Formulation of Tengger Herbal Coffee: Effect of Coffee Type and Fennel Seed Powder

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The Bromo Tengger Semeru National Park (or Taman Nasional Bromo Tengger Semeru/TNBTS) is a popular tourist destination in Indonesia, and the local authorities encourage the development of new local specialty products. One locally available commodity is coffee. This study investigated the best formula for Tengger herbal coffee. The randomized block design (RBD) consisted of two factors, including the coffee types (*i.e.*, Arabica, Robusta, and Arabica:Robusta (50:50)) and the proportion of coffee:fennel seed powders (*i.e.*, 92:8, 90:10, and 88:12). Physicochemical and organoleptic quality parameters were analyzed. In all coffee types, the addition of fennel seed powder at different concentrations significantly affects the sensory attribute (*i.e.*, color, taste, and aroma) and the physicochemical characteristics of Tengger herbal coffee. The blending of coffee with fennel seed powder improved the taste and aroma of the herbal coffee. The best formulation was obtained from A3B3, a mixture of 44% Arabica coffee: 44% Robusta coffee: 12% fennel seed powder. This formula resulted in Tengger herbal coffee with pH 4.9, 16.6 color lightness, 0.64% total insoluble solids (TIS), 0.07% caffeine content, 47.2 mg GAE/g total phenol, 0.49 ppm antioxidant activity (IC_{50}), and 0.58% reducing sugar. The findings confirmed that Tengger herbal coffee offers health benefits from its antioxidant activity, alongside the potential as a traditional beverage product.

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INTRODUCTION

Indonesia is a tropical country that is well-known for its beautiful nature. The Bromo Tengger Semeru National Park (or *Taman Nasional Bromo Tengger Semeru/*TNBTS) is one of Indonesia’s top 10 priority tourism destinations (Akbar and Pangestuti 2017; Utami 2017). TNBTS is famous for its natural beauty and is currently under development in the agricultural sector, particularly coffee plantation. People love coffee due to its distinctive flavor and aroma (Ariefandi *et al.* 2015). Mostly, coffee is served as hot or cold drinks, depending on the customers’ preferences. The TNBTS area has cold temperatures; therefore, hot coffee drinks are popular amongst tourists. Herbal coffee is a processed coffee product, usually made from a mixture of Arabica or Robusta ground coffee with various herbs and spices (fennel, ginger, nutmeg, cinnamon, *etc.*) (Savitri *et al.* 2020; Secilmis *et al.* 2015; Sekeroglu *et al.* 2012). Adding herbs and spices to coffee provides new flavors and aroma, increases nutrient contents, and improves health benefits (Fatmawati *et al.* 2020).

Fennel, a plant cultivated as herbs and its fruits, is widely used for cooking spices or herbal medicine (Valduga *et al.* 2019; Khan *et al.* 2022). The fennel plant (*Foeniculum vulgare* Mill.) mostly grow wild in the highlands or mountainous areas in Indonesia (Rifqiyati and Wahyuni 2019), including in the TNBTS area – Java Island. Fennel seeds have antimicrobial activity and contain potent antioxidants beneficial to protect the human body from cancer, infection, aging, and degenerative neurological diseases (Dahmani *et al.* 2022; Kaveh *et al.* 2022; Maleš *et al.* 2022). Several studies highlighted the use of fennel seeds in various food and beverages products, including culinary or cooking spices (Malhotra 2012); bread (Alalwan *et al.* 2017); herbal tea (Raffo *et al.* 2011); and pastries (Lal 2008). However, limited studies have been reported on using fennel seed to make herbal coffee. Wijana *et al.* (2018) reported that adding fennel seeds and ginger extract adds health benefits to Tengger herbal coffee due to the strong antioxidant content found in fennel seeds. Therefore, there is prospective potency for using fennel seed as additional ingredients to make herbal or functional drink beverages.

This study aimed to formulate the best quality Tengger spiced coffee using different coffee types with the addition of fennel seed powder in terms of sensory atributes and physicochemical properties. The study results is hoped to create a unique herbal coffee products that the local communities in Tengger areas can commercially make. Hence, this study can support to realize the TNBTS as a tourism area with its specialty products of traditional Tengger herbal coffee. With this, creating a new market is plausible, thus providing more economic benefits to local communities.

EXPERIMENTAL

Materials

Two types of coffee beans were used, namely Arabica and Robusta coffee, which were collected from the slope of Mount Arjuno. The coffee beans were cleaned of any impurities such as leaf flakes or coffee husk, then washed with flow tap water to remove any remaining dirt. The beans were then sun-dried for 5 days. The dried coffee beans were roasted at 201 °C for 10 min until the brown color was obtained and cooled for 30 min. The roasted coffee beans were ground to powder size (60 mesh). The fennel seeds were collected from Ngadas Village, located in the TNBTS area, with brownish-green color and having a moisture content of 9.2%. The fennel seeds were cleaned from leaf flakes and washed with flowing tap water. The seeds were then dried using sun-drying methods for 4 days and ground to powder size (60 mesh). The preparation of coffee and fennel seeds samples followed the method described by Wijana *et al.* (2018).

Experimental Set-up

The experiment was set up using randomized block design (RBD). This approach makes it possible to allocate each treatment at random within the unit of block (*i.e.*, restricted randomization), obtain more precision results, and is more flexible, and easy to adapt (Ryan and Morgan 2007). Two factors were evaluated, including coffee types (*i.e.*, Arabica, Robusta, and Arabica:Robusta (50:50)) and the proportion of coffee: fennel seeds powder (*i.e.*, 92:8, 90:10, and 88:12). The proportion of each formula varied depending on the proportion of fennel seed powder added, making the total formulation sum of 100 parts. For the mixture of Arabica and Robusta coffee, a proportion of 50:50 was used. The combination of the experimental design is shown in Table 1.

Table 1. Experimental Design Using RBD

Type of Coffee	Proportion of Coffee:Fennel Seeds Powder (%)		
	92:8 (B1)	90:10 (B2)	88:12 (B3)
Arabica (A1)	A1B1	A1B2	A1B3
Robusta (A2)	A2B1	A2B2	A2B3
Arabica and Robusta (50:50) (A3)	A3B1*	A3B2**	A3B3***

Note: *A3B1 (46 Arabica coffee: 46 Robusta coffee: 8 fennel seed powder)
**A3B2 (45% Arabica coffee: 45% Robusta coffee: 10% fennel seed powder)
***A3B3 (44% Arabica coffee: 44% Robusta coffee: 12% fennel seed powder)

Herbal Coffee Making Procedures

The procedure for making herbal coffee followed the method described by Rohmah (2010) and Wijana *et al.* (2018), with some modifications. First, Arabica and Robusta coffee powder were weighed following the proportion required in each formula. The fennel seeds powder was weighed following the formula and added to the coffee powder. The coffee and fennel seed powder mixture was then homogenously mixed and packaged as herbal coffee.

Sensory Analysis

Sensory analysis was carried out using the hedonic scale scoring method (Yazicioglu 2022), with sensory attributes of color, taste, and aroma. The hedonic test was performed using 15 semi-trained panelists of community leaders in Ngadas Village, TNBTS area. Prior to serving, Tengger herbal coffee was brewed using the "*tubruk*" method (Naidoo *et al.* 2011), with modifications. In this study, 14 g of Tengger herbal coffee was added with 200 mL of hot water (90 °C) and then homogeneously stirred (13 times stirring). Each panelist was asked to evaluate the brewed herbal coffee based on sensory attributes with a five-point hedonic scale, as follows: 1 (not too dark/ not too bitter/ imperceptible fennel aroma), 2 (not dark/ not bitter/ perceptible fennel aroma), 3 (slightly dark/ slightly bitter/ slightly distinctive fennel aroma), 4 (dark/ bitter/ distinctive fennel aroma), and 5 (too dark/ too bitter/ very distinctive fennel aroma). The five-point hedonic scale was used in this study following previous studies (Beekman *et al.* 2021; DePaula *et al.* 2022; Meilgaard *et al.* 2021). This approach is simple and easy to adopt, may provide similar data across sensory attributes, and is better implemented to compare samples with minor differences (Meilgaard *et al.* 2021).

The sensory analysis procedures were carried out following Beekman *et al.* (2021), with some modifications. Each participant has a similar drinking condition: using a coffee paper cup without a lid. Individual coffee brew samples (200 mL) were prepared immediately prior to serving. All panelists consecutively received nine herbal coffee brew samples in balance order. They were then asked to take a few sips but not to drink the entire coffee sample. In each session, all panelists are given three samples and asked to rate the sensory attributes (*i.e.*, aroma, taste, and color). The panelists were given no time limit to provide enough time for sample evaluation. Between the samples serving, five-minute breaks were provided with water and unsalted cracker for palate washing. This was done to avoid any risks of carry-over effect.

Best Formulation Selection

The selection of the best formulation aimed to identify the formulation which results in the best quality Tengger herbal coffee. This was performed using Zeleny multiple attribute method (Zeleny 2003), with best-quality parameters based on color, taste, and aroma obtained from the sensory analysis. The selected best formula for Tengger herbal coffee was then proceeded with physicochemical analysis, including pH, color, total insoluble solids (TIS), caffeine content, total phenolic content (TPC), antioxidant activity (IC_{50}), and reducing sugar content.

Physicochemical Analysis

Besides the selected best formula, the physicochemical analysis was also done on commercial herbal coffee and two herbal coffee samples (each from single- and mixture-blend). This was aimed to compare the effect of coffee types and fennel seed powder addition on the quality.

pH and total insoluble solids (TIS) measurement

The pH was measured based on the method explained by Mazzafera *et al.* (1991), with some modifications. A 3.5 g herbal coffee powder was mixed thoroughly with 50 mL of hot aquadest and. The calibrated pH probe was then immersed into the brewed herbal coffee until a stable pH value was obtained. The total insoluble solids (TIS) were analyzed using the gravimetric method by refluxing herbal coffee powder (2.5 g) with 250 mL hot water for 1 min and followed by filtration. The remaining solid in filter paper was then evaporated using an oven at 105 ºC until reaching a stable weight, and the amount of TSS was calculated (AOAC 2000).

Color measurement

Colorimetric analysis was carried out to measure the color lightness level of the Tengger herbal coffee. The measurement was performed using a colorimeter PCE-CSM 4 (PCE Instruments UK Ltd, UK), following the method described by Yeager *et al.* (2022), with modifications. Each sample was prepared by adding 3.5 g of Tengger herbal coffee with 50 mL of aquadest. This brewed coffee was then poured into a transparent plastic bag and placed on the color reader. The results are expressed in *L** (lightness), *a** (red-green value), and *b** (yellow-blue value).

Caffeine content measurement

Coffee samples tested for the caffeine content was not subjected to any pretreatment methods. Caffeine content was measured using a UV-Vis spectrophotometer, following the standard procedures (AOAC 2000). A 0.01 g of herbal coffee powder was diluted with 10 mL of aquadest to obtain a stock solution of 1000 ppm. An aliquot of 1 mL herbal coffee stock solution was added with 10 mL aquadest, and the sample’s absorbance was measured at 275 nm. The caffeine content was calculated using a standard graph from a caffeine reference sample.

Total phenolic content (TPC) measurement

The total phenolic contents (TPC) of the Tengger herbal coffee were analyzed using the Folin-Ciocalteu (FC) method, following Uslu (2022), with a slight modification. 1 mL of the herbal coffee extracts was mixed with 5 mL of FC reagent (10%) and 2 mL of Na_2CO_3 solution (7.5 % w/v). The sample was then thoroughly mixed and stored in a dark place for 30 min at room temperature. The absorbance value of the sample was measured using a UV-Vis spectrophotometer at 765 nm. Total phenolic content was determined using a gallic acid standard curve and expressed as mg gallic acid equivalent (GAE)/100 g ground coffee. Many studies have also reported the use of the UV-Vis test to measure TPC in fennel and coffee extracts (Kwak *et al.* 2017; Hayat *et al.* 2019; Chongsrimsirisakhol and Pirak 2022; Noreen *et al.* 2023).

Reducing sugar measurement

Reduction sugar was measured using the Nelson-Somogyi method (Somogyi 1945), with some modifications. Approximately 2.5 to 5 g of herbal coffee powder was placed into a 100-mL flask, added with aquadest up to 100 mL, and homogenously mixed. The solution was then poured into a 250-mL flask and added with 25 mL of luff schoorl solution. The mixture was boiled and left for 10 min. 10 mL of KI solution (15%), 25 mL of H_2SO_4 solution, and 25 mL of the starch indicator were added and thoroughly mixed. The blank sample was made by mixing 25 mL luff schoorl solution with 25 mL aquadest and 2-3 mL of the starch indicator. The sample and blank solution were then titrated with 0.1 N $Na_2S_2O_3$ solution until the color changed from blue to white. The titration volume difference between the sample and the blank was converted using the luff school conversion table, which expressed the relationship between the use of $Na_2S_2O_3$ solution with the amount of reducing sugar. Reducing sugar was calculated as follows,

$$Reducing\ sugar\ (\%) = \frac{W_1 - F_p}{W}\ x\ 100\ \% \tag{1}$$

where W_1 represents the amount of glucose in mg (obtaining from the luff school conversion table), F_p represents the dilution factor, and W represents the weight of the sample.

Antioxidant activity measurement

The antioxidant activity of the Tengger herbal coffee was measured using the 2,2-diphenyl-1-picrazil (DPPH) method, as explained by Lee *et al.* (1998) and Devi *et al.* (2023). The antioxidant activity was determined based on the percentage of inhibition and IC_{50} value. The level of antioxidant activity is categorized into very strong (IC_{50} <50 ppm), strong (IC_{50} of 50 to 100 ppm), medium (IC_{50} of 100 to 150 ppm), and weak (IC_{50} of 151 to 200 ppm) (Molyneux 2004).

Statistical Analysis

The statistical analysis for the sensory data set used the Friedman test. While one-way analysis of variance (ANOVA) was carried out to analyze physicochemical parameters. The Tukey's honestly significant difference (HSD) was performed if any significant difference was observed. The statistical analysis was conducted using SPSS 19.0 software, with a confidence level of 95% (α = 0.05).

RESULTS AND DISCUSSION

Sensory Evaluation

This study asked the panelists to quantify sensory attributes (*i.e.*, color, taste, and aroma) noticed in each Tengger herbal coffee brews. The sensory analysis results from different brewed Tengger herbal coffee are shown in Table 2 and reveal significant differences between the respective formulation. The study also reported a significant correlation between color and overall liking. Most of the panelists preferred darker color.

Table 2. Average of Sensory Attributes to The Brewed Tengger Herbal Coffee

Formulation ID	Sensory analysis				Friedman's rank		
	Color	Taste	Aroma	Overall acceptability	Color	Taste	Aroma
A1B1	2.73^{ab}	2.67^{abc}	4.60^{c}	3.33	4.07^{ab}	3.67^{abc}	7.47^{c}
A1B2	2.40^{a}	3.33^{c}	2.40^{a}	2.71	3.00^{a}	5.37^{c}	2.47^{a}
A1B3	4.33^{d}	4.33^{d}	4.67^{c}	4.44	8.07^{d}	7.50^{d}	7.67^{c}
A2B1	2.33^{a}	2.27^{a}	2.67^{a}	2.42	2.83^{a}	2.57^{a}	3.10^{a}
A2B2	4.33^{d}	3.07^{bc}	2.60^{a}	3.33	8.17^{d}	4.57^{bc}	2.93^{a}
A2B3	2.47^{a}	2.67^{abc}	2.27^{a}	2.47	3.17^{a}	3.60^{abc}	2.10^{a}
A3B1	3.67^{cd}	4.33^{d}	3.33^{b}	3.78	6.77^{cd}	7.30^{d}	4.73^{b}
A3B2	2.53^{a}	4.40^{d}	4.40^{c}	3.78	3.47^{a}	7.67^{d}	7.07^{c}
A3B3	3.20^{bc}	2.40^{abc}	4.60^{c}	3.40	5.47^{bc}	2.77^{abc}	7.47^{c}

Note: Note: Same letters next to each value indicate that there is no significant difference among data in the same column (α≤ 0.05)

Specific to color attributes, the average values ranged from 2.33 to 4.33 (not dark to dark). The Friedman test results indicated that different proportions of fennel seed powder to the coffee blending significantly differed the color appearance (α≤ 0.05). This study also found that adding fennel seed powder to different coffee types could produce herbal coffee brews with good color quality. For example, the brewed Tengger herbal coffee from blending 44% Arabica coffee, 44% Robusta coffee, and 8% fennel formulation (A3B1) produced a darker color than using Arabica or Robusta coffee alone at the same proportion of fennel seed powder added. Notably, the brewed Tengger herbal coffee from blending Arabica coffee alone with 12% fennel seed powder (A1B3) exhibited darker colors than other counterparts. A similar trend was observed in brewed Robusta coffee with 10% fennel seed powder (A2B2). This difference could be due to the type of coffee used and the amount of fennel seed added. Furthermore, pure Arabica coffee has a more intense color of dark brown than Robusta coffee of light brown, while fennel seed powder has a yellowish-brown color appearance. Therefore, the color of coffee or fennel grounds could also influence the coffee brew's color. Anisa *et al.* (2017) reported that the color of Arabica coffee grounds directly influenced the color of the brewed coffee. Similarly, Yeager *et al.* (2022) found that a similar color of coffee grounds did not directly translate to the same color of the brews. They found that the darker the coffee grounds, the darker the coffee brews color. Various factors influence this pattern, such as roasting level, brew temperature, coffee origin, coffee plant type, processing methods, grinding size, and brewing methods, affecting the final color of the coffee brew (Bhumiratana *et al.* 2011; Yeager *et al.* 2022).

In terms of taste attribute, the average values were in the range of 2.27 to 4.40 (slightly bitter to bitter). The Friedman test also showed a significant difference from all formulations (α≤ 0.05). The results showed that A3B1 and A3B2 formulations could produce a unique and distinctive taste, coming from a combination of the sour taste of Arabica coffee, the bitter taste of Robusta coffee, and the sweet taste of fennel seed powder. The bitter taste in herbal coffee brews is due to the presence of phenolic compounds. Furthermore, Malhotra (2012) stated that fennel contains anethole with a sweet taste, thus giving a distinctive and refreshing taste. However, adding a small proportion of fennel seed powder to Arabica coffee can add a distinctive taste. This is because Arabica coffee itself already has a good taste quality compared to other coffee types, so adding a small amount of spices can provide the distinctive taste of the coffee brew. Unlike Robusta coffee, adding fennel seed powder in small or large proportions could add sweetness, thus reducing the bitterness of the coffee brews. Furthermore, all respondents also agreed that the formulation tested with different ratios of coffee types and fennel seed powder offered a slightly different taste to the herbal coffee.

In the aroma attribute, the average values from the panelist evaluation were in the range of 2.27 to 4.67 (perceptible to very distinctive fennel aroma), with the Friedman test results showing a significant difference ($\alpha<0.05$) from all formulations. All panelists agreed that fennel addition gave a distinctive aroma to the Tengger herbal coffee. This unique aroma was formed due to the coffee type and additional ingredients used in the formulation. Arabica coffee has higher amounts of acids, pyridines, furans, and aldehydes; therefore, it has a distinctive aroma and tastes to a greater extent than Robusta coffee (Wang *et al.* 2022). Their study also reported that adding a higher proportion of Robusta coffee is correlated with reducing in the aroma and taste of coffee beverages. Previous studies by Bastian *et al.* (2021) and Gemechu (2020) also reported that volatile and semi-volatile compounds (*i.e.*, acids, alcohols, aldehydes, esters, furans, indoles, ketones, phenolic compounds, pyrazines, pyridines, pyrroles, and thiols) are responsible for giving a distinctive aroma in coffee. In addition, fennel seeds contain anethole compounds that give off a sweet and spicy aroma (Jashari *et al.* 2023; Rietjens *et al.* 2023; Saber and Eshra 2019). According to Saber and Eshra (2019), fennel seeds contain essential oils, with the main constituent being 60% of anethole. Therefore, combining different coffee types with different proportions of fennel seed powders may produce coffee brews with a unique and distinctive aroma.

Fennel plants (*i.e.*, fruits and seeds) have health benefits and have been used for a long time as herbal medicine due to their bioactive compounds, which provide antimicrobial, anti-inflammatory, antidiabetic, and hepatoprotective functions, *etc.* (Rather *et al.* 2016; Maleš *et al.* 2022). Thus, fennel seed is promising to be used as an additional ingredient to formulate functional and medicinal beverages (Valduga *et al.* 2019; Maleš *et al.* 2022; Suleiman and Helal 2022). Therefore, in this study, the resulting herbal coffee may also have health benefits.

Best Formulation Selection

Table 3 shows the L1, L2, and L∞ values in each sample to determine the best formulation for making Tengger herbal coffee. The best formulation was chosen from the lowest L1, L2, and L∞ values (or given with rank 1).

Table 3. The Results of L1, L2, and L∞ for the Best Treatment Selection

Formulation ID	L1	L2	L∞	Rank
A1B1	0.178	1.59E-04	0.111	2
A1B2	0.417	1.39E-03	0.146	8
A1B3	0.159	8.30E-04	0.143	5
A2B1	0.297	9.14E-04	0.139	4
A2B2	0.235	7.00E-04	0.133	3
A2B3	0.364	1.41E-03	0.154	9
A3B1	0.305	9.44E-04	0.143	6
A3B2	0.319	1.13E-03	0.145	7
A3B3	0.110	3.77E-05	0.078	1*

Note: *lower rank is preferred for best treatment selection. L1 and L2 is ideal value; L∞ is the maximum value

The results show that A3B3 was selected as the best formulation, giving the sensory attributes of a slightly dark color, not bitter taste, and a very distinctive fennel aroma. The panelists mostly preferred these attributes, which could be proposed as a new and unique product local to the Tengger area.

Physicochemical Characteristics Test Results

The physicochemical analysis was carried out on A3B3 (best formulation), A3B2, A1B3, and commercial herbal coffee to compare the quality of the selected Tengger herbal coffee. The results are shown in Table 4.

pH

Table 4 shows that the average pH value of Tengger herbal coffee was lower than that of commercial coffee. All selected formulations with a higher fennel seed proportion of 12% (*i.e.*, A3B3 and A1B3) had a slightly lower pH than A3B2 (*i.e.*, 10% fennel seed powder addition). This indicates that the proportion of fennel seeds added and the type of coffee could affect the pH of the coffee brew. This study found that an increasing proportion of fennel seeds powder added may reduce the herbal coffee's pH value. Also, Arabica coffee has a more sour taste than Robusta coffee. This is in line with a previous study that the pH of Robusta coffee was 5.54, while Arabica coffee was 5.43 (Velmourougane 2013). Therefore, blending Arabica coffee alone with fennel seeds powder (A1B3) resulted in a more acidic pH than commercial coffee. However, it had a slightly similar pH value to blending Arabica and Robusta coffee with fennel seeds (*i.e.*, A3B2 and A3B3). According to Nurhayati (2017), mixing Arabica and Robusta may produce different pH values due to the difference in the amount of dissolved acid. Furthermore, Wijana *et al.* (2018) found that the herbal coffee made of Robusta coffee with fennel seed powder and ginger extract had pH values ranging from 5.93 to 6.27 due to organic components in the ingredients.

Color

The Tengger herbal coffee brews from different formulations showed low values of *L** (lightness), *a** (red-green value), and *b** (yellow-blue value) compared to the commercial samples (Table 4). According to Nurhayati (2017) and Yeager *et al.* (2022), *L** values close to 100 indicates that the material has brighter color. In this study, the herbal coffee brews from A3B2 and A3B3 formulations have a slightly less dark color than that of A1B3, as indicated by their slightly higher *L** values. The commercial herbal coffee exhibited the brightest color (*i.e.*, light brown) compared to all formulations. This could be due to the raw ingredients used (*i.e.*, Robusta coffee, fennel seeds, and ginger), which affects the coffee brew's color (Zuorro and Lavecchia 2013; Wijana *et al.* 2018). The proportion of fennel seed powder did not significantly impact the herbal coffee brew's color. Both formulations (*i.e.*, A3B2 and A3B3) had almost the same color lightness level, in contrast to that observed in A1B3 (blending of Arabica coffee alone with 12% fennel seed powder).

The initial color of Arabica coffee used in this study was blackish brown, while the Robusta coffee was light brown and the fennel seed powder was brownish yellow. Combining these three ingredients produces a blackish-brown color with a fairly thick consistency. The *a** value (red-green value) shows a red color for *a** (+) value and a green color for *a** (-). The *b** value (yellow-blue value) shows a yellow color for *b** (+) values and a blue color for *b** (-). The results of all herbal coffee formulation samples had *a** (+)

and b^* (+) values, meaning that the coffee brew color tends to be reddish and yellowish. However, the study observed that the color of the Tengger herbal coffee brews was still dark brownish. Therefore, the color of Tengger herbal coffee could be influenced to a greater extent by the initial color of the Robusta and Arabica coffee powder than by the fennel seed powder. This aligns with a previous study by Febrianto *et al.* (2015) that adding cardamon to Robusta coffee did not affect the color of the herbal coffee, as the Robusta coffee grounds have a much darker color (*i.e.*, brownish black).

Total insoluble solids (TIS)

The TIS values for all formulations were higher (0.56 to 0.88%) than the commercial herbal coffee (0.16%) (Table 4). According to the National Standardization Agency of Indonesia (or BSN) (BSN 1992), these values were still above the Indonesian national standard value for instant coffee (SNI 01-2983-1992) of a maximum value of 0.25% (w/w). The Tengger herbal coffee from A3B2 and A3B3 formulations had slightly the same TIS values, while A1B3 formulation had a much higher TIS value. This could be due to the difference in the mineral content in the coffee grounds, where Arabica coffee has a higher value than Robusta coffee (Cruz *et al.* 2015; Wei and Tanokura 2015; Nurhayati 2017). Furthermore, higher mineral content was also reported to affect the water content of coffee grounds as some of the minerals as water-soluble, hence likely to increase the TIS value (Cruz *et al.* 2015). Another study reported that the mineral content in ground coffee is obtained from nutrients absorbed during growth. Arabica coffee is grown at high altitudes of 1000-2000 m above sea level (asl), while Robusta coffee is grown at low altitudes (about 800 m asl) (Ngolo *et al.* 2018; Martins *et al.* 2020).

Table 4. Comparison of Physicochemical Characteristics of Tengger Herbal Coffee with a Commercial Coffee and SNI

Sample ID	pH	Color Measurement			TIS (%)	Caffeine Content (%)	TPC (mg GAE/g)	Antioxidant Activity (IC_{50}) (ppm)	Reducing Sugar (%)
		*L**	*a**	*b**					
A3B3	4.90	16.57	9.76	4.53	0.64	0.07	47.20	0.49	0.58
A3B2	5.10	16.43	10.24	4.51	0.56	0.06	28.70	0.58	0.60
A1B3	4.95	16.19	8.51	3.08	0.88	0.08	43.00	0.53	0.53
Commercial herbal coffee	5.55	17.64	15.59	8.63	0.16	0.05	18.90	4.63	0.20
Indonesian National Standard (Standard Nasional Indonesia/SNI)									
SNI 01-2983-1992*	-	Normal			Max. 0.25	2-8	-	-	Max. 10 [c]
SNI 01-3542-2004**	-	Normal			-	0.92-2/ 0.45-2	-	-	-
SNI 2983-2014***	-	Normal			-	Min. 2.5[a]/ max. 0.3[b]	-	-	Max. 0.45[d]

Note: TIS is total insoluble solids, and TPC is total phenolic content ; * (BSN 1992); ** (BSN 2004); ***(BSN 2014); [a] caffeine content for instant coffee; [b] caffeine content for decaffeinated instant coffee; [c] measured as reducing sugar; [d] measured as total glucose.

Caffeine content

Table 4 shows that all formulation samples had higher caffeine content than the commercial herbal coffee. The results indicate that increasing the proportion of fennel seed powder added results in herbal coffee with higher caffeine content, with a value of 0.07 %. However, the value was still slightly lower than using Arabica coffee alone (A1B3) at the same proportion of fennel seed added. These findings demonstrate that adding fennel seed powder had no effects on the caffeine content, but the coffee grounds had. This aligns with previous studies by Uslu (2022) and Olechno *et al.* (2021) that the coffee types and the amount of coffee added influenced the caffeine content of the coffee. Furthermore, Robusta coffee is reported to have a higher caffeine content than Arabica coffee (Briandet *et al.* 1996; Jeszka-Skowron *et al.* 2020). For instance, Jeszka-Skowron *et al.* (2020) found that Robusta coffee had caffeine content ranging from 13.7 to 25.6 mg/g, while Arabica coffee ranged from 10.1 to 13.9 mg/g. Therefore, blending two types of coffee may likely influence the blended coffee's caffeine content. This study also shows similar patterns where herbal coffee from blending Robusta and Arabica have lower than Arabica only with fennel seed.

The results show that the Tengger herbal coffee met the Indonesia standard (SNI 01-3542-2004) for the caffeine content of coffee grounds (maximum of 2%) (BSN 2004) or for the coffee instant (minimum of 2.5%) (SNI 2983-2014) (BSN 2014). Also, the Tengger herbal coffee' caffeine content was still below its maximum limit in food and beverages of 150 mg/day (SNI 01-3542-2004) (BSN 2004) and 50 mg/serving (SNI 01-7152-2006) (BSN 2006). Therefore, it is safe for consumption. According to Fajara and Susanti (2017), consumption of a high amount of caffeine may lead to various unhealthy symptoms (*i.e.*, heartbeat, sleeping difficulty, *etc.*) and cause poisoning if consumed above 500 mg per one drink.

Total phenolic content (TPC)

Table 4 shows that the commercial herbal coffee had a lower TPC value (18.9 mg GAE/g) than the Tengger herbal coffee (ranging from 28.7 to 47.2 mg GAE/g). The results showed that adding a higher proportion of fennel seed powder (*i.e.*, A3B3 and A1B3) significantly increased the TPC. This could be due to the phenolic compounds present in the fennel seeds. According to Saber and Eshra (2019), fennel seeds contain around 8% essential oil, which contains flavonoid compounds with 50 to 60% anethole, 10 to 15% fenchone, and methylchavicol. Furthermore, the type of coffee may also influence TPC, as coffee beans contain phenolic compounds (*i.e.*, caffeoylquinic acids/CQA, dicaffeoylquinic acids, and caffeoylquin lactone) and essential oils (Sacchetti *et al.* 2009; Pérez-Martínez *et al.* 2010; Olechno *et al.* 2020). For instance, Olechno *et al.* (2020) found that Arabica coffee grounds have higher TPC (657.4 ± 23 mg GAE/100 g) than Robusta coffee grounds (642.7 ± 56 mg GAE/100 g).

This study also observed that blending Arabica coffee and Robusta coffee with fennel seed powder at different proportions significantly impacted the TPC. This is in line with Pérez-Martínez *et al.* (2010), who reported that blending different types of coffee could affect the TPC. Also, a previous study by Sekeroglu *et al.* (2012) demonstrated that herbal coffee from blending coffee with various types of seeds (*i.e.*, tumble thistle/GT, black cumin/NS, date/PD, and carbon/CS) had different TPC of 12.90 ± 0.17 mg GAE/100 g (GT-coffee), 18.78 ± 0.34 mg GAE/100 g (NS-coffee), 76.30 ± 4.59 mg GAE/100 g (PD-coffee), and 33.07 ± 2.21 mg GAE/100 g (CS-coffee), respectively. In this study, different TPC in all formulations could be due to the synergistic or antagonistic effects between the phenolic compounds of coffee with other phenolic compounds in fennel seeds. This interaction may trigger, lessen, or not even affect the biological activities of the coffee phenolics, hence impacting the TPC, as Erskine *et al.* (2022) reported. Their study observed that the main phenolic components in herbal coffee are phenolic acids, phenolic diterpenes, flavonoids, volatile oils (*i.e.*, aromatic compounds), *etc.*

Antioxidant activity (IC_{50})

The antioxidant activity (IC_{50}) of selected Tengger herbal coffee was much lower (0.49 to 0.58 ppm) than the commercial herbal coffee (4.63 ppm) (Table 4). A previous study by Wijana *et al.* (2018) reported that herbal coffee with a mixture of fennel seed and ginger extract had antioxidant content in the range of 75.5 to 69.5 ppm, which was much higher than found in this study. The results also indicate that adding a higher proportion of fennel seed powder (12%) with Arabica coffee only or blending Arabica and Robusta coffee, had smaller IC_{50} values, indicating its higher antioxidant activity. Therefore, the antioxidant activity became stronger when more fennel seed powder was added to the coffee. This could be due to the high antioxidant activity in fennel seeds, which can act as free radical scavengers (Malhotra 2012; Rather *et al.* 2016; Valduga *et al.* 2019; Dahmani *et al.* 2022; Kaveh *et al.* 2022;).

In addition, the type and origin of coffee could also affect its antioxidant activity (Ludwig *et al.* 2013; Ribeiro *et al.* 2014; Wolska *et al.* 2017). Robusta coffee has a higher antioxidant activity than Arabica coffee (Wolska *et al.* 2017), so mixing the two types of coffee or coffee with other ingredients could increase the antioxidant activity in the blended coffee (Ribeiro *et al.* 2014). Similarly, this study found that blending Arabica and Robusta coffee with 12% fennel seeds resulted in much more potent antioxidant activity. However, the commercial herbal coffee made from Robusta coffee had lower antioxidant activity than the other counterparts. This is likely due to the addition of sugar, which may reduce the antioxidant activity of the blended coffee. This is well in agreement with Hernández and Durán (2020); increasing the addition of sugar causes more binding of the polyphenol compounds with sugar molecules, reducing the suspension of the polyphenol components.

The results also showed that Tengger herbal coffee and commercial herbal coffee had IC_{50} lower than 50 ppm, thus classified as having very strong antioxidant activity. This research result is indicated higher level of antioxidant than the results reported by Wijana *et al.* (2018). The smaller the IC50 value, the higher the compound’s antioxidant activity. The study found that the A3B3 formulation has the lowest IC_{50}; thus, it had the strongest antioxidant activity compared to its other counterparts. A potent antioxidant activity in the Tengger herbal coffee could be influenced by the TPC (*i.e.*, the polyphenol compounds) of coffee and fennel seeds. Polyphenols are closely related to antioxidants, which prevent the oxidation process (Ngamsuk *et al.* 2019; Niseteo *et al.* 2012; Sacchetti *et al.* 2009). Therefore, this study found that the higher the TPC, the stronger the antioxidant activity, which agrees with a previous result by Ngamsuk *et al.* (2019). In addition, the phenol group antioxidants found in coffee are chlorogenic acid, ferulic, p-coumaric acid, caffeic, and proanthocyanidins, which play a critical role in the antioxidant activity (Niseteo *et al.* 2012; Zuorro and Lavecchia 2013).

Reducing sugar content

Table 4 shows that the reducing sugar content of all formulations was much higher (0.53 to 0.60%) than the commercial herbal coffee (0.20%). This may be due to the additional sugar ingredient (*i.e.*, sucrose) in the commercial sample. By contrast, the

Tengger herbal coffee only consisted of pure coffee and fennel seeds which contains carbohydrate (*e.g.*, glucose), causing an increase in the reducing sugar content. According to Carcelli *et al.* (2022) and Chen *et al.* (2022), sucrose, as a non-reducing sugar, is broken down into glucose and fructose during the inversion process by the hydrolase glycoside enzyme isomaltose. This sucrose degradation process resulted in the reducing sugars (Geromel *et al.* 2008; Joët *et al.* 2010). This study also indicates that blending Arabica and Robusta coffee with fennel seeds at all concentrations have slightly higher reducing sugar content than their counterpart. Various factors may influence this, including water content (Deliza *et al.* 2021) and the fermentation duration (Chen *et al.* 2022). The proteins (*i.e.*, amino acids) and reducing sugar play a key role in Maillard reactions during coffee bean roasting, influencing their distinctive quality, such as flavor, aroma, taste, *etc.* (Hameed *et al.* 2018).

The results also showed that the reducing sugar content of all formulations was lower than 1%, which was much lower than that of the cardamon herbal coffee (1.245%) reported by Febrianto *et al.* (2015). However, the reducing sugar contents of the Tengger herbal coffee from the selected formulations were well within the standard requirements of < 10% (SNI 01-2983-1992) (BSN 1992) or a maximum of 2.46% (w/w, as glucose) (SNI 2983-2014) (BSN 2014). Therefore, the herbal coffee from this study could be considered to have a good quality for further explore to scale up the production.

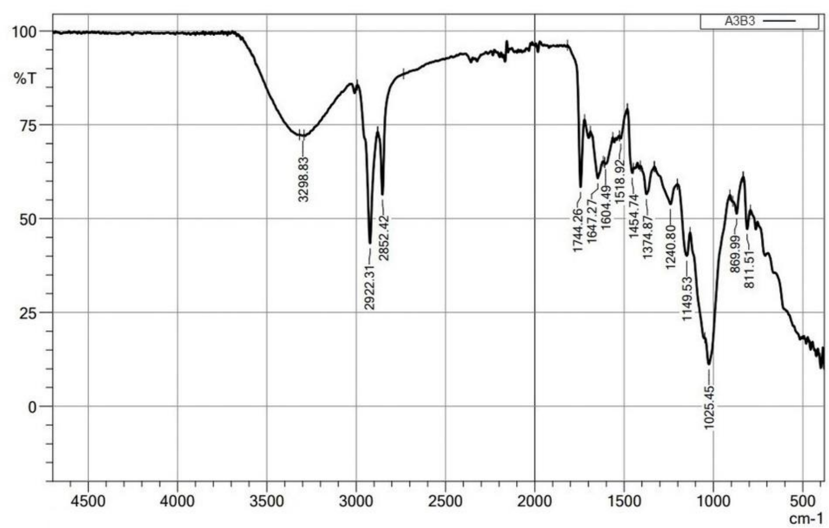

Fig. 1. FTIR spectra of the Tengger herbal coffee from A3B3 formulation

Fourier transform infrared (FTIR) results

The FTIR test was carried out on the Tengger herbal coffee from A3B3 formulation only (as the best formulation) to identify the functional groups that may be present. The FTIR spectra are presented as transmittance (%) against wavelength (cm^{-1}). The results are shown in Fig. 1. The coffee sample has a peak band at a wavelength of 3298.8 cm^{-1}, which represents the stretching vibrations of the O-H bond, indicating the presence of phenol groups. The peak bands recorded at 2852.4 to 2922.3 cm^{-1} and 1374.9 to 1454.7 cm^{-1} show the presence of C-H bonds of alkane functional groups with strong intensity. At the peak band of 1744.26 cm^{-1} the signal demonstrates the presence of the C=O bond, representing aldehydes, ketones, carboxylic acids, or esters. The peak band was also observed in 1149.5 to 1240.8 cm^{-1}, indicating the presence of alcohols, ethers, carboxylic acids, or esters. The peak band of 1025.4 cm^{-1} shows the alkyl aldehyde group. In addition, FTIR spectra also indicate the presence of strong alkenes and aromatic rings. These results align with previous studies that the bioactive compounds found in coffee included phenolic compounds, aldehydes, and carboxylic acids (Bondam *et al.* 2022; Gao *et al.* 2021). In addition, the phenolic compounds found in herbal coffee could also indicate the presence of flavonoids from adding fennel seeds powder, as previously explained. These findings confirmed that the Tengger herbal coffee has secondary metabolite compounds beneficial to health. Thus, it offers promising potential for further development and production as functional or herbal coffee beverages.

CONCLUSIONS

1. The type of coffee and different proportions of coffee:fennel seed powder were found to have significant effects on the sensory characteristics (*i.e.*, color, taste, and aroma) and quality of the Tengger herbal coffee.
2. Based on the sensory attributes, all participants agreed that blending different coffee types with fennel seed powder at different ratios produced coffee with a unique taste and aroma.
3. The best formulation selected was A3B3 (blending 44% Arabica coffee: 44% Robusta coffee: 12% fennel seed powder), producing the coffee brews with unique sensory attributes of a slightly dark color, not bitter taste, and a very distinctive fennel aroma. The selected best formula also has the physicochemical quality that meets the standard requirement, particularly reducing sugar (0.58%) and caffeine content (0.07%). The herbal coffee also contains phenol, aldehyde, and carboxylic acid compounds, showing by a TPC of 47.20 mg GAE/g and antioxidant activity (IC50) of 0.49 ppm, respectively.
4. The findings confirmed that the Tengger herbal coffee has the potential to be an herbal and functional beverage with a potent antioxidant activity that is good for health. This herbal coffee also has a unique and distinct taste and aroma, thus offering a promising opportunity to be developed as a traditional coffee product in the Tengger area. Yet, further in-depth investigation is essential to optimize and scale up the production process.

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REFERENCES CITED

Akbar, A. T., and Pangestuti, E. (2017). "Peran kuliner dalam meningkatkan citra destinasi pariwisata Taman Nasional Bromo Tengger Semeru (The role of culinary in enhancing tourism destination image of Bromo Tengger Semeru National Park)," *Jurnal Administrasi Bisnis* 50, 153-159.

Alalwan, T. A., Mandeel, Q. A., and Al-Sarhani, L. (2017). "Traditional plant-based foods and beverages in Bahrain," *Journal of Ethnic Foods* 4, 274-283. DOI: 10.1016/j.jef.2017.10.003

Anisa, A., Solomon, W., and Solomon, A. (2017). "Optimization of roasting time and temperature for brewed hararghe coffee (*Coffea arabica* L.) using central composite design," *International Food Research Journal* 24, 2285-2294.

Bastian, F., Hutabarat, O. S., Dirpan, A., Nainu, F., Harapan, H., Emran, T. B., and Simal-Gandara, J. (2021). "From plantation to cup: Changes in bioactive compounds during coffee processing," *Foods* 10, 2827. DOI: 10.3390/foods10112827

Beekman, T. L., Huck, L., Claure, B. and Seo, H.-S. (2021). "Consumer acceptability and monetary value perception of iced coffee beverages vary with drinking conditions using different types of straws or lids," *Food Research International* 140, article 109849. DOI: 10.1016/j.foodres.2020.109849

Bhumiratana, N., Adhikari, K., and Chambers, E. (2011). "Evolution of sensory aroma attributes from coffee beans to brewed coffee," *LWT - Food Science and Technology* 44, 2185-2192. DOI: 10.1016/j.lwt.2011.07.001

Bondam, A. F., Diolinda da Silveira, D., Pozzada dos Santos, J., and Hoffmann, J. F. (2022). "Phenolic compounds from coffee by-products: Extraction and application in the food and pharmaceutical industries," *Trends in Food Science & Technology* 123, 172-186. DOI: 10.1016/j.tifs.2022.03.013

Briandet, R., Kemsley, E. K., and Wilson, R. H. (1996). "Discrimination of Arabica and Robusta in instant coffee by Fourier transform infrared spectroscopy and chemometrics," *Journal of Agricultural and Food Chemistry* 44, 170-174. DOI: 10.1021/jf950305a

Carcelli, A., Albertini, A., Vittadini, E., and Carini, E. (2022). "A fibre syrup for the sugar reduction in fruit filling for bakery application," *International Journal of Gastronomy and Food Science* 28, article 100545. DOI: 10.1016/j.ijgfs.2022.100545

Chen, L., Wu, W., Zhang, N., Bak, K. H., Zhang, Y., and Fu, Y. (2022). "Sugar reduction in beverages: Current trends and new perspectives from sensory and health viewpoints," *Food Research International* 162, article 112076. DOI: 10.1016/j.foodres.2022.112076

Chongsrimsirisakhol, O., and Pirak, T. (2022). "Total polyphenol content and antioxidant properties of cold brew coffee extracts as affected by ultrasound treatment and their application in low fat pork sausage," *International Journal of Food Properties* 25, 813-826. DOI: 10.1080/10942912.2022.2056197

Cruz, R., Morais, S., and Casal, S. (2015). "Chapter 66 - Mineral composition variability of coffees: A result of processing and production," in: *Processing and Impact on Active Components in Food*, V. Preedy (ed.), Academic Press, San Diego, pp. 549-558.

Dahmani, K., Moghrani, H., Deghbar, N., Ouarek, S., Allaf, K., and Arab, K. (2022). "Algerian wild fennel essential oils: chromatographic profile, acute toxicity, antioxidant, and antimicrobial activities," *Chemical Papers* 76, 1639-1652. DOI: 10.1007/s11696-021-02008-9

Deliza, R., Lima, M. F., and Ares, G. (2021). "Rethinking sugar reduction in processed foods," *Current Opinion in Food Science* 40, 58-66. DOI: 10.1016/j.cofs.2021.01.010

DePaula, J., Cunha, S. C., Cruz, A., Sales, A. L., Revi, I., Fernandes, J., Ferreira, I. M. P. L. V. O., Miguel, M. A. L., and Farah, A. (2022). "Volatile fingerprinting and sensory profiles of coffee cascara teas produced in Latin American Countries," *Foods* 11,

article 3144. DOI: 10.3390/foods11193144
Devi, M., Soekopitojo, S., Hidayati, L., and Trisnawan, R. (2023). "Antioxidant capacity and phytochemical analysis of broccoli (*Brassica oleracea* L. var *italica*) powder with sun drying technology," *Advances in Food Science, Sustainable Agriculture and Agroindustrial Engineering (AFSSAAE)* 134-143. DOI:
Erskine, E., Gültekin Subaşı, B., Vahapoglu, B., and Capanoglu, E. (2022). "Coffee phenolics and their interaction with other food phenolics: Antagonistic and synergistic effects," *ACS Omega* 7, 1595-1601. DOI: 10.1021/acsomega.1c06085
Fajara, B. E. P., and Susanti, H. (2017). "HPLC determination of caffeine in coffee beverage," *IOP Conference Series: Materials Science and Engineering* 259, article 012011. DOI: 10.1088/1757-899X/259/1/012011
Fatmawati, F., Muhammad, M., and Fokaya, R. (2020). "Feasibility analysis of spice coffee processing business in home industries in Tabahawa Village, Ternate City," *Agrikan: Jurnal Agribisnis Perikanan* 13, 344-351.
Febrianto, N. A., Maulina, V., and Djumarti, D. (2015). "Development of cardamom herbal coffee beverages: A study of physicochemical characteristic and consumer perception towards sensory properties," *Pelita Perkebunan, A Coffee and Cocoa Research Journal* 31, 49-58. DOI: 10.22302/iccri.jur.pelitaperkebunan.v31i1.80
Gao, C., Tello, E., and Peterson, D. G. (2021). "Identification of coffee compounds that suppress bitterness of brew," *Food Chemistry* 350, article 129225. DOI: 10.1016/j.foodchem.2021.129225
Gemechu, F. G. (2020). "Embracing nutritional qualities, biological activities and technological properties of coffee byproducts in functional food formulation," *Trends in Food Science & Technology* 104, 235-261. DOI: 10.1016/j.tifs.2020.08.005
Geromel, C., Ferreira, L. P., Davrieux, F., Guyot, B., Ribeyre, F., Brígida dos Santos Scholz, M., Protasio Pereira, L. F., Vaast, P., Pot, D., Leroy, T., Filho, A. A., Esteves Vieira, L. G., Mazzafera, P., and Marraccini, P. (2008). "Effects of shade on the development and sugar metabolism of coffee (*Coffea arabica* L.) fruits," *Plant Physiology and Biochemistry* 46, 569-579. DOI: 10.1016/j.plaphy.2008.02.006
Hameed, A., Hussain, S. A., Ijaz, M. U., Ullah, S., Pasha, I., and Suleria, H. A. R. (2018). "Farm to consumer: Factors affecting the organoleptic characteristics of coffee. II: Postharvest processing factors," *Comprehensive Reviews in Food Science and Food Safety* 17, 1184-1237. DOI: 10.1111/1541-4337.12365
Hayat, K., Abbas, S., Hussain, S., Shahzad, S. A., and Tahir, M. U. (2019), "Effect of microwave and conventional oven heating on phenolic constituents, fatty acids, minerals and antioxidant potential of fennel seed," *Ind Crop Prod* 140, article 111610. DOI: 10.1016/j.indcrop.2019.111610
Hernández, P. B. N., and Durán, A. C. (2020). "Chemical and sensory characterization of corn oil flavoured by citrus," *Brazilian Journal of Food Technology* 23, 1-11. DOI: 10.1590/1981-6723.05419
Jashari, G., Frühbauerová, M., Mikysek, T., Švancara, I., Metelka, R., and Sýs, M. (2023). "New electroanalytical method for the determination of trans-anethole in spices and sweets," *Food Chem* 408, article 135167. DOI: 10.1016/j.foodchem.2022.135167
Jeszka-Skowron, M., Frankowski, R., and Zgoła-Grześkowiak, A. (2020). "Comparison of methylxantines, trigonelline, nicotinic acid and nicotinamide contents in brews of green and processed Arabica and Robusta coffee beans – Influence of steaming, decaffeination and roasting processes on coffee beans," *LWT - Food Science and*

Technology 125, article 109344. DOI: 10.1016/j.lwt.2020.109344
Joët, T., Laffargue, A., Descroix, F., Doulbeau, S., Bertrand, B., kochko, A. d., and Dussert, S. (2010). "Influence of environmental factors, wet processing and their interactions on the biochemical composition of green Arabica coffee beans," *Food Chem* 118, 693-701. DOI: 10.1016/j.foodchem.2009.05.048
Kaveh, R., Naghmachi, M., Motaghi, M. M., Amirmahani, F., and Danaei, M. (2022). "Antibacterial and antioxidant activities and anticancer effects of fennel seeds (*Foeniculum vulgare*) against lung cancer cells," *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences* DOI: 10.1007/s40011-022-01390-y
Khan, R. U., Fatima, A., Naz, S., Ragni, M., Tarricone, S., and Tufarelli, V. (2022). "Perspective, opportunities and challenges in using fennel (*Foeniculum vulgare*) in poultry health and production as an eco-friendly alternative to antibiotics: A review," *Antibiotics* 11, 1-18. DOI: 10.3390/antibiotics11020278
Kwak, H. S., Ji, S., and Jeong, Y. (2017). "The effect of air flow in coffee roasting for antioxidant activity and total polyphenol content," *Food Control* 71, 210-216. DOI: 10.1016/j.foodcont.2016.06.047
Lal, R. K. (2008). "Stability and genotypes × environment interactions in fennel," *Journal of Herbs, Spices & Medicinal Plants* 13, 47-54. DOI: 10.1300/J044v13n03_05
Lee, S. K., Mbwambo, Z. H., Chung, H., Luyengi, L., Gamez, E. J., Mehta, R. G., Kinghorn, A. D., and Pezzuto, J. M. (1998). "Evaluation of the antioxidant potential of natural products," *Combinatorial Chemistry & High Throughput Screening* 1, 35-46.
Ludwig, I. A., Bravo, J., De Peña, M. P., and Cid, C. (2013). "Effect of sugar addition (torrefacto) during roasting process on antioxidant capacity and phenolics of coffee," *LWT - Food Science and Technology* 51, 553-559. DOI: 10.1016/j.lwt.2012.12.010
Maleš, I., Pedisić, S., Zorić, Z., Elez-Garofulić, I., Repajić, M., You, L., Vladimir-Knežević, S., Butorac, D., and Dragović-Uzelac, V. (2022). "The medicinal and aromatic plants as ingredients in functional beverage production," *Journal of Functional Foods* 96, article 105210. DOI: 10.1016/j.jff.2022.105210
Malhotra, S. K. (2012). 14 – "Fennel and fennel seed," in: *Handbook of Herbs and Spices* (Second Edition), K. V. Peter (ed.), Woodhead Publishing, pp. 275-302.
Martins, P. M. M., Batista, N. N., Miguel, M. G. d. C. P., Simão, J. B. P., Soares, J. R., and Schwan, R. F. (2020). "Coffee growing altitude influences the microbiota, chemical compounds and the quality of fermented coffees," *Food Research International* 129, article 108872. DOI: 10.1016/j.foodres.2019.108872
Mazzafera, P., Crozier, A., and Magalhães, A. C. (1991). "Caffeine metabolism in *Coffea arabica* and other species of coffee," *Phytochemistry* 30, 3913-3916. DOI: 10.1016/0031-9422(91)83433-L
Meilgaard, M. C., Carr, B. T. and Civille, G. V. (2021). *Sensory Evaluation Techniques*, 5th Edition, CRC Press, London.
Molyneux, P. (2004). "The use of the stable free radical diphenylpicrylhydrazyl (DPPH) for estimating antioxidant activity," *Songklanakarin Journal Science of Technology* 26, 211-219.
Naidoo, N., Chen, C., Rebello, S. A., Speer, K., Tai, E. S., Lee, J., Buchmann, S., Koelling-Speer, I., and van Dam, R. M. (2011). "Cholesterol-raising diterpenes in types of coffee commonly consumed in Singapore, Indonesia and India and

associations with blood lipids: A survey and cross sectional study," *Nutrition Journal* 10, 48. DOI: 10.1186/1475-2891-10-48

Ngamsuk, S., Huang, T.-C., and Hsu, J.-L. (2019). "Determination of phenolic compounds, procyanidins, and antioxidant activity in processed *Coffea arabica* L. leaves," *Foods* 8, 389. DOI: 10.3390/foods8090389

Ngolo, A. O., Fernandes Filho, E. I., Ferreira, W. P. M., and Fernandes, R. B. A. (2018). "Agroclimatic zoning for coffee crop in Angola," *Pesquisa Agropecuária Tropical* 48, 19-28.

Niseteo, T., Komes, D., Belščak-Cvitanović, A., Horžić, D., and Budeč, M. (2012). "Bioactive composition and antioxidant potential of different commonly consumed coffee brews affected by their preparation technique and milk addition," *Food Chemistry* 134, 1870-1877. DOI: 10.1016/j.foodchem.2012.03.095

Noreen, S., Tufail, T., Bader Ul Ain, H., Ali, A., Aadil, R. M., Nemat, A. and Manzoor, M. F. (2023). "Antioxidant activity and phytochemical analysis of fennel seeds and flaxseed," *Food Science & Nutrition* 11, 1309-1317. DOI: 10.1002/fsn3.3165

Nurhayati, N. (2017). "Sensory characteristics of dip coffee and instant coffee from Robusta and Arabica varieties," *Jurnal Ilmiah Inovasi* 17, 80-85. DOI: 10.25047/jii.v17i2.547

Olechno, E., Puścion-Jakubik, A., Markiewicz-Żukowska, R., and Socha, K. (2020). "Impact of brewing methods on total phenolic content (TPC) in various types of coffee," *Mol* 25, article 5274. DOI: 10.3390/molecules25225274

Olechno, E., Puścion-Jakubik, A., Zujko, M. E., and Socha, K. (2021). "Influence of various factors on caffeine content in coffee brews," *Foods* 10, article 1208.

Pérez-Martínez, M., Caemmerer, B., De Peña, M. P., Cid, C., and Kroh, L. W. (2010). "Influence of brewing method and acidity regulators on the antioxidant capacity of coffee brews," *Journal of Agricultural and Food Chemistry* 58, 2958-2965. DOI: 10.1021/jf9037375

Raffo, A., Nicoli, S., and Leclercq, C. (2011). "Quantification of estragole in fennel herbal teas: Implications on the assessment of dietary exposure to estragole," *Food and Chemical Toxicology* 49, 370-375. DOI: 10.1016/j.fct.2010.11.011

Rather, M. A., Dar, B. A., Sofi, S. N., Bhat, B. A., and Qurishi, M. A. (2016). "*Foeniculum vulgare*: A comprehensive review of its traditional use, phytochemistry, pharmacology, and safety," *Arabian Journal of Chemistry* 9, S1574-S1583. DOI: 10.1016/j.arabjc.2012.04.011

Ribeiro, V. S., Leitão, A. E., Ramalho, J. C., and Lidon, F. C. (2014). "Chemical characterization and antioxidant properties of a new coffee blend with cocoa, coffee silverskin and green coffee minimally processed," *Food Research International* 61, 39-47. DOI: 10.1016/j.foodres.2014.05.003

Rietjens, I. M. C. M., Cohen, S. M., Eisenbrand, G., Fukushima, S., Gooderham, N. J., Guengerich, F. P., Hecht, S. S., Rosol, T. J., Davidsen, J. M., Harman, C. L., and Taylor, S. V. (2023). "FEMA GRAS assessment of natural flavor complexes: Allspice, anise, fennel-derived and related flavoring ingredients," *Food and Chemical Toxicology* 174, article 113643. DOI: 10.1016/j.fct.2023.113643

Rifqiyati, N., and Wahyuni, A. (2019). "Fennel (*Foeniculum vulgare*) leaf infusion effect on mammary gland activity and kidney function of lactating rats," *Nusantara Bioscience* 11, 101-105. DOI: 10.13057/nusbiosci/n110117

Ryan, T. P. and Morgan, J. P. (2007). "Modern experimental design," *Journal of Statistical Theory and Practice* 1, 501-506. DOI: 10.1080/15598608.2007.10411855

Saber, J. I., and Eshra, D. H. (2019). “Using fennel seeds and their oil as a preservative and functional food to produce some food and drink products to alleviate cough symptoms," *Alexandria Science Exchange Journal* 40, 406-414. DOI: 10.21608/asejaiqjsae.2019.44629

Sacchetti, G., Di Mattia, C., Pittia, P., and Mastrocola, D. (2009). “Effect of roasting degree, equivalent thermal effect and coffee type on the radical scavenging activity of coffee brews and their phenolic fraction," *Journal of Food Engineering* 90, 74-80. DOI: 10.1016/j.jfoodeng.2008.06.005

Savitri, D. A., Amini, H. W., and Darmayanti, R. F. (2020). “Increasing the economic value of coffee into instant spiced coffee (KORE) based on the empowerment of women in Tanah Wulan Village," *Warta Pengabdian* 14, 210-221. DOI: 10.19184/wrtp.v14i4.14863

Secilmis, S. S., Yanık, D. K., and Gogus, F. (2015). “Processing of a novel powdered herbal coffee (Pistacia Terebinthus L. fruits coffee) and its sensorial properties," *Journal of Food Science and Technology* 52, 4625-4630. DOI: 10.1007/s13197-014-1475-7

Sekeroglu, N., Senol, F. S., Orhan, I. E., Gulpinar, A. R., Kartal, M., and Sener, B. (2012). “*In vitro* prospective effects of various traditional herbal coffees consumed in Anatolia linked to neurodegeneration," *Food Research International* 45, 197-203. DOI: 10.1016/j.foodres.2011.10.008

Somogyi, M. (1945). “A new reagent for the determination of sugars," *Journal of Biological Chemistry* 160, 61-68. DOI: 10.1016/S0021-9258(18)43097-9

Suleiman, W. B., and Helal, E. E.-H. (2022). “Chemical constituents and potential pleiotropic activities of *Foeniculum vulgare* (Fennel) ethanolic extract; in vitro approach," *Egyptian Journal of Chemistry* 65, 617-626. DOI: 10.21608/EJCHEM.2021.107991.4938

Uslu, N. (2022). “The influence of decoction and infusion methods and times on antioxidant activity, caffeine content and phenolic compounds of coffee brews," *European Food Research and Technology* 248, 2021-2030. DOI: 10.1007/s00217-022-04027-6

Utami, H. S. (2017). “Pengelolaan kawasan pariwisata (Studi di Balai Besar Taman Nasional Bromo Tengger Semeru) (Management of tourism area (Study at the Bromo Tengger Semeru National Park Centre)," *Jurnal Ilmiah Administrasi Publik* 3, 13-20. DOI: 10.21776/ub.jiap.2017.003.01.2

Valduga, A. T., Gonçalves, I. L., Magri, E., and Delalibera Finzer, J. R. (2019). “Chemistry, pharmacology and new trends in traditional functional and medicinal beverages," *Food Research International* 120, 478-503. DOI: 10.1016/j.foodres.2018.10.091

Velmourougane, K. (2013). “Impact of natural fermentation on physicochemical, microbiological and cup quality characteristics of Arabica and Robusta coffee," *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences* 83, 233-239. DOI: 10.1007/s40011-012-0130-1

Wang, X., Wang, Y., Hu, G., Hong, D., Guo, T., Li, J., Li, Z., and Qiu, M. (2022). “Review on factors affecting coffee volatiles: From seed to cup," *Journal of the Science of Food and Agriculture* 102, 1341-1352. DOI: 10.1002/jsfa.11647

Wei, F., and Tanokura, M. (2015). “Chapter 17 - Organic compounds in green coffee beans," in: *Coffee in Health and Disease Prevention*, V. Preedy (ed.), Academic Press, San Diego, pp. 149-162.

Wijana, S., Perdani, C. G., Febrianata, M. I., and Deoranto, P. (2018). "Tengger herbal (concocted) coffee formulation with fennel seed *(Foeniculum vulgare)* and ginger (*Zingiber officinale*) extract," *Advances in Food Science, Sustainable Agriculture and Agroindustrial Engineering (AFSSAAE)* 1, 17-26. DOI: 10.21776/ub.afssaae.2018.001.02.3

Wolska, J., Janda, K., Jakubczyk, K., Szymkowiak, M., Chlubek, D., and Gutowska, I. (2017). "Levels of antioxidant activity and fluoride content in coffee infusions of Arabica, Robusta and Green coffee beans in according to their brewing methods," *Biological Trace Element Research* 179, 327-333. DOI: 10.1007/s12011-017-0963-9

Yeager, S. E., Batali, M. E., Lim, L. X., Liang, J., Han, J., Thompson, A. N., Guinard, J.-X., and Ristenpart, W. D. (2022). "Roast level and brew temperature significantly affect the color of brewed coffee," *Journal of Food Science* 87, 1837-1850. DOI: 10.1111/1750-3841.16089

Zuorro, A., and Lavecchia, R. (2013). "Influence of extraction conditions on the recovery of phenolic antioxidants from spent coffee grounds," *American Journal of Applied Sciences* 10, 478-486. DOI: 10.3844/ajassp.2013.478.486

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