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Synergetic Effects of *Coffea liberica* and *Curcuma zanthorrhiza*: Study of Sensory Profile, Proximate, and Chemical Compound

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Abstract: Liberica coffee (*Coffea liberica*) thrives on peat soil, unlike Arabica and Robusta, making it an essential commodity in Jambi, Indonesia, where it is known as Liberika Tungkal Komposit (Libtukom) and serves as a primary livelihood. This low-caffeine coffee has a higher economic value than high-caffeine varieties. Adding spices such as temulawak (*Curcuma zanthorrhiza*) to Liberica coffee can create a unique, functional beverage with new aromas and health benefits, thanks to the curcuminoid antioxidants in *Curcuma zanthorrhiza* (*C. zanthorrhiza*). This research aims to develop a spice-infused Liberica coffee with enhanced sensory qualities and health benefits. Methods include spice coffee formulation; sensory evaluation; phytochemical screening; and analysis of phenolics, flavonoids, antioxidants, caffeine, and chlorogenic acid levels. Statistical analysis (ANOVA and Duncan's post hoc test) reveals that *C. zanthorrhiza*-enhanced Liberica coffee is preferred by panelists, with spice coffee outperforming plain Liberica in sensory tests. This study showed that Liberica coffee mixed with *C. zanthorrhiza* affected the sensory performance of Liberica coffee, where the coffee most favored by panelists was spice coffee. Based on the cupping test results, spice coffee had excellent results, while Liberica coffee had very good results. The phytochemical analysis revealed that coffee–*C. zanthorrhiza* exhibited higher concentrations of total phenolics, flavonoids, and antioxidant activity than the original Liberica coffee. However, the caffeine and chlorogenic acid levels in all spiced coffee were lower compared to the original Liberica coffee.

Keywords: *Curcuma zanthorrhiza*; Liberica coffee; sensory profile; synergetic

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1. Introduction

Coffee not only plays an important role as a source of foreign exchange but also as a source of income for coffee farmers in Indonesia [1]. There are various types of coffee grown in Indonesia, including Arabica, Robusta, and Liberica. Liberica coffee contains less caffeine than Arabica and Robusta [2]. Generally, Liberica coffee is known to have a caffeine content of 1.32%, lower than Arabica coffee, at 1.77%, and Robusta, at 2.15% [3]. Liberica coffee is a plantation crop well-suited for cultivation on peat soils, unlike other coffee varieties such as Arabica and Robusta, which are unable to thrive in such conditions [4]. Liberica coffee has been cultivated for generations across various provinces in Indonesia, including Jambi, Riau,

and South Sumatera. It is grown in nutrient-rich peat soil in harmony with native forests; Liberica thrives within a unique agroforestry system. Unlike the more widely known Arabica and Robusta varieties, Liberica offers a truly unique taste experience with its unmistakable hint of jackfruits, which has earned it the nickname "jack coffee" in some regions. This rare flavor profile, combined with its deep cultural roots, makes Liberica coffee a treasured gem in Indonesia coffee [5]. Coffee has high caffeine levels that can affect health. Therefore, decaffeinated coffee (lower caffeine) is a good and safe alternative drink for consumers who are sensitive to caffeine [6]. A more sensible alternative approach to producing decaffeinated coffee involves the addition of spices to coffee beverages. This method is promising to reduce the caffeine content effectively. Spices commonly used in coffee making are cardamom, cinnamon [7], ginger [8], swallow's nest, black cumin, and cloves [9].

Indonesia is also rich in spices, one of which is temulawak. Temulawak (*Curcuma zanthorrhiza*) is one of the medicinal plants of the Zingiberaceae family that is widely grown and used as raw material for traditional medicine in Indonesia [10]. *C. zanthorrhiza* plants are empirically widely used as single or mixed drugs. There are more than 50 traditional medicine recipes using temulawak [11]. The existence of *C. zanthorrhiza* as a medicinal plant has long been recognized, especially among the community. The rhizome part of temulawak is the main ingredient in this research.

In vitro testing of *C. zanthorrhiza* rhizomes has shown its many benefits, one of which is its potential as an antioxidant [11]. The bioactive components in temulawak rhizomes that are responsible for antioxidants are curcumin, demethoxycurcumin, and bisdemethoxycurcumin [12]. In addition, a number of compounds were obtained in temulawak rhizomes, including water, 19.98%; starch, 41.45%; fiber, 12.62%; ash, 4.62%; acid insoluble ash, 0.56%; water essence, 10.96%; alcohol essence, 9.48%; and curcumin, 2.29%. From the test results, it was also found that the content of alkaloids, flavonoids, phenolics, triterpenoids, tannin glycosides, saponins, and steroids was thought to be the cause of the efficacy of temulawak [13].

Coffee with added spices can reduce caffeine levels and enhance radical scavenging activity. The combination of species in coffee plays a role in providing a synergetic effect so that it can produce new aromas and flavors. Moreover, adding spices to coffee can enhance its pharmaceutical properties, transforming it into a functional beverage that is beneficial for health. The coffee–spice combination plays a key role in improving the overall coffee quality by changing its chemical content and flavor profile [14]. Adding spices can impart an acceptable aroma; offer refreshing and warming effects; aid in detoxifying the body; and help eliminate toxins through urine, feces, and sweat [15]. Research on the effects of adding spices to Liberica coffee still needs to be completed. Notwithstanding, our previous study demonstrated that the addition of cinnamon exhibits significantly enhanced total flavonoid and phenolic content, as well as antioxidant activity, in Liberica coffee [16]. Several previous studies have only focused on the analysis of spice combinations with Arabica or Robusta coffee. This study examines how the addition of *C. zanthorrhiza* to Liberica coffee affects the sensory profile of coffee, chemical compounds, antioxidant activity, and proximate analysis. Combining spices and ingredients with coffee, particularly Liberica coffee, can enhance its quality, positioning it as a functional and lifestyle beverage. This combination improves the sensory attributes and increases the health benefits, resulting in antioxidant-rich herbal coffee products. Antioxidants play a crucial role in inhibiting oxidative processes in the body, thereby reducing the risk of diseases associated with oxidative stress, such as cardiovascular disorders, neurodegenerative diseases, and certain cancers. Liberica coffee can offer a flavorful experience and significant health-promoting properties by incorporating herbal elements.

2. Materials and Methods

2.1. Materials and Equipment

The materials used in this study were coffee Liberica beans (*Coffea liberica*) purchased from CV. Haji Bangun Kopi Liberika from Tanjung Jabung Timur Regeny and *C. zanthorrhiza* from CV. Kawa Kerinci from Kerinci Regency, Jambi Province, Indonesia. Other materials used consisted of distilled water (ddH_2O), MeOH (p.a), acetone, HCl, gallic acid standard, ethanol P.A., Folin–Ciocâlteu reagent, Na_2CO_3, quercetin standard, $AlCl_3$, CH_3COONa, formic acid, acetonitrile, caffeine standard, chlorogenic acid standard, trigonelline standard, K_2SO_4, $CuSO_4$, H_2SO_4 concentrated, NaOH, PP indicator, n-hexane, Luff-Schoorl solution, CaCl, Na_2SO_3, amylum indicator, 2,2-diphenyl-1-picrylhydrazy (DPPH), dichloromethane (DCM), and ascorbic acid standard (Sigma-Aldrich, Singapore). Equipment used during the study included a Rotary Evaporator (BUCHI R-300 System, Büchi Labortechnik AG, Flawil, Switzerland), Coffee Roaster Machine Pratter 1.5 (Pratter, Banjarsari Surakarta, Central Java, Indonesia), Coffee Grinder (ICRRI, Jember, Indonesia), Analytical balance, centrifuge tubes, glassware, vortex mixer tools, centrifugation tools, Whatman 54, 41 or 541 filter paper, 0.45 µm membrane filter, crucibles and lids, oven, desiccator, furnace, Kjeldahl flask, a set of distillation apparatus, a set of titration apparatus, a set of Soxhlet apparatus, Buchner funnel, reflux apparatus, glassware, drop pipette, and stirring rod. Analysis in this study using Ultraviolet–Visible spectroscopy (UV-Vis) and Gas Chromatography–Mass Spectrometry (GC-MS) (Thermo-Fischer Orion Scientific, Waltham, MA, USA). Some limitations in this study: This study did not use raw material variability, roasting temperature, or component interactions. Phytochemical analysis is only on total phenolics, flavonoids, caffeine, chlorogenic acid, and antioxidants.

2.2. Sample Preparation

Roasting coffee: The samples studied were the coffee beans of Liberica (*Coffea liberica*) and *C. zanthorrhiza*. The dried coffee beans were roasted at 203 °C for 12 min. Furthermore, the cooled coffee beans were pulverized using a grinder until a fine coffee powder was obtained [17]. *C. zanthorrhiza* drying: *C. zanthorrhiza* was washed, cut, and then dried using an oven-drying technique, at 60 °C for 25 min to 30 min [16]. The combination coffee–*C. zanthorrhiza* was formulated with different ratios (Table 1).

Table 1. Sample codes.

No.	Sample Codes	Information Ratio (%)
1	CB	*C. zanthorrhiza* (100%)
2	CO	Coffee Liberica (100%)
3	CH1	Coffee: *C. zanthorrhiza* (99:1)
4	CH2	Coffee: *C. zanthorrhiza* (97:3)
5	CH3	Coffee: *C. zanthorrhiza* (95:5)

2.3. Cupping Test

The roasted coffee and ground coffee, processed to a fine powder (20-mesh size), were brewed using 150 mL of hot water at a temperature between 94 and 96 °C to prepare samples for sensory profile evaluation. The sensory analysis was conducted by a panel of three experts from the Jambi Cupper Team, Q-Graders from Lymphocyte Coffee Workshop Shah Alam Jaya Ltd, Jambi, Indonesia. The sensory profile was carried out using the SCAA (Specialty Coffee Association of America) scoring system. The scoring ranged from 1 to 10, depending on the coffee's quality. This evaluation method assesses the coffee's aroma, flavor, body, acidity, and aftertaste. It provides a comprehensive profile of its sensory

qualities that is crucial for determining the overall quality and consumer acceptability. Panelists rated each sensory attribute with a score from 6.00 to 6.75 as good, from 7.00 to 7.75 as very good, from 8.00 to 8.75 as excellent, and from 9.00 to 10.00 as outstanding. The final score was obtained by summing the scores of each attribute [18].

2.4. Sample Extraction

The sample (1 g) was extracted into 40 mL of a MeOH-ddH_2O (with ratio 1:1 v/v) solution. This solvent mixture is commonly used to efficiently extract bioactive compounds, including phenolics and flavonoids, due to its ability to dissolve polar and non-polar substances. The resulting extract is often subjected to further analysis to determine the concentration of crucial phytochemicals and assess antioxidant properties, critical for evaluating the sample's functional and health-related potential. Hydrochloric acid (HCl) was added until the mixture reached a pH of 2, followed by vortexing for 3 min. The solution was centrifuged at 4500× g rpm for 10 min, and the resulting supernatant was collected as "Extract 1". The remaining pellet was treated with 40 mL of acetone (70%; acetone/water), vortexed for 3 min, and then centrifuged again. The supernatant from the second extraction was combined with Extract 1 to obtain the final liquid extract [19].

2.5. Total of Phenolics Content (TPC) and Total of Flavonoids (TFC)

Total phenolics content (TPC): A 1000 ppm liquid extract sample and a series of gallic acid (GA) standard solutions at 10, 20, 30, 40, and 50 ppm were each measured at 1 mL. To each, 0.4 mL Folin–Ciocâlteu was added, followed by gentle shaking and incubation at RT for 4–8 min. Next, 4 mL of a 7% Na_2CO_3 solution was added, and the volume was adjusted to 10 mL with distilled water. The mixture was then kept in a dark environment at room temperature for 2 h. Finally, the absorbance was measured at a wavelength of 745 nm [20].

Total Flavonoids Content (TFC): A 1 mL aliquot of 1000 ppm liquid extract and a 1 mL aliquot from a series of quercetin standard solutions (concentrations of 10, 20, 30, 40, and 50 ppm) were each combined with MeOH (3 mL), $AlCl_3$ 10% (0.2 mL), and CH_3COONa 1M (0.2 mL). The mixture was then diluted to a final volume of 10 mL with distilled water. Samples were incubated in a dark environment at room temperature for 30 min. Absorbance readings were obtained using a UV-Vis spectrophotometer at a wavelength of 510 nm [21]. The absorbance data from the gallic acid standard solutions were used to generate a calibration curve correlating concentration and absorbance, yielding a linear equation for calculating the total phenolic content in the samples. The calibration curve for the gallic acid standards is shown in Figure 1.

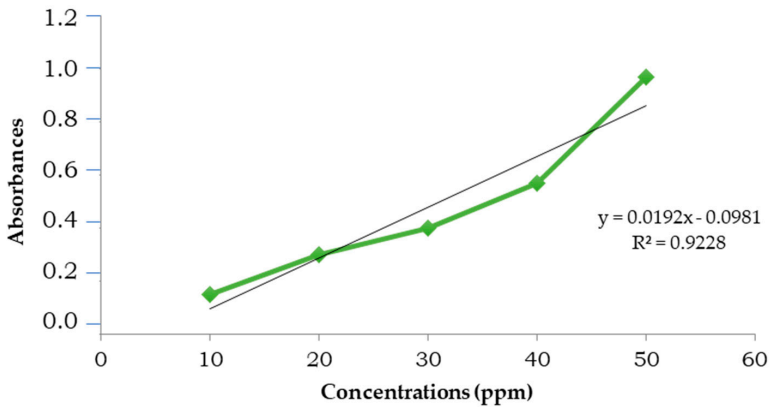

Figure 1. Calibration curve of gallic acid standard solution. The green line represents a linear regression, it means a straight line has been calculated to best fit the data points. Linear regression minimizes the sum of squared differences (errors) between observed data points and the predicted values on the line.

From the calibration curve of gallic acid standard solution in Figure 1 which uses 5 series of standard solutions with a concentration range of 10–50 ppm, the regression line equation y = 0.0192x − 0.0981 is obtained, with an R^2 value of 0.9228. In measuring the absorbance of the sample, two replications were made for data accuracy purposes.

Quercetin was used as a standard solution, which was prepared in five different concentrations: 10, 20, 30, 40, and 50 ppm. Quercetin was measured at a peak of 431 nm. Then, we obtained the absorbance value of quercetin standard at each concentration. The results of the absorbance of the standard solution were used to make a calibration curve that connects the concentration to the absorbance so as to obtain a linear line equation used to calculate the total flavonoid content in the sample. The calibration curve of quercetin standard solution is presented in Figure 2.

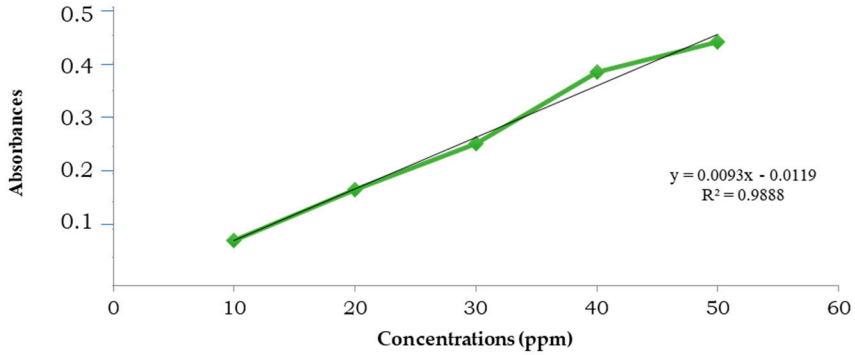

Figure 2. Calibration curve of quercetin standard solution. The green line represents a linear regression, it means a straight line has been calculated to best fit the data points. Linear regression minimizes the sum of squared differences (errors) between observed data points and the predicted values on the line.

2.6. Total Caffeine and Chlorogenic Acids

Caffeine content: A total of 1 g of the samples was dissolved in 150 mL of boiled ddH_2O (approximately 93 °C), with continuous stirring. The samples were then filtered to obtain a filtrate and then transferred into a separatory funnel. Next, 1.5 g of $CaCO_{3(S)}$ was added to the filtrate and then extracted with $CHCl_3$ for 15 min. It was evaporated in 60 °C water bath system. The extract was transferred to a volumetric flask, diluted with ddH_2O up to 100 mL, and thoroughly mixed. Then, 50 mL of the extract was diluted with 100 mL ddH_2O. The caffeine content was measured by a UV-Vis spectrophotometer at 280 nm, the maximum wavelength measured before. Determination of the maximum wavelength was carried out in the wavelength range of 200–400 nm, and the measurement results obtained the maximum wavelength value of the caffeine standard solution, i.e., 286 nm. Absorbance measurements of both the test solution and a series of caffeine standard solutions (at concentrations of 5, 10, 15, 20, and 25 ppm) were taken at the determined maximum wavelength using the UV-Vis spectrophotometer [22]. Then, the absorbance value of caffeine was set at each concentration. The results of the absorbance of the standard solution made a calibration curve that connects the concentration to the absorbance to obtain a linear equation used to calculate the caffeine content in the sample. The calibration curve of the caffeine standard solution is presented in Figure 3.

From the calibration curve of the caffeine standard solution in Figure 3, which uses 5 series of standard solutions with a concentration range of 5–25 ppm, the regression line equation y = 0.0151x − 0.0768 is obtained, and R^2 is 0.9959. Two replications were made to measure the absorbance of the sample for data accuracy purposes.

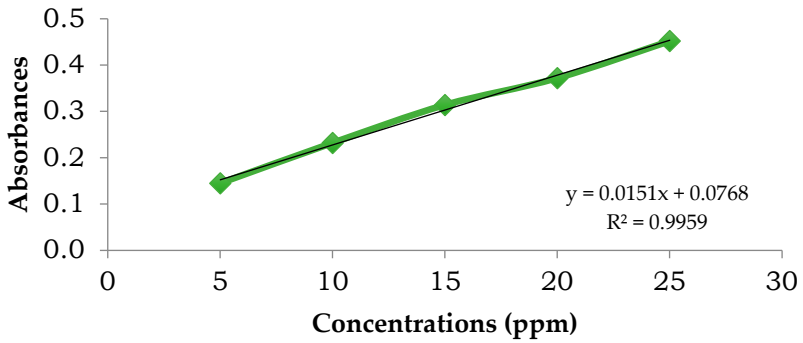

Figure 3. Calibration curve of caffeine standard solution.

Chlorogenic acid (CGA) content: A total of 4.8 mL of the sample coffee extract was added to 25 mL of distilled water. The mixture was stirred continuously for 1 h, using a magnetic stirrer, while heating to 100 °C to ensure thorough extraction. The extraction process was conducted by adding 25 mL of DCM to the sample to separate caffeine and chlorogenic acid. The solution was stirred for an additional 10 min to enhance phase separation. Subsequently, the aqueous and DCM phases were separated using a separatory funnel. The aqueous phase, containing chlorogenic acid, was carefully collected for further analysis. The maximum absorbance wavelength of the CGA solution was determined by scanning over a range of 200–400 nm using a UV-Vis spectrophotometer. For quantification, the absorbance of the test solution and a series of CGA standard solutions (10, 20, 30, 40, and 50 ppm) was measured at the identified maximum wavelength. The calibration curve constructed from the standards was used to calculate the chlorogenic acid concentration in the sample, ensuring accurate and reliable quantification. This method is critical for assessing the bioactive compound profile of coffee and related products, particularly given chlorogenic acid's antioxidant properties and potential health benefits [23].

2.7. Antioxidant Activities

A total of 1.97 mg of DPPH was dissolved in 100 mL of MeOH to obtain 50 µM of DPPH. The standard of ascorbic acid solution was prepared at four concentration variations of 0, 10, 30, and 50 ppm. The test-sample solution was also prepared at four concentration variations. Aliquots containing 0.2 mL of test sample and standard were each added to 3.8 mL of 50 µM DPPH solution. The mixture was homogenized and incubated in the dark for 30 min (RT). Furthermore, the absorbance value was measured using UV-Vis spectroscopy at a wavelength of 517 nm, using a UV-Vis spectrophotometer [24]. The scavenging activity was calculated as the percentage of inhibition using Equation (1).

$$\text{DPPH scavenging activity (\% Inhibition)} = (A_0 - A_1)/A_0 \times 100\% \quad (1)$$

where A_0 is the absorbance of the control (DPPH solution without sample), and A_1 is the absorbance of the sample (DPPH solution with antioxidant samples).

The inhibition curve was created by plotting % inhibition against the logarithm of the sample concentrations. Linear regression is observed using Equation (2a), and IC_{50} is calculated using Equation (2b).

$$y = ax + b \quad (2a)$$

$$IC_{50} = (50 - b)/a \quad (2b)$$

where y is % inhibition, x is log of concentration, m is slope, and c is intercept.

2.8. Proximate Analysis

Determination of moisture content: A petri dish was initially weighed and dried in an oven at 105 °C for 24 h. After cooling for 1 h, 2 g of sample was added to the petri dish, which was then heated again at 1050 °C for 48 h. The final mass was measured, and the water content percentage was calculated using Equation (3).

$$\%\text{Moisture content} = \frac{\text{IM(g)} - \text{F(g)}}{\text{IM(g)} - \text{MEC(g)}} \times 100\% \quad (3)$$

where FM = final mass, MEC = mass of the empty cup, and IM = initial mass.

Determination of ash content: The petri dish was first weighed and then dried in an oven at 105 °C for 24 h. After allowing it to cool for 1 h, 2 g of sample was placed in the dish, which was subsequently heated at 550 °C in a furnace for an additional 3 h. Furthermore, the sample was allowed to cool in a desiccator for 30 min [25]. The final weight was recorded, and the percentage of ash content was calculated using Equation (4).

$$\%\text{Ash content} = \frac{\text{FM} - \text{MEC}}{\text{IMs} - \text{MEC}} \times 100\% \quad (4)$$

where FM = final mass, MEC = mass of the empty cup, and IM = initial mass.

Determination of protein content: A 1 g sample, accompanied by 7 g of K_2SO_4 and 0.8 g of $CuSO_4$, was placed into a 100 mL Kjeldahl flask. Subsequently, 15 mL of concentrated H_2SO_4 was carefully added. The flask was gradually heated, beginning at room temperature, and the temperature was steadily increased until the mixture reached a boiling point. The digestion process continued until the solution became clear and greenish, signifying completion. The digested solution was diluted with 100 mL of distilled water for the distillation step. Following this, 10 mL of NaOH solution (30%) was introduced along the inner wall of the distillation flask. Steam generated from the boiling mixture was collected and added to an Erlenmeyer flask containing 10 mL of HCl (0.1N) and phenolphthalein (pp) indicator. Furthermore, the distillate collected in the Erlenmeyer flask was titrated with 0.1 N NaOH. The titration endpoint was identified by a color change from colorless to pink. A blank sample, prepared without the test substance, was titrated under identical conditions. Finally, the protein content was calculated using Equation (5).

$$\%\text{Protein content} = \frac{(\text{V} - \text{V}_0)}{\text{IN}} \times 0.014 \times \text{CF} \times \text{DF} \times 100\% \quad (5)$$

where IN is the mass of the sample (g), V is the volume of NaOH used for titration of the sample (mL), V_0 is the volume of NaOH used for titration of the blank (mL), N is the normality of NaOH (mol/L), CF is the conversion factor, and DF is the dilution factor.

Determination of carbohydrate content: A 1 g sample was combined with 50 mL of distilled water and 10 mL of 25% HCl. The mixture was refluxed at 100 °C (3 h) and cooled to room temperature. The phenolphthalein (PP) indicator was added, and the solution was neutralized with 20% NaOH while monitoring the pH using a universal indicator. The neutralized solution was transferred to a 250 mL volumetric flask and diluted to the calibration mark with distilled water. A 10 mL aliquot of the prepared solution was mixed with 10 mL of Luff-Schoorl reagent and refluxed (10 min), starting from the onset of boiling. After refluxing, the solution was cooled in an ice bath.

Into the sample, about 5 mL of 20% KI and 5 mL of 25% H_2SO_4 were carefully added. The mixture was immediately titrated with 0.1 N $Na_2S_2O_3$ until it developed a straw-yellow color. At this point, three drops of the starch indicator were introduced, and titration continued until the blue color completely disappeared. A blank titration, prepared using

distilled water in place of the sample, was conducted under identical conditions. The carbohydrate content was determined using Equations (6) and (7).

$$\text{VNt} = (\text{VNb} - \text{VNs}) \times [\text{N}_t] \times 10 \quad (6)$$

$$\%\ \text{Carbohydrate} = \frac{\text{WN} \times \text{DF}}{\text{WS}} \times 0.9 \times 100\% \quad (7)$$

where VNt = $Na_2S_2O_3$ used (mL), VNb = blank titration of $Na_2S_2O_3$ (mL), VNs = sample titration of $Na_2S_2O_3$ (mL), [N_t] = normality of $Na_2S_2O_3$ (N), WS = weight of sample (mg), WN = glucose contained per mL of $Na_2S_2O_3$ (mg), and DF = dilution factor.

Determination of fat content: About 5 g of sample was extracted using n-hexane, in 69 °C. The extraction process ran for approximately 12 cycles within a 6 h extraction time. Additionally, the solvent was distilled to obtain the fat, and the fat was heated at 105 °C for 1 h. Once heated, the fat was cooled in a desiccator for 15 min before weighing. The remaining mass represented the fat weight, which was calculated as the fat content using Equation (8).

$$\%\ \text{Fat} = \frac{\text{IFE(g)}}{\text{IMS(g)}} \times 100\% \quad (8)$$

where IFE = initial fat extracted (g), and IMS = initial mass of sample (g)

2.9. Data Analysis

The data obtained from the phenol content, caffeine content, and antioxidant activity tests were analyzed by ANOVA (analysis of variance), and if the treatment was affected by the observed variables, it was continued with the Duncan's Multiple Range Test (DMRT) test. Sensory with organoleptic tests was carried out using the Chi-Square Test to determine the treatment ranking [16].

3. Results

3.1. Sensory Profile

The sensory profile is a test performed by Q-Grader experts to identify and assess the sensory attributes of coffee. This study measured the sensory profile to assess the quality and characteristics of coffee mixed with *C. zanthorrhiza*. There are several aspects to consider, including aroma, flavor, texture, acidity, sweetness, balance, body, uniformity, aftertaste, clean cup, and an overall score of coffee. The average score was calculated, and the results were used to determine coffee quality standards. The sensory profile present in Table 2 shows that, of the two samples with very good results, the CO (original Liberica coffee) and CH1 (coffee/*C. zanthorrhiza* with a ratio of 99:1). The other two samples, CH2 (coffee/*C. zanthorrhiza* with a ratio of 97:3) and CH3 (coffee: *C. zanthorrhiza* with a ratio of 95:5), are in the excellent category. The data results (Table 2) state that CH3 has the highest total score value compared to CO, CH1, and CH2. Compared to the existing samples, CH3 outperformed the aroma, flavor, and balance parameters.

Table 2. Sensory profile of coffee/*C. zanthorrhiza*.

Parameters	Samples			
	CO ± SD	**CH1 ± SD**	**CH2 ± SD**	**CH3 ± SD**
Aroma	7.58 ± 0.02	7.13 ± 0.12	7.17 ± 0.12	7.17 ± 0.11
Flavor	7.67 ± 0.04	6.92 ± 0.01	7.08 ± 0.01	7.42 ± 0.01
Aftertaste	7.67 ± 0.15	6.92 ± 0.08	7.17 ± 0.03	7.25 ± 0.02
Acidity	7.77 ± 0.09	6.83 ± 0.08	7.08 ± 0.03	7.42 ± 0.05
Body	7.67 ± 0.09	6.58 ± 0.08	7.17 ± 0.04	7.08 ± 0.05

Table 2. *Cont.*

Parameters	Samples			
	CO ± SD	**CH1 ± SD**	**CH2 ± SD**	**CH3 ± SD**
Uniformity	8.00 ± 0.00	10.00 ± 0.00	10.00 ± 0.03	10.00 ± 0.00
Balance	7.67 ± 0.08	6.58 ± 0.15	6.92 ± 0.05	7.33 ± 0.05
Clean cup	8.00 ± 0.00	10.00 ± 0.00	10.00 ± 0.00	10.00 ± 0.00
Sweetness	8.00 ± 0.00	10.00 ± 0.00	10.00 ± 0.00	10.00 ± 0.00
Overall	7.67 ± 0.08	6.25 ± 0.07	6.75 ± 0.07	7.08 ± 0.07
Total score	7.77 ± 0.073	7.72 ± 0.078	7.93 ± 0.051	8.08 ± 0.051
Category	**	**	***	***
Final score	77.7 ± 0.073 [a]	77.2 ± 0.078 [a]	79.3 ± 0.051 [b]	80.8 ± 0.051 [c]
Group	Premium	Premium	Specialty	Specialty

CO = coffee Liberica; CH1 = coffee + *C. zanthorrhiza* (99:1); CH2 = Cofffe + *C. zanthorrhiza* (97:3); CH3 = coffee + *C. zanthorrhiza* (95:5). [a,b,c] superscripts with distinct letters within the same column significant differences ($p < 0.05$). SD represents the standard deviation; ** very good; *** excellent.

3.2. Total Phenolic and Flavonoid

Phenolic compounds are one of the compounds present in plants and have various benefits, one of which is as that they have an antioxidant effect. Phenols help reduce free radicals by giving up one electron from their -OH group, which helps stabilize the free radical. There is a positive correlation between the number of phenolic compounds and antioxidant activity; the more phenolic compounds present, the greater the antioxidant capacity. One example of a phenolic compound is gallic acid, which has three phenolic hydroxyl groups. Gallic acid can be oxidized by Folin–Ciocâlteu reagent in an alkaline atmosphere. This reagent will oxidize the phenolic hydroxyl group in gallic acid and form a molybdenum–tungsten complex that produces a yellow color, which is an indicator of the presence of phenolic compounds. This study uses additional Na_2CO_3 in the sample solution in the phenolic test. This aims to create an alkaline atmosphere, as the Folin–Ciocâlteu reagent reacts to the sample in alkaline conditions caused by phenolic hydroxyl groups in the sample [26].

The results revealed that there was an increase observed in the samples which was directly proportional to the increase in the levels of ginger added to Liberica coffee. This is in accordance with the previous research [27]: The addition of *C. zanthorrhiza* substances to food will increase the pH value and total phenolics but has the potential to reduce the value of total titrated acid and total soluble solids. Further explained, the relationship of phenolic content in a solution mixed with *C. zanthorrhiza* will increase the antioxidant activity that captures free radicals DPPH and IC_{50}. The phenolic content of CH3, measured at 49.146 mgGAE/g, was higher than that of CO. This increase is attributed to the presence of *C. zanthorrhiza*, which has the highest phenolic content among the combinations.

Total flavonoids: Flavonoids are the most widely found group of phenol compounds in nature. The total flavonoid content in all extract samples was determined by using a UV-Vis spectrophotometer. In this test, quinones are used as the standard because quinine is a type of flavonol flavonoid with a ketone group at the C-4 atom and a hydroxyl group at the neighboring C-3 and C-5 atoms.

The calibration curve of quercetin standard solution in Figure 2 uses five series of standard solutions with a concentration range of 10–50 ppm, and the regression line equation $y = 0.0093x - 0.0119$ was obtained. The R^2 value of 0.9888 is nearly equal to 1, indicating that the regression equation is linear, and the absorbance and concentration have a robust correlation. Two replications were made to measure the absorbance of the sample for data accuracy. The results of the total flavonoids are presented in Table 3.

Table 3. Result of total phenolics and flavonoids content.

Samples	TPC (mgGAE/g ± SD)	TFC (mgQE/g ± SD)
CB	103.313 [a] ± 0.037	34.452 [a] ± 0.076
CO	42.271 [b] ± 0.037	8.43 [b] ± 0.001
CH1	43.313 [c] ± 0.037	18.323 [d] ± 0.001
CH2	46.542 [d] ± 0.037	20.903 [e] ± 0.009
CH3	49.146 [e] ± 0.010	24.667 [c] ± 0.076

CO = Coffee Liberica; CH1 = coffee + *C. zanthorrhiza* (99:1); CH2 = coffee + *C. zanthorrhiza* (97:3); CH3 = coffee + *C. zanthorrhiza* (95:5); CB = *C. zanthorrhiza*. [a,b,c,d,e] Superscripts with distinct letters within the same column significant differences ($p < 0.05$). SD represents the standard deviation.

The results indicate that the highest average flavonoid content was 24.667 QE/g, whereas CO had the lowest flavonoid content among all samples, with an average of 8.43 QE/g. Research by [28] shows that coffee is a rich source of flavonoids, especially in organic coffee. The flavonoid concentration in coffee varies depending on the roasting conditions, with levels ranging from 8.6 mg per 100 mL under light roast conditions, 6.3 mg per 100 mL for medium roasts, and 5.1 mg per 100 mL in dark roasts. Based on these data, it can be concluded that temulawak has high flavonoid compounds compared to original coffee. The increase in flavonoids is due to the addition of temulawak to the original Liberica coffee.

3.3. Caffeine and Chlorogenic Acid Content

Caffeine content: Caffeine is a type of alkaloid that belongs to the group of xanthine derivatives and is found in almost all types of coffee. Caffeine, 1,3,7-trimethyl xanthine, is usually found in tea, cocoa, and coffee. Determination of the maximum wavelength aims to obtain a wavelength that gives maximum absorption for the analyte to be analyzed. The maximum wavelength is used to determine the calibration curve and the caffeine content in the sample.

Based on Table 4, it is known that the order of highest caffeine to lowest caffeine is CO, CH1, CH2, and CH3, with a value of 0.858, 0.761, 0.657, and 0.559, respectively. The high caffeine content in CO is because CO specimens consist entirely of coffee. The same was reported by previous studies [29], that the ratio between coffee and its ingredients, such as water, milk, or mixed ingredients, affects the caffeine content contained in coffee. The highest percentage of caffeine content will always be obtained by coffee with more coffee powder than mixed coffee.

Table 4. Results of caffeine and chlorogenic acid content (CGA).

Samples	Caffeine (%) ± SD	CGA (%) ± SD
CH3	0.559 [a] ± 0.041	2.611 [a] ± 0.002
CH2	0.657 [b] ± 0.031	2.788 [b] ± 0.001
CH1	0.761 [c] ± 0.044	2.893 [c] ± 0.001
CO	0.858 [d] ± 0.001	2.984 [d] ± 0.005
CB	0.000 [d] ± 0.000	0.000 [d] ± 0.000

CO = coffee Liberica; CH1 = coffee + *C. zanthorrhiza* (99:1); CH2 = coffee + *C. zanthorrhiza* (97:3); CH3 = coffee + *C. zanthorrhiza* (95:5); CB = *C. zanthorrhiza*. [a,b,c,d] Superscripts with distinct letters within the same column significant differences ($p < 0.05$). SD represents the standard deviation.

Chlorogenic acid (CGA): Chlorogenic acid is a polyphenolic compound with polar properties that allow it to dissolve in water. Chlorogenic acid affects the flavor and aroma

characteristics of processed coffee [30]. The presence of chlorogenic acid is instrumental in determining coffee beans' quality, flavor, and aroma. In this study, UV-Vis spectrophotometric was used to determine the CGA at a 323.4 nm wavelength. Selecting the maximum wavelength was essential to identify the wavelength that produces peak absorption for the analyte. This maximum wavelength was then applied to create a calibration curve and to quantify chlorogenic acid in the sample. The optimal wavelength was determined within the range of 200–400 nm, resulting in a maximum absorption for chlorogenic acid at 323.4 nm. Chlorogenic acid standard solutions with concentrations of 10, 20, 30, 40, and 50 ppm were then measured at this wavelength, and the absorbance for each concentration was recorded. These absorbance values were used to construct a calibration curve, which plotted concentration against absorbance, producing a linear equation. This equation was subsequently used to calculate chlorogenic acid levels in the sample. The calibration curve for the chlorogenic acid standard solution is presented in Table 4.

It was found that the highest chlorogenic acid content in the specimen was obtained by CO (2.984%), followed by CH1 (2.808%), CH2 (2.788%), and CH3 (2.611). The high chlorogenic acid in original coffee is due to the presence of compounds that form chlorogenic acid in coffee. There are at least 30 types of chlorogenic acids contained in coffee, such as *caffeoylquinic acids* (CQAs), *dicaffeoylquinic acids* (DCQAs), tricaffeoylquinic acids (TCQAs), *feruloylquinic acids* (FQAs), and *p-coumaroylquinic acids* (p-CoQAs) [31]. On the other hand, some studies suggest that 5-caffeoylquinic acid (5-CQA) and 3,5-dicaffeoylquinic acid (3,5-DCQA) are the main chlorogenic acids found in coffee by-products [32].

The difference in chlorogenic acid content in the composition of coffee blends may be due to the form of solvent and the roasting effect on coffee. Different blends or solvents in coffee can reduce or increase chlorogenic acid levels in coffee blends. Meanwhile, the roasting effect decreases chlorogenic acid substances in coffee. This is due to the effect of temperature on chlorogenic acid. Most of the chlorogenic acid becomes caffeine and quinic acid during roasting [33].

3.4. Antioxidant Activity

Antioxidants are defined as chemical substances that are able to neutralize free radical agents. These substances work by providing electrons to achieve stability, thus inhibiting oxidative processes that can cause degenerative diseases [34]. Antioxidants can include various types of compounds, both of natural origin and artificially synthesized (synthetic). Antioxidant activity produced from food ingredients can be measured using the DPPH method. IC_{50} (inhibition concentration) is the concentration of sample solution needed to inhibit 50% of DPPH free radicals. The smaller the IC_{50} states, the stronger the antioxidant is in warding off free-radical DPPH, i.e., in terms of having stronger antioxidant activity.

It seems that CH3 has a higher antioxidant activity compared to *C. zanthorrhiza*, IC_{50} 4.984 ppm and 6.1408 ppm, as coffee contains various antioxidant compounds, such as chlorogenic acid, caffeine, and trigonelline (Table 5). Chlorogenic acid, in particular, is an abundant antioxidant compound in coffee and has strong antioxidant activity [28,34]. On the other hand, *C. zanthorrhiza* contains curcumin, also known as an antioxidant compound [13]. Phenolics and flavonoids play a role as antioxidant agents since they can donate hydrogen atoms from hydroxy to radical compounds so that they can be more stable [35]. The coffee with the most spices added has the highest total phenol yield. This is in addition to its large total phenol content. Phenolic and flavonoid compounds play a major role in antioxidant activity, where the greater the phenolic and flavonoid levels, the better the antioxidant activity [36].

Table 5. Antioxidant activity.

Samples	IC_{50} (ppm) ± SD	Antioxidant Activity
CH3	4.984 [a] ± 0.000	Very Strong
CH2	8.39 [c] ± 0.188	Very Strong
CH1	12.221 [d] ± 0.021	Very Strong
Ascorbic Acid	45.393 [e] ± 0.000	Very Strong
CO	72.122 [b] ± 0.004	Strong
CB	6.1408 [f] ± 0.051	Very Strong

CO = Coffee Liberica; CH1 = coffee + *C. zanthorrhiza* (99:1); CH2 = coffee + *C. zanthorrhiza* (97:3); CH3 = coffee + *C. zanthorrhiza* (95:5); CB = *C. zanthorrhiza*. [a,b,c,d,e,f] Superscripts with distinct letters within the same column have significant differences ($p < 0.05$). SD represents the standard deviation.

3.5. Physical–Chemical Analysis

Water content: Water content is the amount of water in a food product or ingredient. Water content is an important parameter in determining the quality of a food ingredient. Water content itself also determines the quality of the shelf life of food ingredients, including food. The lower the water content, the higher the resistance to damage caused by microorganisms [37]. The water content of CO is 4.302%, and that of CB is 8.205%. Meanwhile, the water content of CH1 is 4.302%, that of CH2 is 4.412%, and that of CH3 is 4.522%.

Ash content: Ash content is part of the proximate analysis used to determine the nutritional value of a food ingredient or product. Ash content is one parameter used to evaluate the nutritional value of a food ingredient and an indicator of total food minerals. The higher the ash content, the worse the quality of the food product. Table 6 presents the water content of the test samples. The measurement results show that CO is 4.175% and CB is 3.209%. Meanwhile, the water content for CH1 is 4.232%, that fo CH2 is 4.244%, and that for CH3 is 4.254%.

Table 6. Results of physical–chemical analysis.

Samples	% Waters	% Ash	% Proteins	% Fats	% Carbohydrates
CO	4.302	4.175	17.61	10.17	5.940
CB	8.205	3.209	1.52	1.35	5.185
CH1	4.302	4.232	17.09	10.13	5.300
CH2	4.412	4.244	16.80	9.75	4.742
CH3	4.522	4.254	15.78	9.14	4.318

Total protein: Protein content analysis is the result of protein surface activity, which is related to its hydrophobic and hydrophilic properties. The protein content for Liberica coffee is 17.61%; for curcuma, it is 1.52%; for CH1, it is 17.09%; for CH2, it is 16.80%; and for CH3, it is 15.78%.

Total fat: Fat is the fat contained in food samples' fat content. The principle is to dissolve a material with an organic solvent to separate the crude fat from the other components and then evaporate the organic solvent again to obtain crude fat in the material. The total fat for CO is 10.17%; for CB, it is 1.35%; for CH1, it is 10.13%; for CH2, it is 9.75%; and for CH3, it is 9.14%.

Total carbohydrate content: This aims to classify food ingredients that contain carbohydrates and are used as a source of carbohydrates by observing color changes in the tested ingredients. Table 6 shows that the % carbohydrate for CO is 5.940%; for CB, it is 5.185%; for CH1, it is 5.300%; for CH2, it is 4.742%; and for CH3, it is 4.318%

Adding *C. zanthorrhiza* to Liberica coffee in various formulations led to increased water content, which is attributed to the higher moisture content of curcuma compared to Liberica coffee. The measured water content in the spiced coffee formulations complied

with the quality standards set by SNI 01-3542-2004 (Indonesian National Standard), which specifies a maximum moisture content of 7% *w*/*w* for ground coffee [25]. Similarly, the ash content increased with each formulation, reflecting the higher ash content of *C. zanthorrhiza* relative to coffee.

3.6. Volatile Compound Analysis Results

The spectra data from the GC-MS analysis of Liberica coffee revealed multiple peaks with varying area percentages, indicating differences in the concentration of detected compounds (Table 7). The peak area (%) in the GC-MS spectra correlates directly with the relative abundance of each compound. One of the identified compounds is dodecanoic acid, 1,2,3-propanetriyl ester ($C_{39}H_{74}O_6$), commonly referred to as glyceryl tridodecanoate, glyceryl trilaurate, or lauric acid triglyceride. This compound displayed the highest peak, indicating its predominant presence in the sample. For the chromatogram of *Curcuma zanthorrhiza* (Table 8), 25 peaks were observed, with dodecanoic acid, 1,2,3-propanetriyl ester, again registering as the most abundant compound. Notably, the spiced coffee sample, a blend of Liberica coffee and *C. zanthorrhiza*, exhibited 29 peaks (Table 9), indicating the presence of additional compounds introduced through the mixture. Despite the increase in compound diversity, dodecanoic acid, 1,2,3-propanetriyl ester, remained the predominant compound in the spiced coffee formulation. This suggests that the blending process enriches the chemical profile while maintaining the dominance of key compounds.

Table 7. Results of volatile compound analysis of Liberica coffee.

Peak Compounds	R. Time (Minutes)	Area (%)	Molecular Formula	Compound Names
1	22.307	7.98	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{27}H_{52}O_5$	Dodecanoic acid, 1-(hydroxymethyl)-1,2-ethanediyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
2	22.447	30.97	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{27}H_{52}O_5$	Dodecanoic acid, 1-(hydroxymethyl)-1,2-ethanediyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
3	22.622	10.30	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{49}H_{94}O_6$	Octadecanoic acid, 2,3-bis[(1-oxotetradecyl)oxy]propyl ester
4	22.800	7.16	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{35}H_{66}O_6$	2-Lauro-1,3-didecoin
5	22.875	5.79	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{27}H_{52}O_5$	Dodecanoic acid, 1-(hydroxymethyl)-1,2-ethanediyl ester
6	22.945	9.84	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{35}H_{66}O_6$	2-Lauro-1,3-didecoin
7	23.091	15.82	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{26}H_{48}F_3NO_2$	Dodecanamide, N-Dodecyl-N-(Trifluoroacetyl)
8	23.152	8.41	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{26}H_{48}F_3NO_2$	Dodecanamide, N-Dodecyl-N-(Trifluoroacetyl)
9	23.285	2.35	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{47}H_{90}O_6$	Hexadecanoic acid, 2-[(1-oxododecyl)oxy]-1,3-propanediyl ester
			$C_{55}H_{106}O_6$	Eicosanoic acid, 2-[(1-oxohexadecyl)oxy]-1-[[(1-oxohexadecyl)oxy]methyl]ethyl ester
10	23.444	1.03	$C_{35}H_{66}O_6$	2-Lauro-1,3-didecoin
			$C_{14}H_{26}O_2$	Dodecanoic acid, ethenyl ester
			$C_{17}H_{36}$	2,6,10-Trimethyltetradecane

Table 7. *Cont.*

Peak Compounds	R. Time (Minutes)	Area (%)	Molecular Formula	Compound Names
11	23.545	0.35	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{14}H_{26}O_2$	Dodecanoic acid, ethenyl ester
			$C_{27}H_{52}O_5$	Dodecanoic acid, 1-(hydroxymethyl)-1,2-ethanediyl ester

Table 8. Analysis results of Curcuma volatile compounds.

Peak Compounds	R. Time (Minute)	Area (%)	Molecular Formula	Compound Name
1	15.563	0.40	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
2	16.533	0.64	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
3	17.123	0.98	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{49}H_{94}O_6$	Octadecanoic acid, 2,3-bis[(1-oxotetradecyl)oxy]propyl ester
4	17.758	1.91	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{14}H_{26}O_2$	Dodecanoic acid, ethenyl ester
5	17.865	3.05	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
6	18.602	0.93	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
7	18.732	0.65	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
8	19.249	3.15	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
9	19.367	2.21	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{27}H_{52}O_5$	Dodecanoic acid, 1-(hydroxymethyl)-1,2-ethanediyl ester
			$C_{49}H_{98}O_4$	Lauric acid, 2-(hexadecyloxy)-3-(octadecyloxy)propyl ester
10	19.414	2.87	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{27}H_{52}O_5$	Dodecanoic acid, 1-(Hydroxymethyl)-1,2-Ethanediyl Ester
11	19.696	15.20	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
12	19.833	1.51	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{27}H_{52}O_5$	Dodecanoic acid, 1-(hydroxymethyl)-1,2-ethanediyl ester
13	19.925	1.41	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{49}H_{94}O$	Octadecanoic acid, 2,3-bis[(1-oxotetradecyl)oxy]propyl ester
			$C_{21}H_{36}$	14-β-H-Pregna
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxohexadecyl)oxy]-2-[(1-oxotetradecyl)oxy]propyl ester
14	20.092	12.48	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
15	20.281	4.05	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester

Table 8. *Cont.*

Peak Compounds	R. Time (Minute)	Area (%)	Molecular Formula	Compound Name
16	20.333	0.86	$C_{45}H_{86}O_6$	Tetradecanoic acid, 1,2,3-propanetriyl ester
			$C_{36}H_{72}NO_8P$	L-Dimyristoyl lecithin
			$C_{49}H_{94}O_6$	Octadecanoic acid, 2,3-bis[(1-oxotetradecyl)oxy]propyl ester
			$C_{45}H_{86}O_6$	Tetradecanoic acid, 1,2,3-propanetriyl ester
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
17	20.425	4.72	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
18	20.463	4.03	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxohexadecyl)oxy]-2-[(1-oxotetradecyl)oxy]propyl ester
19	20.747	8.35	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{47}H_{90}O_6$	Hexadecanoic acid, 2-[(1-oxododecyl)oxy]-1,3-propanediyl ester
			$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
20	20.828	9.46	$C_{47}H_{90}O_6$	Hexadecanoic acid, 2-[(1-oxododecyl)oxy]-1,3-propanediyl ester
			$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{35}H_{66}O_6$	2-Lauro-1,3-didecoin
			$C_{47}H_{90}O_6$	Hexadecanoic acid, 2-[(1-oxododecyl)oxy]-1,3-propanediyl ester
21	21.197	6.07	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
22	21.312	2.45	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{47}H_{90}O_6$	Hexadecanoic acid, 2-[(1-oxododecyl)oxy]-1,3-propanediyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
23	21.434	7.81	$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
			$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
24	21.491	2.57	$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
			$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
25	21.571	2.24	$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
			$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{14}H_{26}O_2$	Dodecanoic acid, ethenyl ester

Table 9. Volatile compound of coffee–*C. zanthorrhiza* CH3.

Peak Compounds	R. Time (Minute)	Area (%)	Molecular Formula	Compound Name
1	15.535	0.16	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{49}H_{94}O_6$	Octadecanoic acid, 2,3-bis[(1-oxotetradecyl)oxy]propyl ester
2	17.849	0.72	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
3	18.508	0.65	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{27}H_{52}O_5$	Dodecanoic acid,1-(hydroxymethyl)
4	18.603	1.13	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
5	18.724	0.44	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{27}H_{52}O_5$	Dodecanoic acid, 1-(hydroxymethyl)-1,2-ethanediyl ester
6	19.049	1.03	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester

Table 9. *Cont.*

Peak Compounds	R. Time (Minute)	Area (%)	Molecular Formula	Compound Name
7	19.247	2.10	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
8	19.367	2.92	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{27}H_{52}O_5$	Dodecanoic acid, 1-(hydroxymethyl)-1,2-ethanediyl ester
9	19.411	3.84	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
10	19.592	2.76	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{27}H_{52}O_5$	Dodecanoic acid, 1-(hydroxymethyl)-1,2-ethanediyl ester
11	19.647	3.96	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
12	20.070	7.74	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
13	20.276	3.54	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxohexadecyl)oxy]-2-[(1-oxotetradecyl)oxy]propyl ester
14	20.333	1.10	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{49}H_{94}O_6$	Octadecanoic acid, 2,3-bis[(1-oxotetradecyl)oxy]propyl ester
15	20.455	9.43	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester.
16	20.721	12.90	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
17	20.815	8.81	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
			$C_{49}H_{94}O_6$	Octadecanoic acid, 2,3-bis[(1-oxotetradecyl)oxy]propyl ester
18	20.950	2.38	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{47}H_{90}O_6$	Hexadecanoic acid, 2-[(1-oxododecyl)oxy]-1,3-propanediyl ester
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
19	21.087	8.62	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{47}H_{90}O_6$	Hexadecanoic acid, 2-[(1-oxododecyl)oxy]-1,3-propanediyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
20	21.315	1.13	$C_{47}H_{90}O_6$	Hexadecanoic acid, 2-[(1-oxododecyl)oxy]-1,3-propanediyl ester
			$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{45}H_{86}O_6$	Tetradecanoic acid, 1,2,3-propanetriyl ester
21	21.408	2.18	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxohexadecyl)oxy]-2-[(1-oxotetradecyl)oxy]propyl ester
			$C_{20}H_{38}O_2$	Octadecanoic acid, ethenyl ester
			$C_{19}H_{40}$	n-Nonadecane
			$C_{32}H_{66}$	Dotriacontane
22	21.489	1.46	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
23	21.582	2.65	$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
			$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
24	21.695	5.40	$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
			$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
25	21.784	3.43	$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
			$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
26	21.918	3.27	$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester

Table 9. *Cont.*

Peak Compounds	R. Time (Minute)	Area (%)	Molecular Formula	Compound Name
27	22.014	3.98	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{47}H_{90}O_6$	Hexadecanoic acid, 2-[(1-oxododecyl)oxy]-1,3-propanediyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
28	22.216	1.77	$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{47}H_{90}O_6$	Hexadecanoic acid, 2-[(1-oxododecyl)oxy]-1,3-propanediyl ester
			$C_{57}H_{10}O_6$	Glyceryl tridodecanoate
29	22.514	0.50	$C_{51}H_{98}O_6$	Octadecanoic acid, 3-[(1-oxododecyl)oxy]-1,2-propanediyl ester
			$C_{39}H_{74}O_6$	Dodecanoic acid, 1,2,3-propanetriyl ester
			$C_{47}H_{90}O_6$	Hexadecanoic acid, 2-[(1-oxododecyl)oxy]-1,3-propanediyl ester

4. Discussion

Plant foods and beverages are the main sources of antioxidants in our diet. Nowadays, coffee is not only a lifestyle drink but also acts as a health drink. Studies on bioactive compounds and antioxidant activity of coffee have been widely reported. New properties of coffee beverages that make it beneficial as nutraceutical and pharmaceutical products continue to be discovered [38]. Brewed coffee has many critical functional ingredients that have been known, such as flavonoids (catechins and anthocyanins), ferulic acid, and caffeic acid. In addition, other biological bioactive compounds are also found in coffee, such as trigonelline, caffeine, chlorogenic acid, nicotinic acid, quinolinate, ester groups, hydroxycinnamic acids, and melanoidins, which are known to have good antioxidants.

In the present work, the antioxidant potential of Liberica coffee enriched with curcuma extract was also determined, as well as the ability to inhibit DPPH radicals. The recent literature shows a lack of information concerning DPPH inhibition in Liberica coffee enriched with curcuma extract. The interaction of coffee with herbs has been reported in several previous studies using Arabica and Robusta coffee species [39]. Curcuma contains various polyphenolic compounds and has high antioxidant activity [40]. In this work, we found that the total phenolics and total flavonoids of Curcuma were higher compared to Liberica coffee. Phenolic compounds might interact with many components in the food matrix. The combination might induce synergistic and antagonistic effects in varying circumstances [41]. Investigated the antioxidant capacity of the interaction between three primary phenolic compounds found in coffee—chlorogenic acid, caffeic acid, and ferulic acid—compared to α-tocopherol, within L-α-phosphatidylcholine liposome systems rather than within a food matrix [42].

Along with the increase in the proportion of curcuma in the coffee–Curcuma combination, there was an increase in the total phenolics and flavonoids of Liberica coffee (Table 2). This result is in line with the increase in antioxidant activity. The decrease in the IC_{50} value when adding curcuma shows a synergetic interaction between coffee and curcuma. The same results were found in various studies of herbal coffee interactions [39,43,44]. Moreover, another study reported that parallel to the cocoa proportion in the mixture, antioxidant capacity increases, indicating a more prominent antioxidant activity [45]. The addition of herbs to coffee also has an impact on reducing caffeine and chlorogenic acid. Currently, the market need for low-caffeine coffee is very high because caffeine has negative effects; it will cause adverse effects, such as insomnia, worry, increased blood pressure, and heart rate that is too fast [46]. Similar research was conducted by Kuswardhani et al. [47] adding ginger to reduce the caffeine content of Robusta coffee.

On the other hand, previous studies on combining coffee with spices looked at their interactions with polyphenols and their antioxidant activity. However, there is a lack of research looking at other sensory effects [39,43,47]. In this study, a sensory test was

conducted to see the effect of Curcuma on coffee taste and its effect on antioxidant activity. The addition of spices to coffee has an impact on increasing the taste profile of coffee [7]. The addition of Curcuma to Liberica coffee has an impact on sensory enhancement. Other research also shows that adding ginger and lemongrass improves the organoleptic profile of coffee [48]. Curcuma belongs to herb that is generally added in multiherbal combinations. Adding spices to coffee can enhance its sensory profile since the complex interaction between volatile compounds in coffee and the aromatic compounds in spices creates a more intricate flavor and aroma profile. Spices contribute unique volatile compounds—such as terpenes, phenol, and aldehydes—that introduce new layers of aroma and taste, making the coffee experience more complex and appealing. Previous studies have shown that spices like cardamom, cinnamon, and ginger contain eucalyptol, cinnamaldehyde, and zingiberene, respectively. Depending on the spice added, these compounds blend with coffee's existing flavors and aromas, enhancing sweetness, warmth, or spiciness. Adding spices to coffee significantly impacts its perceived sensory qualities, including flavor complexity and aroma intensity. This synergy between coffee and spices can elevate the sensory experience by creating a more layered and enjoyable beverage.

The GC-MC data show the volatile compounds found in Liberica coffee, *C. zanthorrhiza*, and the combination, with dodecanoic and octadecanoic acid derivatives being the primary constituents. These results align with previous research that underscores the prominence of medium- and long-chain fatty acids in contributing to coffee's aroma and flavor profile. Studies on Liberica coffee show that these fatty acids, along with triglycerides like glyceryl tri-dodecanoate, are crucial in providing the distinct taste and scent of Liberica, differentiating it from other coffee varieties that contain lower levels of these compounds. Similarly, research on Curcuma species emphasizes the role of fatty acid esters like octadecanoic acid esters in enhancing the therapeutic qualities of these plants. Curcuma is known for its anti-inflammatory and antioxidant properties, often attributed to these volatile compounds, which may be beneficial in medicinal and cosmetic applications. The analyzed *C. zanthorrhiza* CH3 sample exhibits a profile close to Curcuma species, suggesting its potential use in similar therapeutic contexts, especially for health-related products leveraging both aroma and bioactive properties. These findings illustrate the chemical richness and functional versatility of these compounds across different applications in food, health, and fragrance industries.

Furthermore, studies on polyphenols and other antioxidant-rich compounds in spices have shown they can enhance coffee's sensory and health profiles. The presence of spices like Curcuma, rich in curcuminoids or cinnamon, with its cinnamic acid derivatives, not only adds to the flavor complexity but also amplifies the beverage's antioxidant activity. This enhancement has been observed in studies where coffee mixed with spices showed improved aroma and taste complexity scores due to these bioactive compounds [42]. Additionally, the Maillard reaction, which contributes to the characteristic coffee aroma during roasting, may interact with certain spice-derived compounds, resulting in more prosperous and desirable sensory characteristics [47]. Thus, adding spices to coffee achieves a sensory boost by adding new aromatic and flavor-enhancing compounds, resulting in an enjoyable beverage that aligns with consumer preferences for functional foods with added health benefits.

Coffee as a beverage also has proximate standards, including water content, ash content, total protein, total fat, and carbohydrates. The addition of Curcuma to Liberica coffee has SNI standard proximate values. Evaluating water and ash content in Curcuma-flavored coffee indicates compliance with the quality standards outlined in SNI 01-3542-2004, which stipulates that ground coffee's maximum permissible ash content is 5% w/w [25]. In the fat content test, the fat content decreased due to the fact that Curcuma has a lower fat

content than coffee, so the fat content in spiced coffee in each formulation decreased. The incorporation of curcuma into coffee at varying ratios resulted in a reduction in fat content, attributed to the lower fat composition of curcuma compared to coffee. This decrease in fat content highlights the impact of ingredient ratios on the overall lipid profile of the blend. Furthermore, carbohydrate compounds in coffee are crucial contributors to the development of its characteristic aroma and sweetness during brewing. The interplay between fatty acids and sugars plays a significant role in creating the distinct sensory attributes of coffee. Fatty acids contribute to the richness and complexity of flavor, while sugars enhance the sweetness and balance the overall taste profile, reinforcing the unique aromatic qualities associated with coffee. Furthermore, it seems that sugars undergo a caramelization process during roasting. On the other hand, some reducing sugars form other aromas and sweetness through interaction with amino acids in the Maillard reaction process [49].

5. Conclusions

Based on the results of the analysis, it was found that among the coffee and curcuma blends, the CH3 sample was the best sample, with a balanced assessment in the aspects of aroma, flavor, aftertaste, acidity, and body. The increase in total phenols was from 42.271 mgGAE/g (CO) to 49.146 mgGAE/g (CH3), and the increase in total flavonoids was from 8.43 (CO) to 24.667c $\pm$ 0.076 mgQE/g (CH3). The alteration was accompanied by a significant improvement in antioxidant activity, as evidenced by the reduction in the IC50 value from 72.122 ppm (CO) to 4.984 ppm (CH3). Liberica coffee added with *Curcuma zanthorrhiz* affected the sensory of Liberica coffee, where the coffee most favored by panelists was spice coffee. Based on the cupping test results, CH3 spice–coffee had excellent results, while Liberica coffee had very good results. The results of phytochemical showed that coffee–*C. zanthorrhiza* contains higher levels of total phenolics, flavonoids, and antioxidant activity than original Liberica coffee. Meanwhile, spice coffee's caffeine and chlorogenic acid levels were lower than those of the original Liberica coffee

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