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Physicochemical and sensory profile of commercial wine coffee in the Gayo Highlands, Indonesia

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ABSTRACT

The Gayo Highlands is one of the largest Arabica coffee producing areas in Indonesia. Wine coffee processing is currently very popular in the Gayo Highlands. This study aims to determine of physicochemical and sensory characteristics of commercial wine coffee in Gayo Highlands. Samples were obtained from active wine coffee producers in Central Aceh and Bener Meriah. Analysis was carried out on coffee beans and brewing, including analysis of bean size, moisture content, color, pH, total dissolved solids (TDS), total phenolic content (TPC), and cupping quality. The results found that Gayo arabica wine coffee has a medium size, moisture content of 8.53%-11.67%, and yellow to brown color. Physicochemical characteristics of brewed wine coffee also showed varying results. The pH of coffee wine brewing ranges from 4.68 to 4.95, TDS 3.93 to 4.5 °Brix, and TPC 12.82 to 30 GAE mg/g. Sensory analysis was conducted using the cupping test method. The cupping score of wine coffee on each attribute varied, except body and sweetness. The wine coffee aroma obtained was 6 (good) to 7.75 (very good), wine coffee flavor 6 (good) to 7.5 (very good), wine coffee aftertaste 6 (good) to 7.0 (very good), wine coffee acidity 6 (good) to 7.0 (very good), wine coffee balance 6 (good) to 6.75 (good), overall wine coffee 6 (good) to 7 (very good). Specific fruit aroma characteristics that dominated the coffee wine were pineapple, banana, passion fruit, lemon/lime, and berries. Aroma characteristics related to fermentation, namely winey, vinegar, overripe, and soury were detected in all wine coffee samples. Further research is needed to analyze the more complex chemical components of wine coffee (volatile and non-volatile) and their correlation with brewing quality to obtain more comprehensive scientific information on wine coffee quality.

Key words: Gayo wine coffee; Chemical characteristic; Cupping test; Sensory profile.

1 INTRODUCTION

Indonesia is one of the coffee producers and exporter countries, ranking fourth in the world after Brazil, Vietnam, and Colombia. Coffee productivity has continued to increase over the last 3 years, from 752.511 tons in 2019 to 765.415 tons in 2021 (Directorate General of Plantations, 2022). One of the coffee-producing regions in Indonesia is the Gayo Highlands which covers Central Aceh, Bener Meriah, and Gayo Lues Regency. The coffee that comes from the Gayo Highlands is dominated by arabica coffee and generally comes from community plantations. The majority of arabica coffee in Indonesia comes from Central Aceh and Bener Meriah with an average production of 64,427 tons with an area of around 96,164 Ha (Badan Pusat Statistik Provinsi Aceh, 2022).

Coffee processing is one of the most important parts of coffee production that affects the final quality. Coffee processing aims to obtain high-quality coffee beans with the focus of increasing the selling price. Coffee processing is known to be carried out by several methods, namely wet, dry, and semi-wet processing. In the Gayo Highlands, coffee processing is generally done by semi-wet processing. However, recently coffee processing methods have developed with various experimental variations (modifications), one of which is a coffee processing method that produces a product called wine coffee. This method is a modified dry processing method by fermenting whole coffee fruit in a closed space for a long time (Juanda et al., 2022; Muzaifa et al., 2023).

Fermentation is a chemical process in which complex molecules are broken down into simpler molecules, resulting in liquid products and volatile compounds. Coffee fruits that are processed immediately after harvesting are likely to ferment spontaneously. Depending on the type of processing performed (wet, dry, semi-wet), the length of fermentation time required for each type of processing varies. The main purpose of the fermentation process in all methods is to remove the mucilage layer which is rich in polysaccharides (pectin) and to reduce the moisture content of the coffee beans. Coffee fermentation will have a positive impact on coffee quality attributes (Haile; Kang, 2019).

The fermentation process in wine coffee production basically mimics the process of fermenting grapes into wine, which was first adopted in coffee fermentation by Sasa Sestic, a 2015 world barista championship winner. The process of preparing coffee wine is done by fermenting coffee cherries in a closed tank accompanied by CO_2 gas injection, the process is known as carbonic maceration. This technique has been adopted by coffee farmers in Indonesia as an alternative method of processing wine coffee with a simpler process. Coffee fruits are placed in plastic, without or submerged in water, and then tied firmly to maintain an anaerobic atmosphere. In the absence of added CO_2 gas, this process is more accurately referred to as semi-carbonic maceration and farmers in Indonesia recognize the name of the product as wine coffee (Mulato, 2022).

The presence of wine coffee products is one of the main attractions for producers and consumers, especially coffee lovers. The presence of wine coffee certainly adds to the vibrant specialty coffee produced by farmers in the Gayo Highlands. Some specialty coffees already exist in the Gayo Highlands, including honey coffee, wild civet coffee, and captive civet coffee (Muzaifa; Hasni, 2016; Muzaifa et al., 2021). Coffee wine processing is currently very popular in the Gayo Highlands as well as in Indonesia. It is increasingly common to find coffee shops serving wine coffee variants. These findings are supported by the results of a wine coffee business feasibility analysis (Juanda et al., 2022). Although the selling price of the product is higher than regular coffee, the wine coffee business is very feasible to develop.

Until now, wine coffee has not had a standardized quality standard. As a product with a relatively new processing method, studies on the quality of wine coffee are still very limited. The quality of wine coffee is not yet known in depth, both in commercial wine coffee and wine coffee research results. Dairobbi et al. (2018) only examined the quality of wine coffee fermentation with fermentation times of 7 and 10 days, but in reality, the fermentation carried out by farmers is generally more than 10 days (Widayat et al., 2021). Therefore, as an initial effort to standardize the quality of wine coffee, it is necessary to conduct exploratory research to analyze the quality of commercial wine coffee, both physicochemical and sensory.

2 MATERIAL AND METHODS

2.1 Materials

The wine coffee green bean as raw material used in this study was obtained from 9 wine coffee producers in the Gayo Highlands. Analytical materials used for analysis include distilled water, methanol 60%, folin-ciocalteu reagent, gallic acid, sodium carbonate (Na_2CO_3), oxalic acid 0.01 N, phenolphthalein (pp) indicator 1%, and NaOH 0.01 N.

2.2 Sampling of green beans of wine coffee

Sampling of commercial wine coffee beans was conducted by 9 wine coffee producers in Aceh Tengah and Bener Meriah districts, Aceh-Indonesia. The producers were determined purposively by considering that the producers processed wine coffee actively and continuously. Each wine coffee bean was taken as much as 1 kg. Samples were put into glass containers that had been coded and tightly closed.

2.3 Physicochemical and sensory analysis of wine coffee

The physicochemical analysis of wine coffee includes bean and brewed coffee analysis. Green bean analysis conducted to coffee bean size, moisture content and coffee bean color. Coffee bean size was analyzed by stratified sieving method, the moisture content was carried out using a cerra tester type 10810TPP No. III/V6 (SNI, 2008) and coffee bean color was determined by visually comparing the color of the green beans of wine coffee with the color of coffee beans in the Specialty Coffee Association of America (SCAA) green bean classification system (Kosalos et al., 2013).

Chemical analysis of wine coffee was carried out on brewed wine coffee that had been roasted, including measurement of pH, total dissolved solids (TSS), and total phenolic content (TPC). The pH value was determined with a pH meter (LaMotte, USA), 1 g of the roasted coffee bean sample was weighed and mashed. Dissolved in 100 ml of distilled water, homogenized for 10 minutes, and then the pH of the sample was measured. Measurement of the total dissolved solids was carried out with a hand refractometer (OSK 7954S-28 Ogawa Seiki, Japan). 1 gram of the sample was weighed, dissolved with 5 ml of distilled water, and homogenized using a stirring shaft. Then the coffee brew was dripped on a hand refractometer and read the soluble solids content using the °Brix scale (Saputri; Lioe; Wijaya, 2020).

The total phenolic content was analyzed by the Folin-Ciocalteu method. A total of 0.5 ml of coffee extract was added to 0.5 ml of follin-ciocalteu reagent and then homogenized with a vortex. After 5 minutes, 1.5 ml of 20% Na_2CO_3 was added to the test tube and homogenized again with a vortex, then incubated at room temperature in a dark room for 60 minutes. The absorbance value was measured at a wavelength of 760 nm with a UV-Vis spectrophotometer (Shimadzu model UV-1900i). The gallic acid solution was used as standard, and total phenolic content was expressed as mg gallic acid equivalent (Indiarto et al., 2019).

Sensory analysis was conducted using the cupping test method referring to SCAA standards using expert panelists (Q-graders) from the Gayo Cupper's Team. Wine coffee was roasted at medium level, brewed, and tested by 3 Q-graders. The taste attributes observed were aroma, flavor, aftertaste, acidity, body, balance, sweetness, and overall. Q-graders also provided notes on the wine coffee flavors related to fruit and fermentation flavors referring to the coffee flavor wheel (Specialty Coffee Association - SCA, 2019).

2.4 Data Analysis

All treatments (samples) were analyzed with 3 replications. The data obtained were subjected to statistical tests using analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) at 5% level. Statistical tests were performed using the Statistical Package for Social Science (SPSS) program version 22.0. The data presented were the average value ± standard deviation.

3 RESULTS

3.1 Characteristics of wine coffee bean

The physicochemical characteristics of wine coffee beans that were observed in the form of bean size, water content, and bean color can be seen in Table 1.

3.2 Brewed Characteristics of wine coffee

The quality of wine coffee, especially the physicochemical characteristics of brewed wine coffee, showed varying results as shown in Table 2.

3.3 Sensory Characteristics of wine coffee

The sensory characteristics of Gayo wine coffee assessed in this study includes aroma, flavor, aftertaste, acidity body, sweetness, balance, and overall according to the SCAA procedure (SCA, 2019). Figure 1 shows the assessment of each attribute.

Fruit characteristics and fermentation-related aromas detected in wine coffee can be seen in Tables 3 and 4.

4 DISCUSSION

4.1 Physicochemical profile of wine coffee bean

Bean size is an important indicator in determining coffee bean quality and will influence the selling price (Towaha; Rubiyo, 2016). The smaller the beans, the lower the selling price. Based on the percentage of bean passability, wine coffee beans from the Gayo highlands are all classified as medium-sized. Green beans with large sizes, according to national quality standards (SNI, 2008), are green beans that remain on a sieve with a diameter of 6.5 mm (sieve number 16) with a maximum number of passes of 5%. Green beans of medium size may tolerate a 6 mm diameter sieve (sieve number 15) with a maximum of 5% of passes through a 6.5 mm sieve. While little green beans are stuck in a sieve with a diameter of 5 mm (sieve number 13), a maximum of 5%

Table 1: Quality of wine coffee bean.

Sample	Screening size			Size bean category	Moisture content (%)	Color
	>6,5 mm	6 mm	5 mm			
KW1	61.8%	33.4%	4.8%	Medium	8.53±0.09^{a}	yellowish
KW2	75.7%	22.9%	1.4%	Medium	8.4±0.16^{a}	brownish
KW3	70.2%	28.0%	1.8%	Medium	9.4±0.16^{b}	brownish
KW4	77.2%	21.7%	1.1%	Medium	10.3±0.16^{c}	brownish
KW5	68.8%	27.5%	3.7%	Medium	9.33±0.21^{b}	brownish
KW6	65.1%	31.9%	3.0%	Medium	11.67±0.05^{e}	yellowish
KW7	59.3%	37.6%	3.1%	Medium	9.5±0.08^{b}	brownish
KW8	61.4%	36.6%	2.0%	Medium	10.8±0.08^{d}	brownish
KW9	71.0%	28.1%	0.9%	Medium	9.3±0.16^{b}	brownish

Table 2: Quality of brewed wine coffee.

Sample	pH	Total Dissolved Solid (°Brix)	Total Phenolic Content GAE (mg/g)
KW1	4.69±0.01^{a}	4.07±0.05^{b}	21.82±2.27^{b}
KW2	4.82±0.03^{d}	4.17±0.05^{b}	19.85±0.84^{b}
KW3	4.95±0.01^{f}	3.93±0.09^{a}	17.22±2.24^{ab}
KW4	4.68±0.01^{a}	4.17±0.05^{b}	12.82±0.69^{a}
KW5	4.82±0.01^{d}	4.4±0.08^{c}	30.29±2.95^{c}
KW6	4.87±0.01^{e}	4.2±0.08^{b}	24.13±0.57^{bc}
KW7	4.74±0.01^{b}	4.57±0.05^{d}	21.03±0.17^{b}
KW8	4.89±0.01^{e}	4.43±0.05^{cd}	28.99±4.09^{c}
KW9	4.78±0.01^{c}	4.47±0.05^{cd}	28.77±3.05^{c}

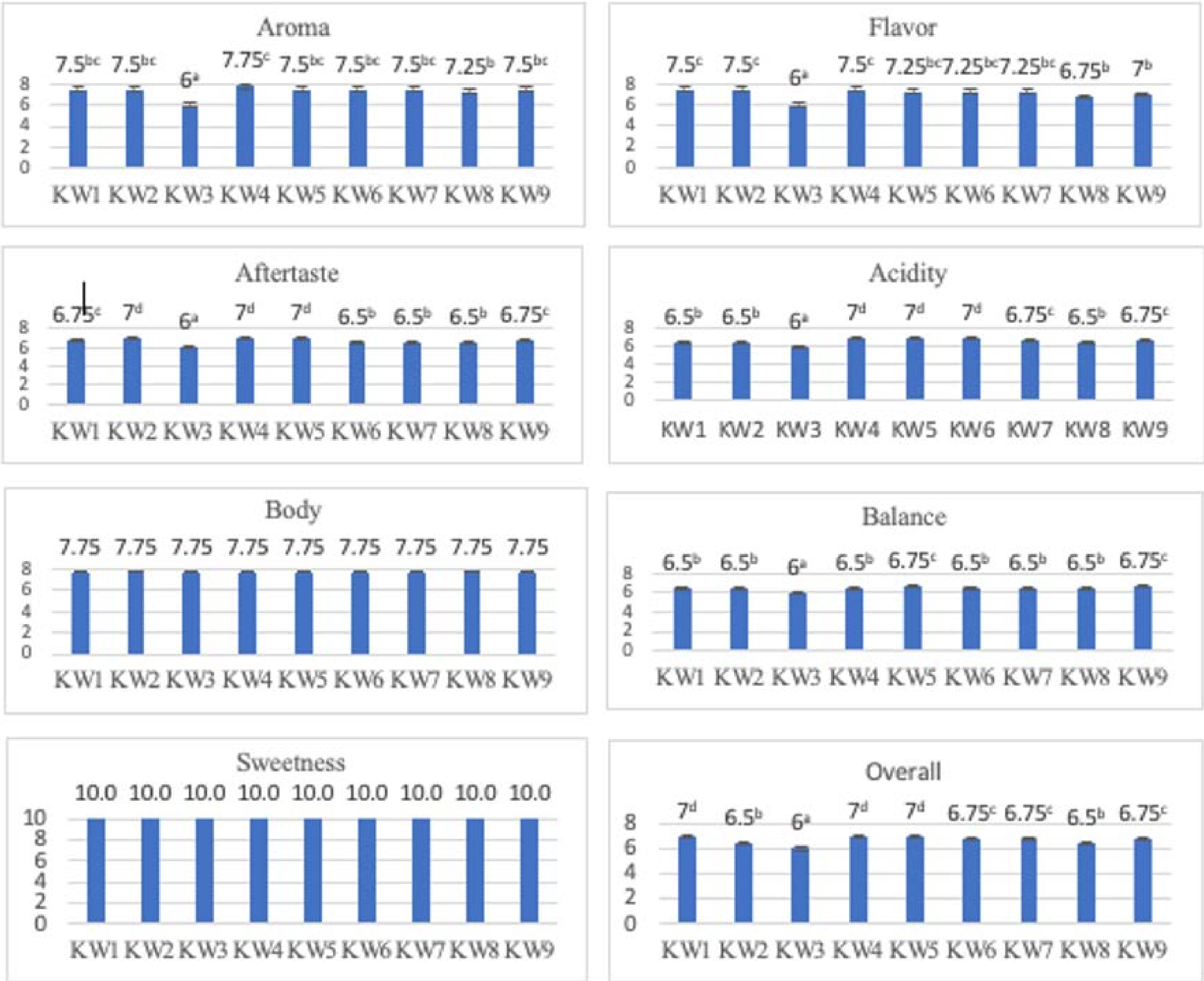

Figure 1: Sensory profile of wine coffee.

Table 3: Fruit aromas detected in brewed wine coffee.

Aroma/flavor	Sample								
	KW1	KW2	KW3	KW4	KW5	KW6	KW7	KW8	KW9
Pineapple	+	+	+	+	+		+	+	+
Banana	+	+	+		+		+	+	+
Passion fruit	+	+		+			+	+	+
Lemon/lime				+	+	+	+	+	+
Orange					+	+	+	+	+
Berries	+	+			+				+
Grapefruit		+		+				+	+
Jackfruit	+	+	+						
Dry fruit/raisin	+	+						+	
Papaya		+					+		

+ = detected.

Table 4: Fermentation-related aromas detected in brewed wine coffee.

Aroma/flavor	Sample								
	KW1	KW2	KW3	KW4	KW5	KW6	KW7	KW8	KW9
Winey	+	+	+	+	+	+	+	+	+
Vinegar	+	+	+	+	+	+	+	+	+
Citrucy	+				+		+	+	+
Soury	+	+	+	+	+	+	+	+	+
Overripe	+	+	+	+	+	+	+	+	+
Mouldy				+			+	+	+
Earthy		+		+			+		
Stinker		+	+						

+ = detected.

passes through a sieve with a diameter of 6 mm. Because the percentage of green beans that can pass through a sieve with a diameter of 6.5 mm is greater than 5%, the complete sample is classed as medium bean size. These wine coffee beans are the same size as standard Gayo Arabica coffee, which is medium (Abubakar; Hasni; Wati, 2022). These findings suggest that processing wine coffee with lengthy fermentation does not affect bean size. Coffee bean size is more influenced by coffee varieties rather than by the processing method (Yusianto; Widyotomo, 2013).

Furthermore, Table 1 illustrates that the moisture content of wine coffee ranges from 8.4%-11.67%, meeting the quality standards of coffee beans set by the Indonesian National Standard (SNI) and SCAA, which is lower than 12-12.5%. Higher moisture content is undesirable because it is susceptible to microorganism attack, so the moisture content of green beans must be controlled between 8-12.5% (Reh et al., 2006; Adnan; Hörsten; Pawelzik, 2017). The moisture content of this wine coffee is lower than the average moisture content of Gayo arabica coffee in the previous study (Abubakar; Hasni; Wati, 2022), presumably due to differences in processing methods. Gayo arabica coffee is generally processed with semi-wet processing and the drying process is not as intensive as in the processing of wine coffee beans.

The color of the wine coffee beans obtained in this study varied from yellowish to brownish. SNI requires the color of coffee beans to be normal, without a foul or moldy odor. The color of this wine coffee is dominated by a brownish color, quite different from the color quality of regular Gayo Arabica coffee, which has a greenish color (Abubakar; Hasni; Wati, 2022). The greenish bean color will provide a well-balanced flavor, between acidity and body, and does not leave a disturbing aftertaste (Haile; Kang, 2019).

The darker color of wine coffee beans is related to the processing process, which uses whole coffee cherries in the process. The coffee cherries are fermented without stripping the skin and carried out over a long period (Juanda et al., 2022). The coffee fruit consists of 6 parts, namely the outer skin layer (exocarp), the pulp (outer mesocarp) which is combined with the outer skin known as the pulp, mucilage (inner mesocarp), parchment, epidermis and the innermost part, namely the coffee bean (endosperm). The chemical content of each part varies, consisting of alkaloids, phenolic compounds, lipids soluble compounds, carbohydrates, amino acids/proteins, and organic acids) (Hall; Trevisan; de Vos, 2022). In the fermentation process, these chemical components certainly change. The fermentation process will decompose the components in each layer of the coffee fruit. Pigments in the coffee fruit skin, phenolic compounds, and sugars contained in the mucilage will break down to become more dilute and soak the coffee fruit for a long period according to the length of the fermentation process carried out. This reddish-brown liquid will enter the coffee beans and affect the color of the coffee beans produced. This process is very different from the processing of regular Arabica coffee, where the coffee fruit is fermented after stripping the skin and the fermentation is also quite short, only 12-24 hours.

4.2 Brewed characteristics of wine coffee

Table 2 describes that the pH of coffee wine brewing ranges from 4.68 ± 0.01 to 4.95 ± 0.01. This result is not much different from the pH value of coffee wine studied by Sunarhanum and Farhan,[19] which is 4.9. However, this pH is slightly lower than the average pH of regular Gayo arabica coffee, which is 5.02 (Abubakar et al., 2023), as well as the results of arabica coffee studied by Pereira et al. (2021) ranging from 5.07-5.14. The lower pH value is thought to be related to the length of the fermentation process so that higher acids are produced. It is known that during fermentation, microorganism activity will break down coffee mucilage as a substrate into organic acids, which causes a decrease in pH, along with the increase in organic acids produced. The length of the fermentation will affect the pH of the coffee beans from 5.29 to 4.38 (Perez et al., 2022). Organic acids produced in coffee fermentation include lactic acid, acetic acid, butyric acid, and other carboxylic acids (Silva et al., 2013; de Melo Pereira et al., 2014; Pereira et al., 2016; Haile et al., 2020). Some of the acid-producing bacteria detected during coffee fermentation are lactic acid bacteria and acetic acid bacteria. Lactic acid-producing bacteria identified as dominant in coffee fermentation are *Leuconostoc, Lactococcus, and Lactobacillus* (de Bruyn et al., 2017). Carbohydrate metabolism by lactic acid bacteria is carried out through two pathways, namely glycolysis (Embden-Meyerhof pathway) with the main product being lactic acid (homofermentative) and the pentose phosphate pathway which produces ethanol, CO_2, and other acids besides lactic acid (heterofermentative) (Papagianni et al., 2012; Mora-Villalobos et al., 2020). The acetic acid bacteria identified as dominant in coffee fermentation are *Acetobacter* and *Gluconobacter* (de Bruyn et al., 2017).

The total soluble solids of wine coffee ranged from 3.93 to 4.5 ºBrix, higher than the results of Sunarhanum and Farhan (2020), which were 0.94-1.74%. The total dissolved solid content is related to the content of metabolites such as glucose and fructose produced during coffee fermentation due to the activity of microorganisms and the enzymes produced. At the beginning of fermentation (0 hours of fermentation), the total dissolved solid content of coffee is 5.3 ºBrix, increasing during fermentation until it stabilizes around 8 ºBrix at the end of fermentation (48 hours)(de Oliveira et al., 2019). This result was supported by Pérez et al. (2022) with a similar pattern; an increase in total dissolved solid content during coffee fermentation. This outcome is due to the action of hydrolytic enzymes that break down pectin, cellulose, sucrose, and other complex carbohydrates of coffee pulp, into glucose and fructose monomers, resulting in an increase in total dissolved solid content and stabilizing at the end of fermentation. In wine coffee processing, the fermentation time is much longer than regular coffee, which is only 24-48 hours, which will affect the amount of total dissolved solid content produced. It is suspected that further decomposition of glucose, fructose and other metabolites occurs with continued fermentation, resulting in lower total dissolved solid content.

Total phenolic content in this research ranged from 12,82±0,69 to 30,29±٢,٦١ GAE mg/g, which is higher compared to Alnsour et al. (2022) who reported that the total phenolics of regular arabica coffee averaged 14.92-16.55 GAE mg/g. Wine coffee has a higher total phenol content compared to regular coffee, which is believed to be related to the intensive fermentation process. The longer fermentation time will result in a higher total phenol content. When fermentation takes place, microorganisms will produce metabolites that can break down complex phenol bonds into active, simple, and easily absorbed ones. Then the fermentation process will also weaken the bonds of phenol compounds so that those are easier to extract (Maksum; Wijonarko; Purbowati, 2021). During fermentation, proteolytic enzymes from budding organisms hydrolyze phenolic complexes into freely soluble simple phenols and more biologically active, easily absorbed forms (Haile; Kang, 2019). The results of Rochín-Medina et al. (2018) corroborate that fermentation can increase total phenol content. Fermented coffee beans have a higher total phenol content (10.51 GAE mg/g) than coffee beans without fermentation (7.74 GAE mg/g).

The phenolic compounds in coffee beans are mostly chlorogenic acids. Other phenolic compounds in small amounts are simple free volatile and non-volatile compounds such as caffeic, vanillic, ferulic, p-coumaric, and p-hydroxybenzoic acids, and small amounts of more complex phenolic compounds such as anthocyanins and tannins (Clifford et al., 2017; Haile; Bae; Kang, 2020). Furthermore, the presence of phenolic compounds in coffee beans can be proven by the detection of several flavonoid compounds in coffee grounds obtained after making coffee drinks. Coffee grounds still contain phenolic compounds such as gallic, chlorogenic, caffeic, ellagic, cumaric, and ferulic (López-Barrera et al., 2016).

4.3 Sensory characteristics of wine coffee

The aroma is the smell of coffee when brewed with hot water. The flavor is a combined impression of all gustatory sensations and retro-nasal aromas flowing from the mouth to the nose. The aftertaste is the duration of positive taste and aroma qualities originating at the back of the palate and remaining after the coffee is swallowed. Acidity indicates the preferred level of coffee acidity that contributes to the fruity character of the coffee drink. Body is the tactile feeling of liquid in the mouth, felt between the tongue and palate. Balance indicates how the flavor, aftertaste, acidity, and body of the coffee drink work together and complement or contrast with each other. Sweetness refers to the fullness of the pleasant taste (sweetness) and overall indicates the final assessment of a tester indicating a holistic integrated rating of the sample as perceived by a tester (SCA, 2019; Torres et al., 2023).

Based on Fig 2, it can be noticed that in all wine coffee samples, the cupping score (quality scale referring to Table -1) on each attribute varied, except for body (all 7.5) and sweetness (all 10). The lowest wine coffee aroma was 6 (good) and the highest reached 7.75 (very good), the lowest wine coffee flavor was 6 (good), and the highest reached 7.5 (very good), the lowest wine coffee aftertaste was 6 (good) and the highest reached 7.0 (very good), the lowest wine coffee acidity was 6 (good) and the highest reached 7.0 (very good), the lowest wine coffee balance was 6 (good) and the highest reached 6.75 (good), the lowest wine coffee overall assessment was 6 (good) and the highest reached 7 (very good).

Comparing with the sensory profiles of Gayo coffee studied by previous researchers, result of this study shows that there are no prominent sensory attributes of wine coffee and they tend to be lower in general. Each quality attribute of Gayo coffee rarely receives a score of 6 (good). Generally, Gayo arabica coffee has a score range of above 7.00 (very good) to 8.50 (excellent) (Muzaifa; Hasni, 2016; Purba et al., 2020; Abubakar et al., 2017). It is suspected that the unusual fermentation process (very long) is the cause of this result and hence there are some deviations in characteristics compared to regular coffee, such as color and high acidity. However, the presence of special flavors associated with the fermentation process is thought to be the main attraction for wine coffee.

The sensation of certain fruit aromas emerging as a result of fermentation is thought to influence consumer preference and is suspected to be the reason wine coffee is increasingly in demand and its production is increasing in the Gayo highlands (Muzaifa et al., 2023). Fruit characteristics and fermentation-related aromas detected in wine coffee can be seen in Tables 3 and 4. According to wine coffee producers, some strong fruity characteristics will appear in brewed wine coffee. Based on Table 4, the most frequently detected fruit flavor was pineapple, followed by banana, lemon, passion fruit, orange, and grapefruit. This study showed that pineapple flavor appeared in 80% of the wine coffee samples. According to De Melo Pereira et al. (2019), the perception of fruit aroma is related to the volatile components contained. Some groups of compounds that can contribute to the appearance of fruit aroma in coffee include acidic compounds, aldehydes, esters, furans, furanones, alcohols, ketones, and terpenes. In particular, pineapple aroma can come from ester compounds such as ethyl hexanoate, ethyl octanoate or diethyl malonate. Banana aroma can be derived from alcohol (isoamyl alcohol) or furan (furfuryl acetate) compounds.

Specific tests to detect fruit aromas in coffee are rarely conducted, usually only general mentions of fruit, flower, or spice aromas are detected throughout the coffee cupping test. Only a few specific fruity aromas are often detected such as citrus or lemony in both regular Gayo arabica coffee and other specialty coffees (Abubakar; Hasni; Rasdiansyah, 2019; Purba et al., 2020; Muzaifa et al., 2021; David et al., 2022) the remaining aromas are more often mentioned generically as fruity, without explaining the specific fruit name. In this study, more specific fruit aroma characteristics were analyzed and wine coffee characteristics were obtained that are indeed different from regular Gayo Arabica coffee in general. Regular Gayo coffee from several local varieties has floral, nutty, chocolaty, and fruity characteristics (Abubakar et al., 2017). Furthermore, as a fermented product, there are still some other specific aroma and flavor characteristics that are often associated with coffee wine by coffee addicts, one of which is winey flavor. In this study, winey flavor was indeed detected in all samples (100%) as shown in Table 4.

Winey is the term given by coffee tasters to coffee with a slightly wine-like brewing characteristic. In addition to winey, other characteristics such as vinegar, citrucy sour and overripe, were also detected in almost all wine coffees. These results corroborate the high acidic characteristics of wine coffee, as evidenced by the analysis of the pH value of the coffee in this study which is lower than the pH value of regular arabica coffee which is generally above 5 (Abubakar et al., 2020). Winey perception can be related to ester compounds and alcohols such as methyl acetate, isobutyl alcohol, and 3-methyl-pantanol (Pereira et al., 2016). The overripe characteristics of fruits are also associated with esters and alcohol compounds (El-Mageed et al., 2017; Farcuh et al., 2020). Perceptions of vinegar, citrucy and soury are perceptions that indicate that the product has acid characteristics that can come from various acidic compounds (acetic, butyric, isobutyric, decanoic, benzoate, isovalerate, and valeric acid) and terpene compounds (linalool, limonene, α-terpeniol and β-citronellol). Further research is needed to prove these findings.

Table 4 also illustrated the presence of moldy and earthy characteristics detected in approximately 33-44% of the wine coffee samples. These results indicate that improper processing of wine coffee can potentially lead to negative aromas because moldy and earthy are essentially flavor defects. Moldy and earthy are associated with improper drying or storage (humid storage conditions) and can occur due to contamination with soil during drying (Boot, 2017). The compound associated with both aroma defects is pyrazine (Batista; Chalfoun, 2015; Poisson et al., 2017; De Melo Pereira, 2019). Cantergiani et al. (1999) previously mentioned that moldy and earthy are mainly associated with 2-methyl-isoborneol and geosmin. These compounds are produced mainly by Eurotium molds and some Actinomycetes. Another flavor defect present in wine coffee is a stinker, which was detected in 22% of wine coffee samples. Stinker is a characteristic of coffee beans with an unpleasant odor (rotten smell) due to over-fermentation. This foul odor is associated with a predominant overgrowth of lactic acid bacteria (*Lactobacillus brevis*), possibly associated with methyl-butanoic acid derivatives, cyclohexanoic acid esters, and sulfur-containing organic compounds (Poltronieri et al., 2016). Stinker is an aroma defect that generally occurs at the fermentation stage of the process (Boot, 2005), so it is not surprising that this aroma defect can be found in wine coffee whose production involves an intensive fermentation process.

5 CONCLUSIONS

Gayo highland wine coffee has diverse physicochemical and sensory characteristics. Green bean of wine coffee from Gayo highland is medium in size with moisture content meeting national and SCAA standards with a range of 8.4%-11.67%. The color of wine coffee green bean varies from yellowish to brownish, the pH value of brewed wine coffee ranged from 4.68 to 4.95 and total phenolic content ranged from 12.82±0.69 to 30.29±2.61 GAE mg/g. The cupping score of wine coffee on each attribute varied, except for body and sweetness. The lowest wine coffee score was 6 (good) and the highest reached 7.75 (very good). Specific fruit aroma characteristics dominant in wine coffee are pineapple, banana, passion fruit, lemon/lime and berries. Aroma characteristics related to fermentation, namely winey, vinegar, overripe and soury were detected in all wine coffee samples. The aroma defects detected in wine coffee were moldy, earthy and stinker. With the variety of taste sensations produced, wine coffee has the potential to be further developed. On a large scale, consistency of quality and standards is certainly needed. Further research is needed to analyze the more complex chemical components of wine coffee (volatile and nonvolatile) and their relation to brew quality, in order to obtain more comprehensive scientific information.

6 AUTHORS' CONTRIBUTION

Conceptual idea: Muzaifa, M.; Abubakar, Y.; Nilda,C.; Methodology design: Muzaifa, M.; Nilda, C.; Abubakar, Y.; Data collection: Nilda, C.; Muzaifa, M.; Data analysis and interpretation: Muzaifa, M.; Nilda, C., and Writing and editing: Muzaifa, M.; Nilda, C.

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