientific work

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