Antioxidant activity and characteristics of a cocoa drink formulated with encapsulated green coffee extract

Rossi Indiarto, Souvia Rahimah, Edy Subroto, Nur Alifia Gardiantini Putri, and Aldila Din Pangawikan

Department of Food Industrial Technology, Faculty of Agro-Industrial Technology, Universitas Padjadjaran, Jalan Raya Bandung-Sumedang km. 21, Jatinangor, Sumedang, West Java 45363, Indonesia

ABSTRACT
Cocoa drinks are made from powdered cocoa beans that have been processed. Cocoa powder has antioxidants, but processing may lower the antioxidant activity. Therefore, adding powerful antioxidants, such as green coffee extract, is essential. The extract needs to be encapsulated to preserve its stability and properties. This study investigated the antioxidant activity and characteristics of a cocoa drink incorporated with encapsulated green coffee extract. The percentage of encapsulated coffee extract in cocoa drinks was designated as C1 (0%), C2 (2%), C3 (4%), C4 (6%), C5 (8%) and C6 (10%). The results showed that incorporating a higher percentage of the encapsulated extract increased the number of total polyphenols and flavonoids and antioxidant activity. Additionally, before brewing, the powdered form showed a significant increase in hygroscopicity and total color difference, along with an increase in the percentage of encapsulated extract in the cocoa drink formulation. However, the moisture content of the powder decreased significantly. After brewing the pH value, dissolution time and sedimentation decreased while the viscosity, total soluble solids, and solubility increased as the encapsulated extract percentage increased. According to the sensory evaluation, all sensory attributes of the new cocoa drink formulation were acceptable. Therefore, cocoa drink can be used as a ready-for-consumption drink rich in healthy functional compounds.

Introduction
Cocoa drinks are one of the cocoa-derived products that are in high demand among consumers. Powdered cocoa drink is easily soluble in water, is convenient to serve, and has an extended shelf life. Cocoa powder, a semifinished product derived from cocoa beans, is the primary ingredient in producing cocoa drinks. Cocoa beans contain antioxidants, including catechins, epicatechins, polyphenols, and procyanidins. Nevertheless, cocoa powder antioxidants decrease during cocoa bean processing due to the degradation of bioactive compounds caused by postharvest processing of cocoa pods, such as fermentation, drying, roasting, and alkalinization.\(^1\)\(^2\) In addition, several bioactive compounds, including catechins, epicatechins, and procyanidins B1 and B2, are reduced.\(^3\) Therefore, the cocoa powder in commercial cocoa drinks has a generally low antioxidant content. The retail cocoa drinks sold today have a nutritional deficit and an unbalanced composition. Sari et al.\(^4\) investigated a chocolate beverage with added spices to improve its functional properties, with a phenolic content ranging from 50.83 to 93.05 mg GAE/100 mL. In addition, many consumers have opted to consume safer and healthier products, resulting in a growing demand for functional foods.\(^5\)

CONTACT Rossi Indiarto, rossi.indiarto@ unpad.ac.id Department of Food Industrial Technology, Faculty of Agro-Industrial Technology, Universitas Padjadjaran, Jalan Raya Bandung-Sumedang km. 21, Jatinangor, Sumedang, West Java 45363, Indonesia

This article has been corrected with minor changes. These changes do not impact the academic content of the article.

© 2022 Rossi Indiarto, Souvia Rahimah, Edy Subroto, Nur Alifia Gardiantini Putri and Aldila Din PangawikanPublished with license by Taylor & Francis Group, LLC.

This is an Open Access article distributed under the terms of the Creative Commons Attribution License [http://creativecommons.org/licenses/by/4.0/], which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.
Green coffee is unroasted coffee with a high polyphenol content. Due to the influence of biological activities, polyphenols have recently emerged as one of the most promising components for the functional food industry. One of the many benefits of green coffee is that it contains chlorogenic acid. Caffeoylquinic acid, dicaffeoylquinic acid, feruloyl quinic acid, p-coumaroylquinic acid, and caffeoyl feruloyl quinic acid diesters are the most common chlorogenic acids. Chlorogenic acid has antioxidant properties. In addition, chlorogenic acid can stimulate metabolism and increase fatty acid oxidation. However, it decreases the triglyceride levels in the liver and inhibits the activity of pancreatic amylase and lipase enzymes. Green coffee also contains several flavonoid compounds, including ferulic acid, caffeic acid, nicotinic acid, p-coumaric acid, trigonelline, and tannic acid. These compounds have strong antioxidant and anticancer potential and suppress hyperglycemia, hyperinsulinemia, and hyperlipidemia.

The compounds in green coffee are less stable during storage, and its extract has a slightly bitter taste. Furthermore, phenolic compounds are susceptible to deterioration under the typical food processing conditions of heat, pH, light, and oxygen. However, due to their low stability, solubility, and bioavailability, the application of these phenolic compounds is complicated, necessitating methods to protect these components. An encapsulation technique was developed to mask the bitter flavor and enhance the sensory reception of the cocoa drink in addition to maintaining the stability of green coffee. Furthermore, maltodextrin and gum arabic were utilized as coatings for encapsulating green coffee extract.

Antioxidant-rich cocoa drinks have been the subject of research in previous studies. Muhammad et al. added encapsulated cinnamon to chocolate beverages; adding cinnamon colloidal nanoparticles to chocolate beverages increased the total phenolic content and antioxidant activity but did not have a positive effect. Zain et al. added green coffee beans to bread, increasing the phenolic content and antioxidant activity of the bread. However, this was inversely proportional to the organoleptic properties, namely, a reduction in overall acceptance due to a bitter smell and taste. Information relating to the characteristics of cocoa drinks incorporating encapsulated green coffee extract is still limited. Therefore, research is required to investigate the antioxidant, physiochemical, and sensory properties of various formulations of cocoa drinks.

Materials and methods

Materials

Alkalized cocoa powder (pH 7.2) was obtained from a cocoa plantation and processed in Gunungkidul, Yogyakarta. Green coffee beans of the Arabica variety from Sumedang, Indonesia; maltodextrin DE 10–12; gum arabic; and gum xanthan were all food grades. Aluminum chloride, gallic acid, ethanol, hexane, glacial-chloroform acetic acid, DPPH (1,1-diphenyl-2-picrylhydrazyl), potassium iodide solution, potassium carbonate solution, quercetin standard solution, methanol, sodium carbonate, and Folin Ciocalteu reagent were all Pro Analysis quality chemical reagents.

Green coffee bean extraction

A combination of solvent-ultrasonic technology was used to extract green coffee beans. Two hundred grams of dry green coffee beans were ground with a grinder and sieved to acquire 60-mesh green coffee bean powder. In a glass beaker, 70 grams of powder was dissolved with 350 mL of ethanol (1:5 w/v). The sample was extracted using an ultrasonication probe (Sonicator Q125, QSonica, USA) with an amplitude of 65% for 45 minutes. The solution was filtered with a vacuum filter and concentrated with a rotary evaporator (R-300, BUCHI, Switzerland). The concentrated extract was freeze-dried (ALPHA 1–4 LSCplus, Martin Christ, Germany) for 48 hours at −20°C. The extracts were placed in dark bottles and in a freezer for further analysis.
The encapsulation of green coffee bean extract

Spray dryers were used to perform encapsulation as described by Nosari et al.\textsuperscript{[17]} Maltodextrin (80\%) and gum arabic (20\%), as coating materials with a total solids ratio of 1:3.5 (w/w), were dissolved in distilled water at room temperature using a magnetic stirrer at 250 revolutions per minute. Additionally, the green coffee extract was dissolved in distilled water at a ratio of 1:10. The coating material and diluted green coffee extract were homogenized for 15 minutes at 10,000 rpm and then hydrated for 18 hours at 10–12°C. After being hydrated, the mixture was homogenized for 5 minutes at 14,000 rpm. The mixture was spray dried (Mini Spray Dryer B-290, BUCHI, Switzerland) with an inlet temperature of 170°C, a flow rate of 6 mL/minute, an atomization pressure of 6 barometers, and an atomization air flow rate of 50 mL/minute.

Cocoa drink preparation

Premixing was used to prepare the chocolate powder drink. Following the formulation shown in Table 1, alkalized cocoa powder was weighed. The remaining ingredients, including sugar, maltodextrin, and xanthan gum, were weighed according to the existing recipe. After quantifying the weight of the solid materials, they were added to a container and thoroughly mixed to produce a cocoa powder beverage.

Total polyphenol content determination

The total polyphenol content was determined according to Mansour et al.\textsuperscript{[18]} with slight modification. One milliliter of 1500 ppm sample was mixed with 0.5 mL of 50\% Folin-Ciocalteu reagent. Afterward, 2.5 mL of a 20\% Na₂CO₃ solution was added. The samples were incubated for 30 minutes in the dark. The absorbance of the sample was then analyzed using a spectrophotometer UV–VIS (Perkin Elmer Lambda 35, USA) at 725 nm. Gallic acid was the standard used. The total polyphenols are expressed in mg gallic acid equivalent (GAE)/g sample.

Total flavonoid content determination

The total flavonoid content was determined according to Indiarto et al.\textsuperscript{[3,19]} with slight modification. First, 0.2 mL of a 10\% AlCl₃ solution was added to as much as 0.5 mL of the sample at 2000 ppm. After allowing it to stand for three minutes, 0.2 mL of 1 M CH₃COOK solution was added and vortexed. The mixture was diluted to 10 mL with distilled water. For thirty minutes, the samples were incubated in the dark. The absorbance of the sample was measured at 450 nm using a UV–VIS spectrophotometer (Perkin Elmer Lambda 35, USA). As a standard, quercetin was used. The total flavonoid content is expressed in mg quercetin equivalent (QE)/g sample.

Table 1. Cocoa drink formulation with different percentages of encapsulated green coffee bean extract.

| Sample formulation | Encapsulated green coffee extract | Alkalized cocoa powder | Sugar | Xanthan gum | Maltodextrin |
|--------------------|-----------------------------------|------------------------|-------|------------|-------------|
| C1                 | 0                                 | 30                     | 40    | 1          | 29          |
| C2                 | 2                                 | 30                     | 40    | 1          | 29          |
| C3                 | 4                                 | 30                     | 40    | 1          | 29          |
| C4                 | 6                                 | 30                     | 40    | 1          | 29          |
| C5                 | 8                                 | 30                     | 40    | 1          | 29          |
| C6                 | 10                                | 30                     | 40    | 1          | 29          |
Antioxidant activity determination

Antioxidant activity measures the IC₅₀ (ppm) value on DPPH free radical scavenging activity according to Choudhary et al. [20] A total of 2 mL of each sample was placed in a test tube. Then, 4 mL of 0.004% DPPH dissolved in methanol was added. The sample was then homogenized using a vortex and incubated in a dark room for 30 minutes. At a wavelength of 517 nm, the absorbance was measured using a UV–VIS spectrophotometer. Ascorbic acid was used as the standard antioxidant. The following formula can be used to determine the % inhibition of the radical scavenging activity of DPPH:

\[
\% \text{ inhibition} = \left( \frac{\text{Blank absorbance} - \text{Sample absorbance}}{\text{Blank absorbance}} \right) \times 100\%
\]

Determination of moisture content

The moisture content was determined using the method conducted by Rushchits et al. [21] with slight modifications. The cup was dried at 105°C for 30 minutes or until the weight was constant. After cooling in a desiccator for 30 minutes, the cup was weighed; this was repeated until a constant weight was reached. The sample was weighed (up to 2 grams) in a stable cup and then dried in an oven at 105°C for three hours until it achieved a stable weight. The sample was weighed after being cooled with a desiccator for 15 minutes. Then, the weighing test was performed on the sample periodically until it reached a constant weight difference of fewer than 0.002 grams. Finally, the observations were calculated utilizing the wet weight (wb) and dry weight (db) of the sample.

Hygroscopicity determination

With slight modification, the hygroscopicity was determined using the method described by Botrel et al. [22] Powder samples weighing approximately 1 g from each treatment were placed in a container with a saturated NaCl solution (75.29% relative humidity) at 25°C. After one week, the samples were weighed, and the hygroscopicity was expressed as a percentage. To determine these parameters, the powder samples were predried to a constant weight in an oven at 105°C.

Color determination

Color determination was established following Arifin et al. [23] with slight modification. The sample was placed in a cup and then onto a spectrophotometer (CM-5, Konica Minolta, Japan). The method employed was the absolute measurement method of the color system, specifically L*, a*, and b*. The following formula is used to calculate the total color difference (ΔE):

\[
\Delta E = \sqrt{(L_0^* - L^*)^2 + (a_0^* - a^*)^2 + (b_0^* - b^*)^2}
\]

The ΔE values are classified into very different (ΔE > 3), different (1.5 < ΔE < 3), and slightly different (ΔE < 1.5). [24, 25]

pH value determination

The pH value determination was based on the method described by Sioriki et al. [26] with some modifications. The test was conducted by calibrating the pH meter (PHB-4 Portable pH Meter, Henan, China) using buffer solutions with a pH of 4 and 7. When the pH meter was ready, the cocoa drink sample was placed in a container, and the electrode on the pH meter was inserted while waiting for the pH meter to stabilize.
**Viscosity**

A Brookfield Viscometer (Brookfield Viscometer LVT, Massachusetts, USA) was used to measure viscosity according to Jensen et al.\textsuperscript{[27]} The spindle was connected to a Brookfield viscometer. The spindle position was measured until it was just right. The “on” button of the viscometer was pressed, and the solution temperature was measured until it reached 75°C while being heated on a hot plate. The process was then continued by reading the scale of the viscometer after one minute of two complete rotations with the No. 2 spindle. The rotational speed of the tool was 50 rpm.

**Total soluble solids**

Following Rongtong et al.,\textsuperscript{[28]} the total soluble solids were determined with slight modification. The sample was measured with an Atago PAL-1 Digital Refractometer (Atago Co., Tokyo, Japan) at 25°C, and the results were reported as °Brix.

**Solubility and dissolution time**

With some modifications, the determination of solubility was based on Botrel et al.\textsuperscript{[22]} A 1 g powder sample was weighed and added to 30 mL of distilled water in a beaker, stirring at a low speed (500 rpm) for one minute. After the samples were added, the stirrer was set to a higher rate (1000 rpm) for two minutes. The substance was then placed in a 50 mL centrifuge tube and centrifuged at 3000 \(\times\) g for five minutes. A 5 mL aliquot of the supernatant was placed in a calibrated Petri dish and dried in a 105°C oven for four hours. The equation for calculating water solubility (S) is as follows:

\[
S(\%) = \frac{\text{Solid grams in supernatant}}{\text{Sample weight in grams}} \times 100\%
\]

The dissolution time was determined; a 5-gram sample was weighed and then dissolved in 100 ml water. Then, using a stopwatch, time required for the powder to fully dissolve was noted.

**Sedimentation**

The sedimentation index described by Jensen et al.\textsuperscript{[27]} was used with slight modification. The samples were centrifuged for 10 minutes at 6000 rpm. The supernatant was decanted, and the centrifuge tubes were inverted for 30 minutes. Sediment is expressed as a percentage by weight.

**Sensory evaluation**

The sensory evaluation employed the hedonic test with the scoring method.\textsuperscript{[29]} Twenty panelists, 50% women and 50% men, conducted the sensory evaluations. There were five possible scores: (1 = dislike very much, 2 = dislike slightly, 3 = neither like nor dislike, 4 = like slightly, 5 = like very much). The panelists evaluated characteristics including aroma, color, flavor, aftertaste, viscosity, and overall acceptability.

**Statistical analysis**

The statistical analysis data utilized SPSS 26.0 tools for a one-way analysis of variance (ANOVA). The formula-specified antioxidant activity and physicochemical and sensory properties of the cocoa drink were analyzed. Duplicate measurements were taken. The test was conducted at a significance level of \(p < .05\) to examine differences in mean values. The value presented represents the mean ± standard deviation.
RESULTS AND DISCUSSION

Total polyphenol, total flavonoid, and antioxidant activity of cocoa drinks in different formulations

Total polyphenol content

The green coffee extract contained TPC 333.85 ± 0.93 mg GAE/g extract. The TPC of the green coffee extract is affected by the different green coffee bean varieties, drying methods, extraction methods, and solvents used during the extraction process. This study employed the ultrasonic-assisted extraction method, which can produce more polyphenols due to cavitation, an effect of ultrasonic wave radiation in the liquid. These phenomena include microwave formation, growth, and rupture, which cause the formation of microparticles and shockwaves that disintegrate solid cell walls and release their contents.\(^{[30]}\)

The encapsulated green coffee extract had a TPC of 76.59 ± 0.01 mg GAE/g sample. Green coffee extract encapsulation affected the polyphenol value. Following encapsulation, the TPC of green coffee extract decreased. The proportion of green coffee extract utilized in the encapsulation process was only 22%, while the encapsulation material accounted for 88% of the total. The encapsulation method and coating-to-core ratio are also factors.

Table 2 shows that adding the encapsulated green coffee extract to cocoa drinks resulted in significantly different TPCs (p < .05). In addition, the TPC of cocoa drinks varied considerably between samples. Adding the higher encapsulated green coffee extract increased the TPC in cocoa drinks. The TPC of cocoa drinks ranged from 9.47 to 16.71 mg GAE/g. The highest TPC was 16.71 ± 0.09 mg GAE/g when 10% encapsulated green coffee extract was added. This was significantly different from the sample that did not contain encapsulated extract, which had a GAE concentration of 9.47 ± 0.16 mg GAE/g. The TPC of cocoa drink sample C6 was significantly higher than that of sample C1. The sample formulation with encapsulated green coffee extract at different percentages increased the TPC.

The bioactive compounds in green coffee include caffeic acid, coumaric acid, ferulic acid, and synaptic acid. These compounds are significant polyphenol sources in green coffee.\(^{[31]}\) Additionally, green coffee beans contain chlorogenic acid, which is recognized as a potent antioxidant. Other key ingredients, such as cocoa powder, can alter the TPC of cocoa drinks. Catechins, leucocyanidin, and anthocyanins are the primary polyphenolic compounds in cocoa powder.\(^{[32]}\)

Total flavonoid content

The TFC in the green coffee extract was 295.88 ± 1.34 mg QE/g of extract. The TFC using ultrasonic-assisted extraction is relatively high compared with other extraction methods because of the cavitation effect of ultrasound waves. This study used a solvent ratio of 1:5. The solvent will penetrate the plant cell wall and enter the cell cavity containing flavonoids, dissolving and removing them. After encapsulation, the spray drying process permits the degradation of flavonoids. The encapsulated

| Sample formulation | Parameter          | Value          |
|--------------------|--------------------|----------------|
|                    | TPC (mg GAE/g)     | TFC (mg QE/g)  | Antioxidant activity, IC\(_{50}\) (ppm) |
| C1                 | 9.47 ± 0.16\(^a\) | 3.06 ± 0.02\(^a\) | 166.95 ± 3.93\(^a\) |
| C2                 | 10.89 ± 0.11\(^b\) | 3.45 ± 0.02\(^b\) | 148.74 ± 2.11\(^b\) |
| C3                 | 13.08 ± 0.22\(^c\) | 5.10 ± 0.02\(^c\) | 132.58 ± 2.40\(^c\) |
| C4                 | 14.90 ± 0.39\(^d\) | 6.69 ± 0.03\(^d\) | 118.49 ± 1.07\(^d\) |
| C5                 | 15.81 ± 0.42\(^e\) | 7.40 ± 0.03\(^e\) | 102.55 ± 1.43\(^e\) |
| C6                 | 16.71 ± 0.09\(^f\) | 7.96 ± 0.04\(^f\) | 95.41 ± 1.98\(^f\) |

Values indicate mean ± deviation standard deviation (n = 4); different lowercase notations in the same column show a significant difference at p < 0.05. TPC: extract (mg GAE/g extract) = 333.85 ± 0.93; encapsulated extract (mg GAE/g sample) = 76.59 ± 0.01 TFC: extract (mg QE/g extract) = 295.88 ± 0.45; encapsulated extract (mg QE/g sample) = 22.71 ± 0.05 Antioxidant activity: extract (ppm) = 18.48 ± 0.40; encapsulated extract (ppm) = 18.48 ± 0.40
green coffee extract had a TFC of 22.71 ± 0.05 mg QE/g sample. Based on Table 2, the encapsulated green coffee extract added to cocoa drinks significantly increased TFC (p < .05). However, the TFC varied significantly among the samples. Adding green coffee extract with a higher encapsulation level led to a significant increase in the TFC of cocoa drinks.

The TFC in cocoa drinks varied between 3.06 and 7.96 mg QE/g. The cocoa drink containing 10% encapsulated green coffee extract had the highest total flavonoid content, measuring 7.96 ± 0.04 mg QE/g. Compared with the sample without encapsulated extract, this sample contained the least amount of flavonoids at 3.06 ± 0.02 mg QE/g. Flavonoids are an essential nutrient because they serve as natural antioxidants in food.[33,34] These compounds' content comprises catechin, epicatechin, and procyanidin B2 dimer.[19,35] Thus, the higher the flavonoids, especially in the number of monomers and dimers in cocoa products, the greater the health benefits obtained.[19]

**Antioxidant activity**

The IC₅₀ of the green coffee bean extract was 18.48 ± 0.40 ppm, and that of the encapsulated extract was 73.20 ± 0.73 ppm. The smaller the IC₅₀ value is, the more effective a sample is as an antioxidant compound. A compound is a very strong antioxidant if its IC₅₀ value is 0–50 ppm, a strong antioxidant if its IC₅₀ value is 51–100 ppm, a moderate antioxidant if its IC₅₀ value is 101–150 ppm, and a weak antioxidant if its IC₅₀ value is 151–200 ppm[36]. According to this study, green coffee extract is classified as a strong antioxidant. Total polyphenols and flavonoids affect antioxidant activity; high levels produce stronger activity.

Table 2 shows that adding the encapsulated green coffee extract to cocoa drink significantly changed the IC₅₀ value (p < .05). However, the cocoa drink samples all had significantly different IC₅₀ values. A higher percentage of encapsulated green coffee extract significantly decreased the IC₅₀ value of cocoa drinks (p < .05). The IC₅₀ value of the cocoa drink without encapsulated green coffee extract was 166.95 ± 3.93 ppm, which was significantly higher than the IC₅₀ value of the cocoa drink containing 10% encapsulated green coffee extract, 95.41 ± 1.98 ppm. Encapsulated green coffee extract with IC₅₀ values between 101 and 150 ppm had moderate antioxidant activity, specifically in the C2, C3, C4, and C5 samples. In addition, C1 had weak antioxidant activity in cocoa drink, whereas C6 had strong antioxidant activity.

The encapsulated green coffee extract can affect (p < .05) the IC₅₀ value of cocoa drinks to increase antioxidant activity. This is due to the free phenolic compounds such as chlorogenic acid, caffeic acid, ferulic acid, and p-coumaric acid in green coffee and tocopherols, which have antioxidant properties. In addition, coffee is rich in antioxidants from the hydroxycinnamic acid group, such as caffeic, chlorogenic, coumaric, ferulic, and sinapic acid. Additionally, biological compounds with significant antioxidant potential include caffeine, nicotinic acid, trigonelline, cafestol, and kahweol.[37] The use of alkaline cocoa powder can influence the IC₅₀ value of beverages. According to Abbe Maleyki and Ismail,[38] alkalization in cocoa powder can reduce the antioxidant activity of DPPH.

**Characteristics of cocoa drinks in different formulations before brewing**

**Moisture content**

Table 3 shows that encapsulated green coffee extract added to cocoa drink significantly affected the moisture content (p < .05). The moisture content of the cocoa drinks varied greatly. The higher amounts of encapsulated green coffee extract decreased the moisture content of the cocoa drinks. The moisture content of cocoa drink varied between 3.04 and 3.84%. The highest total moisture content was 3.84% without encapsulated green coffee extract. This is significantly different from the sample containing 10% encapsulated green coffee extract, which contained 3.04% moisture. This result demonstrates that the cocoa drink sample C1 had a higher moisture content than sample C6. Powder beverage products must comply with SNI 01-4320-1996,[39] specifically the 3.0 to 5.0% moisture content requirements. Powder durability depends on the moisture content. However, the moisture content in this study remains SNI-compliant.[39]
Table 3. Characteristics of cocoa drinks in different formulations before brewing (powder).

| Parameter                | Sample formulation |
|--------------------------|--------------------|
|                          | C1     | C2     | C3     | C4     | C5     | C6     |
| Moisture content (%)     | 3.84 ± 0.05<sup>a</sup> | 3.71 ± 0.02<sup>b</sup> | 3.66 ± 0.04<sup>c</sup> | 3.42 ± 0.03<sup>d</sup> | 3.22 ± 0.02<sup>e</sup> | 3.04 ± 0.03<sup>f</sup> |
| Hygroscopicity           | 8.56 ± 0.02<sup>a</sup> | 9.57 ± 0.09<sup>b</sup> | 10.48 ± 0.05<sup>c</sup> | 11.75 ± 0.04<sup>d</sup> | 12.62 ± 0.03<sup>e</sup> | 13.13 ± 0.03<sup>f</sup> |
| L<sup>*</sup>            | 61.14 ± 0.03<sup>a</sup> | 62.06 ± 0.02<sup>b</sup> | 62.69 ± 0.04<sup>c</sup> | 63.03 ± 0.01<sup>d</sup> | 63.45 ± 0.03<sup>e</sup> | 64.06 ± 0.02<sup>f</sup> |
| a*                      | 10.63 ± 0.03<sup>a</sup> | 9.72 ± 0.04<sup>b</sup> | 8.94 ± 0.04<sup>c</sup> | 8.11 ± 0.02<sup>d</sup> | 7.50 ± 0.05<sup>e</sup> | 6.60 ± 0.03<sup>f</sup> |
| b*                      | 11.89 ± 0.09<sup>a</sup> | 11.06 ± 0.02<sup>b</sup> | 10.81 ± 0.05<sup>c</sup> | 10.15 ± 0.03<sup>d</sup> | 9.94 ± 0.02<sup>e</sup> | 9.13 ± 0.02<sup>f</sup> |
| ΔE                      | 1.52 ± 0.09 | 2.54 ± 0.02 | 3.57 ± 0.01 | 4.36 ± 0.01 | 5.69 ± 0.03 |
| Color profile            |        |        |        |        |        |        |

Values indicate the mean ± standard deviation (n = 4); different lowercase notations in the same row show a significant difference at p < 0.05.

Based on Table 3, increasing the encapsulated green coffee extract percentage decreased the moisture content of the cocoa drink. However, the more encapsulated green coffee extract is added, the more maltodextrin is added as well. In addition, maltodextrin is an encapsulated green coffee extract that reduces the moisture content in cocoa drinks. As maltodextrin binds free water, adding it to encapsulated green coffee extract reduces the moisture content.<sup>[40]</sup>

**Hygroscopicity**

Table 3 shows that adding the encapsulated green coffee extract to a cocoa drink affected its hygroscopicity (p < .05). All cocoa drink samples had significantly different hygroscopicities (Table 3). High-concentration encapsulated green coffee extract increased the hygroscopicity of the cocoa drinks. The hygroscopicity ranged from 8.56 to 13.13%. With 10% encapsulated green coffee extract, the hygroscopicity was 13.13%; with no encapsulated green coffee extract, it was 8.56%. The hygroscopicity increases with the concentration of encapsulated green coffee extract. Maltodextrin is used as a coating material in the encapsulation process of green coffee extract. The addition of maltodextrin can increase hygroscopicity. Hygroscopicity is a material’s tendency to absorb water or air. <sup>[41]</sup> Schuck et al.<sup>[42]</sup> stated that a powder sample with hygroscopicity <10% is non-hygrosopic, and that with a hygroscopicity of 10.1–15% is slightly hygrosopic. The greater the maltodextrin concentration, the greater the number of hydroxyl groups. Maltodextrin has a high level of hygroscopicity. <sup>[43]</sup> Excessive maltodextrin causes an increase in the number of hydroxyl groups. Therefore, it increases the sample’s ability to bind water due to a hydrophilic maltodextrin layer.<sup>[44]</sup>

**Color**

Table 3 shows that incorporating the encapsulated extract of green coffee into a cocoa drink impacted its color (p < .05). The cocoa drink color attribute was significantly different in all samples. Table 3 shows that higher levels of encapsulated extract addition to cocoa drinks increased L* (lightness) and decreased a* (redness) and b* (yellowness). In this study, L* was inversely proportional to a* and b*. However, lightness increased with the concentration of encapsulated extract levels. Sample C1 had the lowest L* of 61.14, which was significantly different from sample C6, which had the highest L* of 64.06. The maltodextrin and gum arabic used as a coating in encapsulation affect this property. Cocoa powder is dark brown, but adding white encapsulated green coffee lightens it. Alkalization of cocoa powder can affect the L* value of the brightness level.<sup>[26]</sup> The higher the alkali concentration is, the darker the cocoa powder color (the L* value is smaller). The color change of cocoa powder due to alkalization is related to the caramelization process and the Maillard reaction, which intensifies with increasing pH.<sup>[45]</sup> The enzymatic activity of polyphenol oxidase can impact the characteristic color of alkalized cocoa powder. <sup>[46]</sup> As the pH increases, the phenolic compounds change color from reddish brown to black; the darker the cocoa powder is, the higher the pH.
In contrast, a* and b* values decreased when the encapsulated extract was added to the cocoa drinks. This is because adding white encapsulated green coffee alters the reddish hue and degree of yellowness of the cocoa powder. The more encapsulated green coffee extract is added, the less redness and yellowness appears. Table 3 shows that the ΔE value is significantly different in all sample formulations (p < .05). ΔE is the color difference between the sample treatment and the control (without treatment). Adding 10% encapsulated extract resulted in the highest ΔE value. ΔE can vary depending on the level of encapsulated extract added. The greater the concentration of encapsulated extracts added, the greater its ΔE. The total color difference in sample C2 is categorized as slightly different, that of C3 is different, and those of samples C4, C5, and C6 are very different.

**Characteristics of cocoa drinks in different formulations after brewing**

**pH value**

According to Table 4, the addition of encapsulated green coffee extract to the cocoa drink resulted in a significant (p < .05) change in the pH of the final cocoa drink. All cocoa drink samples had a different pH. The pH of the cocoa drink decreased significantly due to the higher concentration of encapsulated extract added. The pH range of the cocoa drinks was 6.44 to 7.10. The highest pH was 7.10, which is neutral, and there were variations without the addition of encapsulated green coffee extract. This is significantly different from the sample to which 10% encapsulated green coffee extract was added, which had an acidity level of 6.44. The pH of the cocoa drink decreased proportionally with the concentration of encapsulated green coffee extract.

Table 4 shows that the more encapsulated green coffee extract added to cocoa drinks, the lower the pH compared with C1. All sample formulations were significantly different in pH value. Green coffee bean extract is acidic, affecting the pH of cocoa drinks. The encapsulated green coffee extract can reduce the pH of cocoa drinks. Positive and negative ions, which can affect the acidity, can contaminate the formulation’s ingredients and contribute to the decrease in pH. Additionally, the change in pH may be caused by the phenolic compounds and chlorogenic acid present in green coffee that are capable of releasing H+ ions and lowering the pH value.

The alkalization of cocoa powder can alter the pH of cocoa drinks. Alkalization neutralizes acids, raising the pH. As the concentration of alkali increases, the pH value will increase. The alkaline solution will permeate the cocoa beans and stimulate color changes caused by sugar degradation, the Maillard reaction, and anthocyanin polymerization. The pH value rises proportionally with increasing concentration and diminishing acidity. However, due to the partial deamination of proteins, a rise in pH will encourage the formation of browning compounds. The pH of cocoa beans treated with alkalization is typically closer to neutral. This is because the alkaline solution is alkaline, which causes the pH to become more neutral.

Additionally, other ingredients used in producing cocoa drinks can influence the pH level. Maltodextrin used in the encapsulation of green coffee extract can also affect the pH of cocoa drinks; products containing maltodextrin filler have a lower pH value. According to SNI 06–7599-2010,

**Table 4. Characteristics of cocoa drinks in different formulations after brewing.**

| Parameter                  | Sample formulation | C1            | C2            | C3            | C4            | C5            | C6            |
|----------------------------|--------------------|---------------|---------------|---------------|---------------|---------------|---------------|
| pH value                   |                    | 7.10 ± 0.02<sup>a</sup> | 6.95 ± 0.02<sup>b</sup> | 6.80 ± 0.02<sup>c</sup> | 6.67 ± 0.02<sup>d</sup> | 6.55 ± 0.03<sup>e</sup> | 6.44 ± 0.03<sup>f</sup> |
| Viscosity (cps)            |                    | 58.50 ± 3.11<sup>a</sup> | 78.25 ± 1.71<sup>b</sup> | 85.50 ± 1.29<sup>c</sup> | 104.25 ± 1.26<sup>d</sup> | 119.50 ± 3.87<sup>e</sup> | 132 ± 1.83<sup>f</sup> |
| Total soluble solids, °brix (%) |                  | 2.75 ± 0.12<sup>a</sup> | 3.23 ± 0.15<sup>b</sup> | 3.78 ± 0.12<sup>c</sup> | 4.25 ± 0.13<sup>d</sup> | 4.70 ± 0.08<sup>e</sup> | 5.23 ± 0.09<sup>f</sup> |
| Solubility (%)             |                    | 77.37 ± 0.11<sup>a</sup> | 81.42 ± 0.11<sup>b</sup> | 82.90 ± 0.06<sup>c</sup> | 84.09 ± 0.04<sup>d</sup> | 86.04 ± 0.02<sup>e</sup> | 88.50 ± 0.07<sup>f</sup> |
| Dissolution time (s)       |                    | 76.54 ± 0.19<sup>a</sup> | 70.31 ± 0.38<sup>b</sup> | 63.69 ± 0.34<sup>c</sup> | 51.35 ± 0.34<sup>d</sup> | 46.86 ± 0.10<sup>e</sup> | 33.25 ± 0.30<sup>f</sup> |
| Sedimentation (%)          |                    | 2.93 ± 0.05<sup>a</sup> | 2.59 ± 0.10<sup>b</sup> | 2.31 ± 0.12<sup>c</sup> | 1.71 ± 0.15<sup>d</sup> | 1.21 ± 0.06<sup>e</sup> | 0.95 ± 0.10<sup>f</sup> |

Values indicate the mean ± standard deviation (n = 4); different lowercase notations in the same row show a significant difference at p < 0.05.
maltodextrin has a pH value between 4 and 6. Another coating, gum arabic, has a neutral pH of approximately 5.0 to 7.0; thus, the pH of the cocoa drink decreases as the concentration of gum arabic-coated encapsulated green coffee extract increases.

**Viscosity**

According to Table 4, incorporating encapsulated green coffee extract into the cocoa drink changed (p < .05) its viscosity. Each sample of the cocoa drink had a significantly different viscosity. Adding a higher level of encapsulated green coffee extract increased the solubility of the cocoa drinks. The range of formulated cocoa drink viscosity was 58.50–132 cps. Adding 10% encapsulated green coffee extract increased the viscosity to 132 cps. Compared with the sample without encapsulated green coffee extract, which had a viscosity of 58.50 cps, sample C6 had a higher viscosity than C1. Increasing the concentration of encapsulated green coffee extract increased the viscosity of the cocoa drink. Gum arabic, a coating material in the encapsulation of green coffee extract, can cause gel formation and increased viscosity. This is because gum arabic is an emulsifier that thickens solutions. Therefore, gum arabic can absorb water molecules, reducing the mobility of a mixture and giving it consistency and shape. Adding stabilizers or hydrocolloids affects the viscosity of beverages. High-molecular-weight stabilizers or hydrocolloids produce viscous solutions. Viscosity can be affected by xanthan gum, and low-concentration xanthan gum increases viscosity. The increase in viscosity is due to the formation of hydrogen bonds between branched xanthan gum molecules and water, other xanthan gum molecules, or the macromolecules present in cocoa drink products to form molecules with a higher molecular weight.

**Total soluble solids**

Based on Table 4, adding the encapsulated green coffee extract to cocoa drink significantly altered the total soluble solids of the cocoa drink (p < .05). Each cocoa drink formulation has a different total soluble solid. The total soluble solids of the cocoa drink increased significantly due to the addition of encapsulated extract at a higher level. Table 4 shows that the range of total soluble solids in the cocoa drinks was between 2.75 and 5.23%. Total soluble solids were highest with the addition of 10% encapsulated extract. The total soluble solids in the variant without encapsulated green coffee extract was 2.75.

Total solids are substances dissolved in a solution. Total soluble solids are increased by adding the encapsulated extract (Table 4). The presence of maltodextrin in encapsulated green coffee is one of the factors contributing to the increase in total soluble solids. Maltodextrin is highly soluble in water and has a fast merging of two phases. Because maltodextrin contains reducing sugars, the total soluble solids will increase. Maltodextrin has a hydroxyl group that binds with water, making it soluble in water. The higher the free hydroxyl groups there are, the higher the solubility, increasing the total soluble solids. The stabilizer used can increase total soluble solids. The more particles the stabilizer can bind, the more total soluble solids will increase and reduce precipitates.

**Solubility**

Table 4 shows that encapsulated green coffee extract changed the solubility of the cocoa drink (p < .05). In all samples, the solubility of the cocoa drink varied significantly. Adding encapsulated green coffee extract at a higher level significantly (p < .05) increased the solubility of the cocoa drinks. The solubility was 77.37–88.50%. The highest level of solubility was 88.50% when 10% encapsulated green coffee extract was added. This is significantly different from the sample without encapsulated green coffee extract, which had a solubility of 77.37%. Sample C6 yielded a more soluble than C1. The content of cocoa drinks C2, C3, C4, C5, and C6 was derived from the manufacturing ingredients (cocoa powder, xanthan gum, and maltodextrin) as well as encapsulated green coffee extract, which was added to increase solubility compared with sample C1, which was derived solely from manufacturing ingredients (without encapsulated green coffee extract).
The higher the encapsulated green coffee extract concentration was, the more soluble the cocoa drink. The more encapsulated green coffee extract was added, the more maltodextrin was present. Several studies have found that increasing the maltodextrin content increases solubility in sour cherry powder.\(^{[53]}\) Maltodextrin has a high solubility level because it can absorb water and has a fast dispersion process.\(^{[54]}\) The more free hydroxyl groups in the filler, the higher the solubility. Higher solubility means better product quality because it is easier to present. According to Ernawati et al.,\(^{[55]}\) the solubility percentage is inversely proportional to the encapsulation moisture content. The higher the moisture content is, the lower the solubility, and the product forms large, nonporous granules that are hard to dissolve in water. Xanthan gum can affect solubility; a high concentration will increase solubility. The increased solubility was due to the stabilizer xanthan gum binding free water, thereby increasing the soluble material. The more particles are bound by the stabilizer, the less precipitate is formed. In the presence of a stabilizer, suspended particles will be trapped in the system and will not settle due to the force of gravity.\(^{[56]}\) Sugar is another ingredient used in producing cocoa drinks that can affect their solubility; it dissolves readily and has better solubility than cocoa powder. In addition, cocoa drinks use 40% more sugar than cocoa powder.

**Dissolution time**

Table 4 shows that adding the encapsulated green coffee extract to cocoa drinks significantly increased the dissolution time (p < .05). The higher encapsulated green coffee extract reduced the time required to dissolve the cocoa drink. The dissolving time of cocoa drinks varied between 33.25 and 76.54 s. The highest dissolution time was 76.54 s without the use of encapsulated green coffee extract, significantly different from that of sample C6, which was 33.25 s. Sample C1 had the longest dissolution time compared with the other samples. The higher the encapsulated green coffee extract concentration, the slower the cocoa drink dissolves.

The moisture content affects the dissolution rate.\(^{[57]}\) The more water in the cocoa powder, the longer it takes for the chocolate to dissolve. Fillers are food additives that improve product quality.\(^{[58]}\) Maltodextrin can be used in cocoa drinks because it has high solubility, accelerating the dissolving time.\(^{[59]}\) Increased moisture content in cocoa powder forms a bond that causes lumps and makes it harder to separate particles. Cocoa powder can influence the dissolution rate of cocoa drinks. Because fat is hydrophobic, it can increase the dissolution time in the sample.

Additionally, adding other ingredients, such as sugar, affects the dissolution time. When sugar is dissolved in a liquid, its hydrophilic structure and large particle size allow water to penetrate more quickly. As a result, sugar sinks faster due to its higher density.

**Sedimentation**

The addition of encapsulated green coffee extract to the cocoa drink resulted in significantly different sedimentation (p < .05), as shown in Table 4. All sample treatments of the cocoa drink had sedimentation that differed significantly. The higher encapsulated extract reduced the cocoa drink sedimentation. According to Table 4, the cocoa drink sedimentation index ranged from 0.95% to 2.93%. The sedimentation reached its maximum value of 2.93% without encapsulated extract. A higher level of the encapsulated extract can reduce the sedimentation percentage in cocoa drinks. The sample with 10% encapsulated extract added showed the lowest sedimentation of 0.93%. The fat content of cocoa powder influences its sedimentation. Cocoa powder is hydrophobic and is not suspended.\(^{[60]}\)

In contrast, the addition of a stabilizer during the production of cocoa drinks can decrease sedimentation.\(^{[61]}\) In addition, xanthan gum is a stabilizer used to produce cocoa drinks. The number of solid particles in the liquid increases, and friction between particles increases, making it more difficult for particles in the solution to move and settle.\(^{[62]}\) Numerous variables, including particle number, viscosity, and particle size, can affect sedimentation.\(^{[13]}\) However, the addition of maltodextrin during encapsulated extract production can enhance the solubility of cocoa drinks. Maltodextrin is easily soluble in water, and it can reduce precipitation.
Sensory evaluation

In Figure 1, not all sensory attributes show a significant difference ($p > .05$). The aromas of the cocoa drinks were generally liked. C3 had a more pleasant aroma than the other samples, scoring 4.15. The encapsulated green coffee extract had no significant effect ($p > .05$) on cocoa drink aroma preferences. Cocoa powder contains aromatic compounds such as pyrazine, esters, ketone aldehydes, and pyrrole. The aroma of chocolate comes from a complex reaction that continues during processing, such as fermentation and roasting, which produce aroma precursors. Roasting releases the chocolate aroma because the precursor compound undergoes a nonenzymatic browning reaction (Maillard). Alcohol, ether, furan, and thiazole, precursors produced by glyoxal and glycine through the Maillard reaction, interact to form the cocoa aroma. The use of alkaline cocoa powder results in a more intense aroma profile. Green coffee has a weak aroma compared with roasted coffee; thus, the cocoa powder in cocoa drinks imparts a strong aroma.

The panelists generally liked the color of the cocoa drink. Nonetheless, the sample formulation C4 had a color attribute that the panelists preferred over the other samples, as indicated by its score of 4.35. Color is essential for determining product quality and affected the acceptance rates of the panelists. The color of the cocoa drink comes from the cocoa powder. During roasting, quinones from polyphenolic compounds react with polyphenol oxidase (PPO) enzymes and free amino acids to produce a brown cocoa color. Flavonoid complexes are formed during fermentation, giving cocoa beans a brown color. When the color alkalization process in cocoa powder causes it to become browner, the cocoa pigment and alkali reaction in the presence of oxygen and heat allows the cocoa color to develop. The cocoa powder becomes darker when alkaline. The addition of encapsulated green coffee extract altered the color of the cocoa drink but had no other significant effect.
Encapsulated green coffee extract is white because it has a maltodextrin coating and contains gum arabic.

Panelists liked the taste of all of the cocoa drink samples, but C2 could have had a more favorable taste attribute than the other samples. The panelists accepted the taste attribute of cocoa drinks in the different formulations. However, the taste score tended to decrease with increase concentration of encapsulated extract. As the encapsulated green coffee extract has a slightly bitter taste, the addition of excessive encapsulated extract tended to be less favored by the panelists. Green coffee has a greater bitterness because it contains more chlorogenic acid and caffeine. Green coffee does not undergo a roasting process, so the bitter taste is more intense.

Cocoa powder contains between 1.5–3% theobromine. The bitter taste in chocolate is natural. The compound theobromine is responsible for the flavor profile. Alkalization generates a robust flavor in cocoa powder. In addition to cocoa powder, green coffee has a bitter taste from forming lactones and phenol derivatives. However, green coffee was encapsulated in this study to reduce its bitterness. Using alkaline cocoa powder makes the taste of cocoa powder softer than that of natural cocoa powder. If the cocoa powder is very alkaline, the resulting taste is more intense and quite bitter, and this process can reduce the bitterness and astringency of the cocoa powder.[65] In addition, cocoa drinks cause an aftertaste that is quite strong in the mouth. In general, the panelists liked the aftertaste of the cocoa drink, but C4 had a more favorable aftertaste than the other samples. The more encapsulated green coffee extract was used, the greater the impact on the aftertaste of the cocoa drinks. Cocoa drink has a sweet and slightly bitter flavor and leaves a lingering aftertaste.

The panelists liked the viscosity of all cocoa drink formulations. However, the viscosity of C5 was preferred over that of the other samples. The addition of encapsulated extract to cocoa drinks can increase their viscosity. As a coating material, gum arabic forms a gel, allowing the viscosity to increase. Additionally, adding xanthan gum as a stabilizer and improving physical stability can

Figure 2. Heat map of Pearson’s correlation coefficient between variables (r). TPC (total polyphenol content), TFC (total flavonoid content), IC₅₀ (antioxidant activity), MC (moisture content), SL (solubility), DT (dissolution time), V (viscosity), H (hygroscopicity), L* (lightness), a* (redness), b* (yellowness), ∆E (total color difference), S (sedimentation), TSS (total soluble solid), and pH.
increase the viscosity of cocoa drinks. The panelists accepted the cocoa drink in its totality. However, the addition of encapsulated green coffee extract had no discernible effect on any cocoa drink samples, thereby not affecting the overall acceptance by the panelists.

**Correlation between the variables**

According to the results of the Pearson correlation analysis (Figure 2), all parameters had significant values of p < .01, which is 0.000, indicating the existence of a correlation between variables. The r values 0.00–0.20 indicate no correlation; 0.21–0.40 indicate a weak correlation; 0.41–0.60 indicate a medium correlation; 0.61–0.80 indicate a strong correlation, and 0.81–1.00 indicate a very strong correlation. Based on Figure 2, there is a very close relationship between the variables (r > 0.9 or r < −0.9). A positive correlation coefficient (r) indicates a positive relationship between variables and vice versa.

Figure 2 shows a very strong positive correlation between the total polyphenols and flavonoids (r = 0.990). The higher the amount of total polyphenols, the higher the amount of total flavonoids. This is because flavonoids are part of a group of polyphenols. Total polyphenols and flavonoids were very strongly negatively correlated with IC₅₀, with r = −0.987 and r = −0.981, respectively. In this study, the lower the IC₅₀ value was, the more polyphenols and flavonoids there were – the lower the IC₅₀ value was, the stronger the antioxidant activity in the sample. According to Indiarto et al., total flavonoids directly affect antioxidant activity. Natural antioxidants act as free radical scavengers containing phenolic compounds, vitamin C, and vitamin E.

Solubility and hygroscopicity are inversely related to moisture content, with r = −0.951 and r = −0.973, respectively. The lower the solubility and hygroscopicity are, the higher the moisture content is. One of the factors that can influence solubility and hygroscopicity is the moisture content. A high moisture content causes the material to agglomerate, making it difficult to spread in water. A high moisture content also reduces solubility and hygroscopicity. However, moisture content and dissolution rate have a very strong positive correlation (r = 0.984). The longer the dissolution rate, the greater the moisture content. An increase in the moisture content of cocoa powder will cause lumps and increase time needed for the particle bonds to break. The total soluble solids are also inversely proportional to the sedimentation index. The sedimentation value decreases with increasing total soluble solids.

The total polyphenols and flavonoids in the sample had a very strong positive correlation with the value of L* (lightness) (r = 0.978 and r = 0.960) and the value of ΔΕ (r = 0.972 and r = 0.966) but a negative correlation with a* (redness) (r = −0.985 and r = −0.981) and b* (yellowness) (r = −0.967 and r = −0.954). The greater the concentration of encapsulated green coffee extract, the greater the L*, as maltodextrin and gum arabic, used as a white coating during the encapsulation process, impart a brighter color. The ΔΕ also has a very strong positive correlation because adding more encapsulated extract increases the total color difference. However, it is inversely proportional to a* and b* values, with the redness and yellowness values decreasing as the amount of encapsulated extract added increases. In addition, the total polyphenols and total flavonoids of the samples were strongly negatively correlated with the pH value, with r = −0.982 and r = −0.983, respectively. When the total value of polyphenols and flavonoids increases, the pH value decreases because the phenolic compounds and chlorogenic acid in green coffee beans can release H+ ions, and there is a decrease in the pH value.

**Conclusion**

The encapsulated green coffee extract significantly altered the antioxidant activity and properties of the cocoa drinks. The total polyphenol content, flavonoid content, and antioxidant activity were significantly increased with increasing percentages of encapsulated extract. In addition, before brewing, the cocoa drinks exhibited a significant increase in hygroscopicity and total color
difference with an increase in the percentage of encapsulated extract. In contrast, the moisture content of the powder decreased significantly. After brewing for pH values, dissolution time and sedimentation decreased, while viscosity, total soluble solids, and solubility increased as the percentage of encapsulated extract increased. In addition, the cocoa drinks formulated with the addition of 2% to 10% encapsulated extract were acceptable to the panelists based on all sensory attributes. Thus, cocoa drink can be used as an alternative to beverages abundant in healthy and antioxidant rich.

Acknowledgments

The authors would like to acknowledge to Universitas Padjadjaran and the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia for their facilities provided

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research was supported by Universitas Padjadjaran Research Grant, RKDU Scheme, number: 2203/UN6.3.1/PT.00/2022

References

[1] Oracz, J.; Zyzelewicz, D.; Nebesny, E. The Content of Polyphenolic Compounds in Cocoa Beans (Theobroma Cacao L.), Depending on Variety, Growing Region, and Processing Operations: A Review. Crit. Rev. Food Sci. Nutr. 2015, 55(9), 1176–1192. DOI: 10.1080/10408398.2012.686934.
[2] Wollgast, J.; Anklam, E. Review on Polyphenols in Theobroma Cacao: Changes in Composition during the Manufacture of Chocolate and Methodology for Identification and Quantification. Food Res. Int. 2000, 33(6), 423–447. DOI: 10.1016/S0963-9969(00)00068-5.
[3] Indiarto, R.; Pranoto, Y.; Santos, U. In Vitro Antioxidant Activity and Profile of Polyphenol Compounds Extracts and Their Fractions on Cacao Beans. Pakistan J. Biol. Sci. 2019, 221, 34–44. DOI:10.3923/pjbs.2019.34.44.
[4] Sari, P.; Utari, E.; Praptiningsih, Y.; Maryanto. Karakteristik Kimia-Sensori Dan Stabilitas Polifenol Minuman Cokelat-Rempah. J. Agroteknologi 2015, 9(1), 54–66.
[5] Baker, M. T.; Lu, P.; Parrella, J. A.; Leggette, H. R. Consumer Acceptance toward Functional Foods: A Scoping Review. Int. J. Environ. Res. Public Health. 2022, 19, 3. DOI: 10.3390/ijerph19031217.
[6] Garrett, R.; Vaz, B. G.; Hovell, A. M. C.; Eberlin, M. N.; Rezende, C. M. Arabica and Robusta Coffees: Identification of Major Polar Compounds and Quantification of Blends by Direct-Infusion Electrospray Ionization-Mass Spectrometry. J. Agric. Food Chem. 2012, 60(17), 4253–4258. DOI: 10.1021/jf300388m.
[7] Patriche, S.; Boboc, M.; Leah, V.; M. D. R. Extraction and Evaluation of Bioactive Compounds with Antioxidant Potential from Green Arabica Coffee Extract. J. Food Technol. 2015, 39(2), 88–95.
[8] Esquivel, P.; Jiménez, V. M. Functional Properties of Coffee and Coffee By-Products. Food Res. Int. 2012, 46(2), 488–495. DOI: 10.1016/j.foodres.2011.05.028.
[9] Depeursinge, A.; Racoceanu, D.; Iavindrasana, J.; Cohen, G.; Platon, A.; Poletti, P.-A.; Muller, H. Fusing Visual and Clinical Information for Lung Tissue Classification in HRCT Data. Artif. Intell. Med. 2010, 229, A1RTMED1118.
[10] Mahdavee Khazaei, K.; Jafari, S. M.; Ghorbani, M.; Hemmati Kakhki, A. Application of Maltodextrin and Gum Arabic in Microencapsulation of Saffron Petal’s Anthocyanins and Evaluating Their Storage Stability and Color. Carbohydr. Polym. 2014, 105(1), 57–62. DOI: 10.1016/j.carbpol.2014.01.042.
[11] Indiarto, R.; Indriana, L. P. A.; Andoyo, R.; Subroto, E.; Nurhadi, B. Bottom–up Nanoparticle Synthesis: A Review of Techniques, Polyphenol-Based Core Materials, and Their Properties. Eur. Food Res. Technol. 2022, 248(1), 1–24. DOI: 10.1007/s00217-021-03867-y.
[12] Milincić, D. D.; Popović, D. A.; Lević, S. M.; Kostić, A.; Tešić, Ž. L.; Nedović, V. A.; Pešić, M. B. Application of Polyphenol-Loaded Nanoparticles in Food Industry. Nanomaterials. 2019, 9(11), 1629. DOI: 10.3390/nano9111629.
[34] Indiarto, R.; Pratama, A. W.; Sari, T. I.; Theodora, H. C. Food Irradiation Technology: A Review of the Uses and Their Capabilities. SSRG Int. J. Eng. Trends Technol. 2020, 68, 12. DOI: https://dx.doi.org/10.14445/22315381/IJETT-V68I12P216.

[35] Lamuela-Raventós, R. M.; Romero-Pérez, A. I.; Andrés-Lacueva, C.; Tornero, A. Review: Health Effects of Cocoa Flavonoids. Food Sci. Technol. Int. 2005, 11(3), 159–176. DOI: 10.1177/108203205054498.

[36] Simorangkir, M.; Nainggolan, B.; Silaban, S. Antioxidant activity of vacuum column chromatography fractions of ethanol extract of sarang banu (Clerodendrum fragrans vent will) leaves Journal of Physics: Conference Series. 2019, 1374 1 12016 https://doi.org/10.1088/1742-6596/1374/1/012016 DOI: 10.1088/1742-6596/1374/1/012016

[37] Minamisawa, M.; Yoshida, S.; Takai, N. Determination of Biologically Active Substances in Roasted Coffees Using a Diode-Array HPLC System. Anal. Sci. 2004, 20(2), 325–328. DOI: 10.2116/ansci20.325.

[38] Abbe Maleyki, M. J.; Ismail, A. Antioxidant Properties of Cocoa Powder. J. Food Biochem. 2010, 341, 111–128. DOI:https://doi.org/10.1111/j.1745-4514.2009.00268.x.

[39] BSN. SNI 01-4320-1996 : Serbuk Minuman Tradisional. 1996, 1–6.

[40] Putra, S. D. R.; Ekawati, L. Kualitas Minuman Serbuk Instan Kulit Buah Manggis Dengan Variasi Maltodextrin Dan Suhu Pemanasan. Univ. Atma Jaya Yogyakarta. 2013.

[41] Mahdi, A. A.; Mohammed, J. K.; Al-Ansi, W.; Ghaleb, A. D. S.; Al-Maqtari, Q. A.; Ma, M.; Ahmed, M. I.; Wang, H. Microencapsulation of Fingered Citron Extract with Gum Arabic, Modified Starch, Whey Protein, and Maltodextrin Using Spray Drying. Int. J. Biol. Macromol. 2020, 152, 1125–1134. DOI: 10.1016/j.ijbiomac.2019.10.201.

[42] Schuck, Pierre, Dolivet, Anne, Jeantet, Romain 2012 Determination of the Sorption Isotherm, Water Activity and Hygroscopicity of Powders Analytical Methods for Food and Dairy Powders (New York, USA: John Wiley & Sons, Ltd.)167–190 9781118307397 doi:https://doi.org/10.1002/9781118307397.ch11

[43] Goula, A. M.; Adamopoulou, K. G. Effect of Maltodextrin Addition during Spray Drying of Tomato Pulp in Dehumidified Air: II. Drying Technol. 2008, 266, 726–737. DOI: 10.1080/07373930802046377.

[44] Kania, W.; Andriani, M. M.; Siswanti. Pengaruh Variasi Rasio Bahan Pengikat Terhadap Karakteristik Fisik Dan Kimia Granul Minuman Fungsional Instan Kecambah Kacang Komak (Lobal Purpuresus (L.) Sweet.). Teknosin Rang Pangan2015, 4(3), 16–29.

[45] Li, Y.; Zhu, S.; Feng, Y.; Xu, F.; Ma, J.; Zhong, F. Influence of Alkalization Treatment on the Color Quality and the Total Phenolic and Anthocyanin Contents in Cocoa Powder. Food Sci. Biotechnol. 2014, 23(1), 59–63. DOI: 10.1007/s10068-014-0008-5.

[46] Rodriguez, P.; Pérez, E.; Guzmán, R. Effect of the Types and Concentrations of Alkali on the Color of Cocoa Liquor. J. Sci. Food Agric. 2009, 897, 1186–1194. DOI:10.1002/jsfa.3573.

[47] Jeszka-Skowron, M.; Sentkowska, A.; Pyrzyńska, K.; De Peña, M. P. Chlorogenic Acids, Caffeine Content and Antioxidant Properties of Green Coffee Extracts: Influence of Green Coffee Bean Preparation. Eur. Food Res. Technol. 2016, 242(8), 1403–1409. DOI:10.1007/s00217-016-2643-y.

[48] Indiarto, R.; Subroto, E.; Sukri, N.; Djali, M. 2021. Cocoa (Theobroma cacao L.) beans processing technology: A review of flavonoid changes. Asian J. Plant Sci. 20(4), 684–693. doi:10.3923/ajps.2021.684.693

[49] Arziyah, D.; Mutiar, S. Effect of Alkalization on Cocoa Paste on the Yield of Pressed Oil. J. Litbang Ind 2021, 11, 97–102. DOI: 10.24960/jli.v11i2.6901.97-102.

[50] Abedi, F.; Sani, A. M.; Karazhiyan, H. Effect of Some Hydrocolloids Blend on Viscosity and Sensory Properties of Raspberry Juice-Milk. J. Food Sci. Technol. 2014, 51(9), 2246–2250. DOI: 10.13181/jfst-012-0705-0.

[51] Shogren, R.; Biresaw, G. Surface Properties of Water Soluble Maltodextrin, Starch Acetates and Starch Acetates/Alkenylsuccinates. Colloids Surfaces A Physicochem. Eng. Asp. 2007, 2983, 170–176. DOI:10.1016/j.colsurfa.2006.10.070.

[52] Santos, M.; Widyorini, R.; Prayitno, T. A.; Sulisty, J. Bonding Performance of Maltodextrin and Citric Acid for Particleboard Made from Nipa Fronds. J. Korean Wood Sci. Technol. 2017, 45, 432–443. DOI:10.5688/WOOD.2017.45.4.432.

[53] Moghadam, A. D.; Pero, M.; Askari, G. R. Optimizing Spray Drying Conditions of Sour Cherry Juice Based on Physicochemical Properties, Using Response Surface Methodology (RSM). J. Food Sci. Technol. 2017, 54(1), 174–184. DOI: 10.1007/s13197-016-2449-8.

[54] Chuaychan, S.; Benjakul, S. Effect of Maltodextrin on Characteristics and Antioxidative Activity of Spray-Dried Powder of Gelatin and Gelatin Hydrolysate from Scales of Spotted Golden Goatfish. J. Food Sci. Technol. 2016, 53 (9), 3583–3592. DOI: 10.1007/s13197-016-2340-7.

[55] Ernawati, U. R.; Khasanah, L. U.; Anandito, R. B. K. Pengaruh Variasi Nilai Dextrose Equivalents (DE) Maltodextrin Terhadap Karakteristik Mikroenkapulsan Pewarna Alami Daun Jati (Tectona Grandis L. F.). J. Teknol. Pertan 2014, 15(2), 111–120.

[56] Akkarachaneeyakorn, S.; Tinrat, S. Effects of Types and Amounts of Stabilizers on Physical and Sensory Characteristics of Cloudy Ready-to-Drink Mulberry Fruit Juice. Food Sci. Nutr. 2015, 3(3), 213–220. DOI: 10.1002/fsn3.206.
[57] Gabbott, I. P.; Al Husban, F.; Reynolds, G. K. The Combined Effect of Wet Granulation Process Parameters and Dried Granule Moisture Content on Tablet Quality Attributes. *Eur. J. Pharm. Biopharm.* 2016, 106, 70–78. DOI: 10.1016/j.ejpb.2016.03.022.

[58] Ni’mah, M.; Hasbullah, U.; Retnowati, E. Production of Robusta Instant Coffee Powder with Variation of Fillers. *Agrotek J. Teknol. Ind. Pertan.* 2021, 15, 932–942. DOI: 10.21107/agrotek.v15i3.10629.

[59] Chng, Y.; Chang, L.-S.; Pui, L. P. Effects of Maltodextrin Concentration and Inlet Temperature on the Physicochemical Properties of Spray-Dried Kuini Powder. *Asia Pacific J. Mol. Biol. Biotechnol.* 2020, 84, 117–131. DOI: 10.35118/apjmbb.2020.028.4.10.

[60] Selamat, J.; Hussin, N.; Mohd Zain, A.; Che Man, Y. B. Effects of Alkalized Cocoa Powder and Soy Lecithin on Physical Characteristics of Chocolate Beverage Powders. *J. Food Process. Preserv.* 1998, 22(3), 241–254. DOI: 10.1111/j.1745-4549.1998.tb00348.x.

[61] Wüstenberg, T. Cellulose and Cellulose Derivatives in the Food Industry. *Fundamentals and Applications*. 2014.

[62] Fitriani, C.; Yulianti, A. Formulasi dan Evaluasi Stabilitas Fisik Suspensi Ubi Cilembu (Ipomea Batatas L.) Dengan Suspending Agent CMC Na Dan PGS Sebagai Antihiperkolesterol Formulation and Evaluation of Physical Stability of Suspension Cilembu (Ipomea Batatas L.) with Suspend. *J. Farm. Sains Dan Terap* 2015, 2(1), 23.

[63] Wijayanti, N. P. A. D.; Putra, A. A. G. R. Y.; Suryantari, I. A. P.; Dwiantari, G. A. D. UJI AKTIVITAS ANTIOKSIDAN EKSTRAK DAN FRAKSI KULIT BUAH MANGGIS (Garcinia Mangostana L.) MENGGUNAKAN METODE DPPH. *J. Kim* 2018, 74. DOI: 10.24843/jchem.2018.v12.i01.p14.

[64] Septianti, E.; Salengke,.; Langkong, J. Profile of Bioactive Compounds, Antioxidant and Aromatic Component from Several Clones of Cocoa Beans during Fermentation. *IOP Conf. Ser. Earth Environ. Sci.* 2020, 575, 1. DOI: 10.1088/1755-1315/575/1/012009.

[65] Quealal-Vásconez, M. A.; Lerma-García, M. J.; Pérez-Esteve, É.; Talens, P.; Barat, J. M. Roadmap of Cocoa Quality and Authenticity Control in the Industry: A Review of Conventional and Alternative Methods. *Compr. Rev. Food Sci. Food Saf.* 2020, 19(2), 448–478. DOI: 10.1111/1541-4337.12522.

[66] Quintana-López, G.; Maldonado-Cañón, K.; Flórez-Suárez, J. B.; Méndez-Patarroyo, P.; Coral-Alvarado, P.; Calvo, E. Correlation and Agreement between Physical and Ultrasound Examination after a Training Session Dedicated to the Standardization of Synovitis Assessment in Rheumatoid Arthritis Patients. *Adv. Rheumatol.* 2021, 611, 68. DOI: 10.1186/s42358-021-00227-y.

[67] Laitonjam, W. S.; Natural Antioxidants (NAO) of Plants Acting as Scavengers of Free Radicals. In *Studies in Natural Products Chemistry*; Atta-ur-Rahman, B. T.-S. in N. P. C., Ed.; Elsevier, 2012; Vol. 37, pp 259–275. DOI: 10.1016/B978-0-444-59514-0.00009-2.