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Influence of Cultivars and Cultivation Land Slope on Sensory Quality of Gayo Arabica Coffee

Pengaruh Kultivar dan Kemiringan Hamparan Lahan Tanam terhadap Mutu Sensoris Kopi Arabika Gayo

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Abstract

All processes involved influence the quality of brewed coffee. One factor that has not been explored well is the influence of environmental conditions, such as cultivation land slopes. This research examines the influence of cultivation area position on the taste quality of coffee from three local cultivars commonly cultivated in the Gayo Highlands. This research used a factorial randomized block design consisting of 2 factors: cultivar (V) and land area (H). The cultivars (V) observed were V1 = Timtim, V2 = Borbor, V3 = Ateng Super, and V4 = multi variety. The expanse of coffee cultivation land (H) consists of M1 = flat expanse of land and M2 = sloping expanse of land with a slope of 25%-35%. The experiment was carried out with three replications. The results showed that the coffee brew from Ateng Super had higher acidity (low pH value, 4.90) than the other two cultivars. Cupping test results show that sloping land tends to produce better-tasting coffee brews. Borbor planted on sloping land produces coffee with the highest cupping score. The total cupping score for all treatments ranged from 80,04 – 85,08 with mean value 83,89, which shows that the coffee in this study meets the category of specialty coffee based on the standards of the Specialty Coffee Association of America (SCAA).
Keywordss: arabica, coffee, cupping test, Gayo Highland, quality

Abstrak

Mutu seduhan kopi sebagai produk akhir sangat dipengaruhi sejak awal proses hingga penyeduhan. Salah satu faktor yang belum terkesplorasi dengan baik adalah pengaruh kondisi lingkungan, seperti kemiringan lahan tanam. Penelitian ini bertujuan untuk mengkaji pengaruh posisi hamparan lahan tanam terhadap kualitas cita rasa kopi dari tiga kultivar lokal yang umum dibudidayakan di Dataran Tinggi Gayo. Penelitian ini menggunakan Rancangan Acak Kelompok Faktorial yang terdiri dari 2 faktor, yaitu kultivar (V) dan hamparan lahan (H). Kultivar (V) yang diamati adalah V1 = Timtim, V2 = Borbor dan V3 = Ateng Super dan V4 = multivarietas. Hamparan lahan tanam kopi (H) terdiri dari M1 = hamparan lahan datar, dan M2 = hamparan lahan miring dengan tingkat kemiringan 25-35%. Eksperimen dilakukan dengan 3 (tiga) ulangan. Hasil penelitian menunjukkan bahwa seduhan kopi dari Ateng Super memiliki keasaman tinggi (nilai pH rendah, 4,90) dibandingkan dua kultivar lainnya. Hasil uji cita rasa menunjukkan bahwa hamparan lahan miring cenderung menghasilkan seduhan kopi bercita rasa lebih baik. Borbor yang ditanam pada lahan miring menghasilkan seduhan kopi dengan cupping score tertinggi. Total cupping score semua perlakuan berkisar80,04-85,08 dengan rerata 83,89 yang menunjukkan bahwa kopi yang dihasilkan dalam penelitian ini masuk dalam katagori kopi specialty *berdasarkan standar* Specialty Coffee Association of America (SCAA).
Kata kunci: *arabika,* cupping test*, dataran tinggi Gayo, kopi, kualitas*

INTRODUCTION

Indonesia's position is considered quite strategic in the international coffee trade. Indonesia is the fourth largest coffee exporting country after Brazil, Vietnam and Colombia in 2022 (Hall et al., 2022). In the final quarter of 2021, Indonesian coffee exports reached 2.8 million bags of 60 kg (International Coffee Organization, 2023). The majority of coffee exported by Indonesia is robusta. However, Indonesia is also famous for arabica coffee, especially from the Gayo Highlands, the largest coffee-growing area in

Indonesia. The Gayo Highlands are governmentally located in three regencies (Central Aceh Regency, Gayo Lues Regency, Bener Meriah Regency) and has 126,490 ha of small-holder coffee farm in 2021. According to Statistics of Central Aceh Regency, this coffee plantation is estimated to increase to 127,464 ha in 2022 (Badan Pusat Statistik Kabupaten Aceh Tengah, 2021).

Gayo arabica coffee is one of Indonesia's leading commodities and is well-known internationally. Some Gayo arabica coffees are marketed to the specialty segment because of their distinctive and unique taste (Andini et al., 2021). Gayo arabica coffee exports' long-term development is primarily determined by improving the commodity quality and competitiveness (Baihaqi et al., 2020). The quality of brewed coffee is usually judged by its taste, and it all comes down to the coffee bean quality. The coffee bean quality is greatly influenced by its chemical components, followed by proper post-harvest handling (Abubakar et al., 2022). The chemical composition of coffee beans results from dynamic interactions between coffee plant genetics and growing environmental conditions during the coffee growing season (Bastian et al., 2021; Hall et al., 2022).

Coffee plant genetics refers explicitly to the varieties and cultivars of coffee cultivated. Arabica coffee cultivation should use cultivars with good quality potential, can quickly adapt to growing environmental conditions, have high yields, and are resistant to major pests and diseases (Andini et al., 2021). Local arabica coffee cultivars generally cultivated in the Gayo Highlands are the Timtim, Borbor, and Ateng Super (Hulupi et al., 2013; Sinaga & Julianti, 2021). Timtim, Borbor, and Ateng Super are three superior coffee cultivars that have adapted through natural selection and are suitable to the environmental conditions in the Gayo Highlands (Widayat et al., 2015). These three local cultivars are reported to produce specialty quality coffee and cupping scores above 83.00 in various types of coffee processing (Abubakar et al., 2019).

Environmental conditions for growing coffee include geographic topography, rainfall, soil fertility, and water source distance (Fathurrozi et al., 2022). Geographic topography, which includes the land's height, slope, and steepness, is the leading agricultural and environmental factor influencing coffee quality (Hameed et al., 2018). Several studies in Brazil and Ethiopia show that the topographic conditions of the cultivation land are positively correlated with the quality of coffee beans as measured by bean size, caffeine or chlorogenic acid content, and brew quality (Diego et al., 2016; Figueiredo et al., 2018). The results of Gas Chromatography-Mass Spectrometry (GC-MS) testing on volatile compounds show that coffee grown in the highlands has higher concentrations of ethanol and acetone compounds, while coffee originating from lower cultivation areas tends to contain higher levels of alcohol, aldehydes, hydrocarbons, and ketones (Bertrand et al., 2012). The components of chlorogenic acid, caffeine, and sucrose are also reported to vary. Chlorogenic acid and caffeine in coffee beans from higher cultivation areas tend to be lower than those from lower cultivation areas. The sucrose content and acidity of coffee brews produced from higher cultivation areas tend to increase (Worku et al., 2018).

The Gayo Highlands area has hills, valleys, flat land, and sloping land (facing east and west). Gayo farmers cultivate their coffee according to the land conditions they have. The land stretch position allegedly influences coffee quality because the light intensity received by coffee plants varies according to its relative position to the sunlight (Hameed et al., 2018; Zaidan et al., 2017). An influence study of the cultivation area height and land position according to the sun direction in the morning and evening shows that coffee grown in the highlands tends to produce good sensory quality if the land position receives afternoon sunlight and vice versa for coffee planted in the lowlands (Ferreira et al., 2022; Pereira et al., 2018).

A holistic study is needed to maintain and improve the quality of Gayo arabica coffee in the future to meet the quality criteria and competitiveness of the world coffee market. Several studies have been conducted regarding the influence of the ripe cherry coffee quality (Abubakar et al., 2022), the cultivation area height ranging from 1,000 to 1,600 meters above sea level (Abubakar et al., 2017), the influence of processing variations (Abubakar et al., 2019), the influence of roasting degree (Abubakar et al., 2021), and coffee blending formulation (Abubakar et al., 2020) on the Gayo coffee taste quality. This research is expected to complete scientific references regarding the influence of the cultivation land slope and coffee cultivars on Gayo arabica coffee's physical quality and taste quality so that more comprehensive information can be obtained in producing the best quality Gayo arabica coffee.

METHODS

This research was conducted on the arabica coffee people's plantations in Gayo Highlands. Samples were obtained from coffee cultivation in Bebesen Districts and Bies Districts, Central Aceh Regency, with an elevation of 1,400 to 1,600 meters above sea level, in Bandar District, Bener Meriah Regency, with an elevation of 1,000 – 1,200 meters above sea level and Bukit District, at an elevation of 1,200 to 1,400 meters above sea level. Samples were taken from small-holder coffee plantations with a density of 1,400 – 1,800 plants per hectare and shade of 315 – 405 *Leucaena leucocephala* trees per hectare. Post-harvest handling, such as the roasting process and semi-wash coffee processing, was performed at the Oro Coffee Gayo Cooperative, Jalan Raya Bireuen - Takengon, Mongal Village, Bebesen District, Central Aceh Regency, Aceh Province, Indonesia. The sensory quality analysis of coffee was performed by three certified Q-graders (members of the Gayo Cupper Team) at the Mini Laboratory, Gayo Cupper Team, Takengon, Central Aceh, Indonesia. Other coffee quality analyses were conducted at the Food Analysis Laboratory and Sensory Evaluation Laboratory, Department of Agricultural Product Technology, Faculty of Agriculture, Syiah Kuala University, Banda Aceh, Indonesia.

Material and Tools

The research material is the arabica ripe cherry of Timtim, Borbor, and Ateng Super cultivars, picked manually during the first (May-August) and second (November-January) harvest seasons. The materials used in the chemical analysis process are distilled water and mineral water. The floating and semi-wash processing tools are plastic buckets, plastic sacks, plastic baskets, plastic tarpaulins and plastic bags, scales, pulpers, hullers, grinders, and altimeters. Equipment for analyzing coffee quality is a pH meter, beaker, analytical scales, cupping equipment (cups and spoons) and sensory evaluation sheets according to Specialty Coffee Association of America (SCAA) standards (Specialty Coffee Association of America, 2015), water bath, and stirrer.

Research Design

This research used a Randomized Block Design with a factorial pattern of 2 factors. The first factor is the Gayo coffee cultivar (V), which consists of 4 levels: V1 = Timtim, V2 = Borbor, V3 = Ateng Super, and V4 = multivariety (mixed harvested ripe coffee cherry from V1, V2 and V3). The second factor is land expanse (H), which consists of 2 levels: M1 = flat land expanse and M2 = sloping land expanse. The slope percentage of flat land is 0% to 15%. Meanwhile, the slope percentage of sloped land is 15% to 25% (at the mountain side facing east or west). The treatment combination was 4 x 2 = 8, using three replications to obtain 24 experimental units. The data obtained was processed statistically using SPSS 22.0. The influence of the research factors was analyzed using ANOVA. If the research factors have a significant effect, then it will be continued with the Least Significant Difference (LSD) test.

Research Procedures

Ripe Coffee Cherry Harvest

6 kg of arabica coffee cherries were picked manually. Three coffee cultivars from healthy and well-maintained coffee plants aged 7 – 18 years were harvested. The coffee cherries picked must be fully ripe with an entirely red-colored fruit. The ripe coffee cherries were sorted manually to separate the deformed cherries, twigs, and leaves. Cherry floating was conducted by pouring the red coffee cherries into a water-filled plastic bucket. Floating red coffee cherries are separated and considered defective fruit. The submerged ripe coffee cherries are washed and drained for further processing.

Semi-Wash Processing

Ripe cherry coffee was peeled using a pulper machine (the duration between harvesting and peeling is 4 hours – 5 hours). The coffee grain (coffee bean with parchment) produced from the pulping process was then fermented for 12 hours using a plastic sack, then washed manually in a plastic bucket, and drained. The wet coffee grain was dried under the sunlight. They were dried on a tarpaulin for ± 1 day from 9 AM to 3 PM to produce coffee grain with around 30% - 40% of moisture content. The parchment of half-dried coffee grain were peeled using a small huller machine. The coffee beans were dried again for 3 - 4 days (depending on the weather) until the water content reaches ± 12%. The coffee beans were

sorted using a Sutton machine to obtain grade 1 and 2 coffee quality (based on bean size). Further ssortation was manually conducted (on grade 1 and grade 2 coffee bean) to separate dirt, gravel, and defective coffee beans. Coffee beans were stored in burlap sacks until the coffee roasting procedure occurs.

Coffee Bean Roasting

Roasting was conducted based on the standard cupping test by the Specialty Coffee Association of America (SCAA). The roasting was conducted 10 hours before the tasting process, and then the roasted coffee beans were cooled down to room temperature (Specialty Coffee Association of America, 2015). The coffee beans are roasted using a drum roaster machine at medium roast level with a temperature of 204 °C for 10 minutes – 15 minutes. The roasting degree is then evaluated by visually comparing the roasted coffee beans' colors with the Agtron Scale 65 catalog. Evaluation is needed to ensure the roasting degree accuracy. The cooled coffee beans are ground finely to a 20-mesh size using a grinder. The ground coffee is then stored in an airtight container and ready for analysis.

Product Analysis

The coffee quality observed were physical, chemical, and sensory. The physical quality test was conducted by calculating the number of normal bean (undamaged coffee bean) per 100 grams of green beans, while the green bean moisture content was tested by using a digital grain moisture tester. The chemical quality measured was the coffee pH using a pH meter. The sensory quality test refers to the cupping test procedure consisting of ten sensory attributes i.e. fragrance/aroma, flavor, acidity, aftertaste, body, balance, sweetness, clean cup, uniformity, and overall. The scale used is 6.00-10.00 with an interval of 0.25; 6.00-6.75 is good, 7.00-7.75 is very good, 8.00-8.75 is excellent, and 9.00-10.00 is outstanding (Specialty Coffee Association of America, 2015). The total value of the cupping test (cupping score) is the sum of the ten attribute values minus the number of defects. The classification and description of the cupping score can be seen in Table 1. According to the treatment, coffee is weighed and placed in a uniform cupping container. Sensory quality testing begins with the assessment of the dry coffee powder aroma (fragrance). Coffee is then brewed with a ratio of 8.25 grams of coffee powder and 125 mL of water at a temperature of 92 °C-95 °C. Three certified Q-graders from the Gayo Cupper Team, Takengon-Indonesia, assessed the coffee quality. Attribute testing is carried out sequentially according to SCAA procedures.

Table 1. Classification and description of cupping score values based on SCAA

Range of Score	Description	Quality Classification
90.00 – 100.00	Outstanding	Specialty
85.00 – 98.99	Excellent	
80,00 – 84.99	Very Good	
< 80.00	Below Specialty Quality	Not Specialty

Source: Specialty Coffee Association of America (2015)

RESULTS AND ANALYSIS

Table 2 shows that land expanse and local cultivar factors significantly affect six out of the ten coffee sensory attributes tested in the cupping process (fragrance, flavor, acidity, aftertaste, balance, and overall). Therefore, the discussion of sensory quality in this research was only performed on these six attributes. The ANOVA results showed no influence of the two research factors and the interaction of the two factors ($P>0.05$) on body parameters. ANOVA could not be carried out for the sensory attributes of sweetness, clean cup, and uniformity because all treatment samples obtained identical sweetness, clean cup, and uniformity of 10 scores. The same thing was also reported by Abubakar et al. (2019) and Muzaifa & Hasni (2016), who stated that Gayo arabica coffee using wet and semi-wet processing, luwak and from various heights had the highest (outstanding) and identical sweetness, clean cup, and uniformity scores.

Number of Normal Bean

The number of normal beans (referred to the number of coffee beans without physical defects in 100 grams of green beans) is shown in Table 3. Table 3 shows that the number of normal beans was ranged from 497.72 to 530.44 with an average of 511.92 normal beans per 100-gram of green bean. The ANOVA results showed no influence of the local cultivar (V) and land expanse (M) and their interactions on the number of normal coffee beans. However, the three Gayo local cultivars and multivariety planted in sloping land produce a higher average of normal coffee beans. This might due to length of exposure to sunlight. Coffee plants cultivated in sloping land tend to receive sunlight during the optimal periods. Sloping areas facing east tend to receive more optimal morning sunlight, while sloping areas facing west will receive sunlight in the afternoon (Ferreira et al., 2022).

Periodic exposure to sunlight in the morning or evening affects environmental temperature and optimizes the photosynthesis process, so the coffee cherry growth optimally, ripens well and is more prominent in size and better able to withstand pest and disease attacks (Ayalew, 2018; Piato et al., 2020). Different things happen to coffee on flat land that receives exposure to sunlight throughout the day. This condition is thought to influence the temperature increase of the cultivation environment, thereby speeding up the process of photosynthesis and plant metabolism. This condition causes the fruit to ripen more quickly but produces smaller seeds. Rodrigues et al. (2018) reported that coffee cultivation on flat land, without protective plants, and with directly exposed sunlight for a long time has higher environmental temperatures that make it difficult for coffee plants to maintain photosynthetic activity, measured by the low stomatal conductance on the coffee plants' leaves.

Table 2. ANOVA results of Gayo arabica coffee quality parameters based on land expanse and local cultivar factors

Parameters	F-Test of Research Factors			F -Satistics 0,05 of Research Factors		
	Land Expanse (M)	Local Cultivars (V)	MV Interaction	Land Expanse (M)	Local Cultivars (V)	MV Interaction
Standard coffee bean	0.01 ns	0.66 ns	1.71 ns			
Water content	0.00 ns	0.49 ns	2.84 ns			
pH	0.98 ns	11.16**	8.27**			
Cupping Score	12.55**	6.25**	1.11 ns			
Fragrance	11.81**	3.10 ns	0.06 ns			
Flavour	11.96**	7.93**	0.25 ns	4.60	3.34	3.34
Acidity	7.45**	1.89 ns	1.70 ns			
Aftertaste	6.03**	9.23**	0.24 ns			
Body	3.30 ns	2.11 ns	0.47 ns			
Balance	8.30 **	5.6**	0.12 ns			
Overall	13.96**	3.65*	0.60 ns			

ns (not significant P>0,05); *(significant P<0,05); ** (very significant P<0,01)

Table 3. Number of normal beans and moisture content based on land expanse and local arabica coffee cultivar

Treatment	Number of Normal Coffee Bean per 100 g	Moisture Content (%)
Flat land expanse - Timtim	499.47±24.44	13.09±0.64
Flat land expanse - Borbor	497.72±28.61	12.55±0.32
Flat land expanse - Ateng Super	493.81±37.71	13.10±0.24
Flat land expanse – multivarietas	513.28±25.64	12.86±0.19
Slope land expanse – Timtim	528.06±46.75	13.01±0.58
Slope land expanse - Borbor	503.72±12.02	13.34±0.12
Slope land expanse - Ateng Super	528.83±57.12	12.47±0.66
Slope land expanse – multivarietas	530.44±29.96	12.78±0.14
Average	511.92	12.90
Flat land expanse average	501.07	12.90
Slope land expanse average	522.76	12.90
Timtim average	513.77	13.05
Borbor average	500.72	12.95
Ateng Super average	511.32	12.79
Multivariety average	521.86	12.82

Moisture Content

Moisture content of green coffee beans in this study ranged between 12.47% and 13.34% (Table 3). The ANOVA results showed no influence of local cultivar (V), land expanse (M) and their interactions on the coffee beans' moisture content. The beans' moisture content in this study is in accordance to the moisture content of Gayo Arabica coffee green bean reported by Abubakar et al. (2019) and Muzaifa & Hasni (2016), who reported that Gayo arabica coffee, which is processed using wet, semi-wet, luwak, or natural processing has a water content of around 11-13%. This study's coffee beans' water content is also close to the Specialty Coffee Association of America (2015) standard of 9-13%. Water content that exceeds this standard is still within tolerance limits. According to Al-Rosyid & Komarayanti (2021).

pH

Acidity is one of the characteristics of arabica coffee. The acid content in coffee, such as chlorogenic acid, quinic acid, lactic, citric, acetic, and malic acid, produces a special acidity for a cup of brewed coffee. The sour taste causes the coffee brew to be unique, has a distinctive aroma, and has a pleasant effect on coffee consumers (Sunarharum et al., 2014). The pH measurement results show that the pH value of coffee brew in this study ranged from 4.98 – 5.06, with an average of 5.02. The ANOVA results show that the local cultivar factor (V) and the interaction between the two factors (MV) have a very significant effect ($P \leq 0.01$) on the pH value of coffee brewing, as shown in Figure 1.

Figure 1 shows that there are very significant differences in the pH of coffee brews coming from the same cultivar but planted on different land slopes. Timtim (V1) and Ateng Super (V3) planted on sloping land (M2) tend to have a lower pH value and are significantly different from those are planted on flat land (M1). This trend is similar to the decrease in the brewed coffee pH of Timtim (V1) and Ateng Super (V3) cultivars when planted on a farm with elevation above 1,500 meters above sea level. The Borbor cultivar (V2) and multivariety (V4) tend to have a higher pH when planted on sloping land. This result might related to a relatively low organic acid content in both cultivars, so that the pH of the coffee brew and the sensory acidity attribute are also low. The pH values of the three cultivars and multivarieties of Gayo arabica coffee is in accordance with the pH reported by Abubakar et al. (2017), which is 4.90 to 5.09.

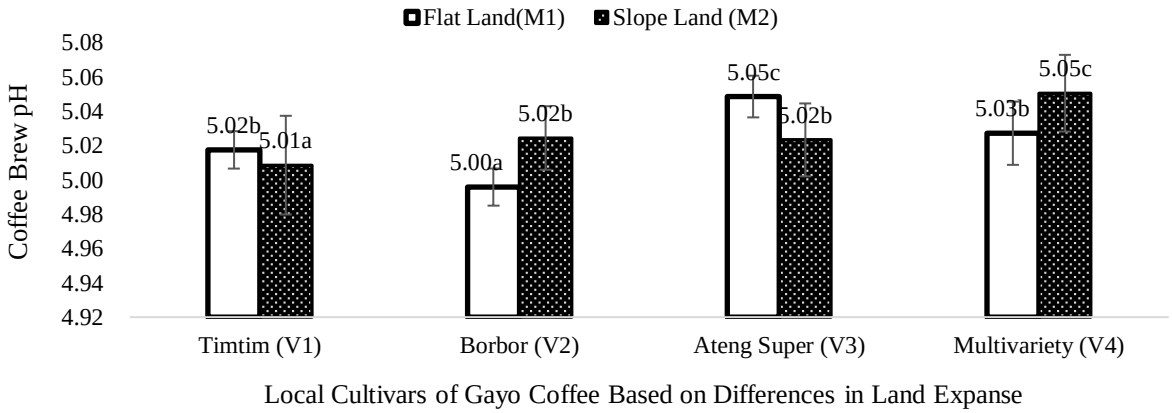

Figure 1. Interaction Effect of four Gayo coffee local cultivars and two cultivated land expanse on the coffee brew pH at $LSD_{0.05}$ 0.019 at n=24

Amalia et al. (2021) reported that the variety, farm elevation level, and post-harvest handling greatly influence the acidity of coffee beans. The roasting degree greatly influences the pH value of roasted coffee beans. The roasting degree is a combination of temperature and roasting duration of coffee beans, classified as light, medium, and dark (Sunarharum et al., 2014). A light roasting degree with a low roasting temperature (180°C - 195 °C) and a shorter time (8-10 minutes) will produce coffee with a high degree of acidity compared to coffee roasted at a medium or dark roasting degree. A study on the degree of brewed coffee acidity is essential because acidity and sour taste are considered the determinants of

coffee quality (Cotter et al., 2021; Farah, 2019). Changes in coffee brewing pH have been reported to influence the sensory profile of coffee and consumer preferences (Batali et al., 2021).

The acid content influences the degree of acidity and sour taste in coffee. The acid content in coffee is generally classified as chlorogenic acid and organic acid. Chlorogenic acid is considered the most influential acid on the coffee beans' pH because chlorogenic acid indicates the coffee cherry's ripeness (Farah & dePaula Lima, 2019; Yeager et al., 2023). The chlorogenic acid content of arabica coffee in Minas Gerais, Brazil, grown more than 1,200 meters above sea level, is 6.27%. This acid content is higher than arabica coffee in Minas Gerais, Brazil, grown below 1,000 meters above sea level at 5.19% (Diego et al., 2016). Researchers assume that the Gayo arabica coffee cultivar planted on a sloping land expanse can maximize the genetic potential and the coffee quality so that the photosynthesis process occurs better and the fruit matures perfectly. It is thought that coffee cultivated on sloping land expanse and at a higher cultivation area tends to receive shorter but more optimal sunlight, especially in the morning and afternoon, which is adjusted to the position of the land facing east or west throughout the day from morning to afternoon at lower temperatures (Ferreira et al., 2022). This condition causes photosynthesis to occur slowly, and the chemical composition changes in coffee cherry flesh during ripening to occur more efficiently.

Sensory Quality

Cupping Score

According to the Specialty Coffee Association of America (2015), the total cupping score is the sum of ten coffee sensory attributes scores assessed by the q-grader minus the number of coffee defects detected. The cupping score for Gayo arabica coffee brew in this study is ranging between 80.04 and 85.08, with average score 83.89. All coffee brews produced in this study qualify as specialty coffee because the cupping score is above 80 and is in the outstanding category. The ANOVA results show that the factors of cultivation land expanse and local cultivar ($P \leq 0.01$) significantly influence the cupping score of coffee brew, as shown in Figure 2.

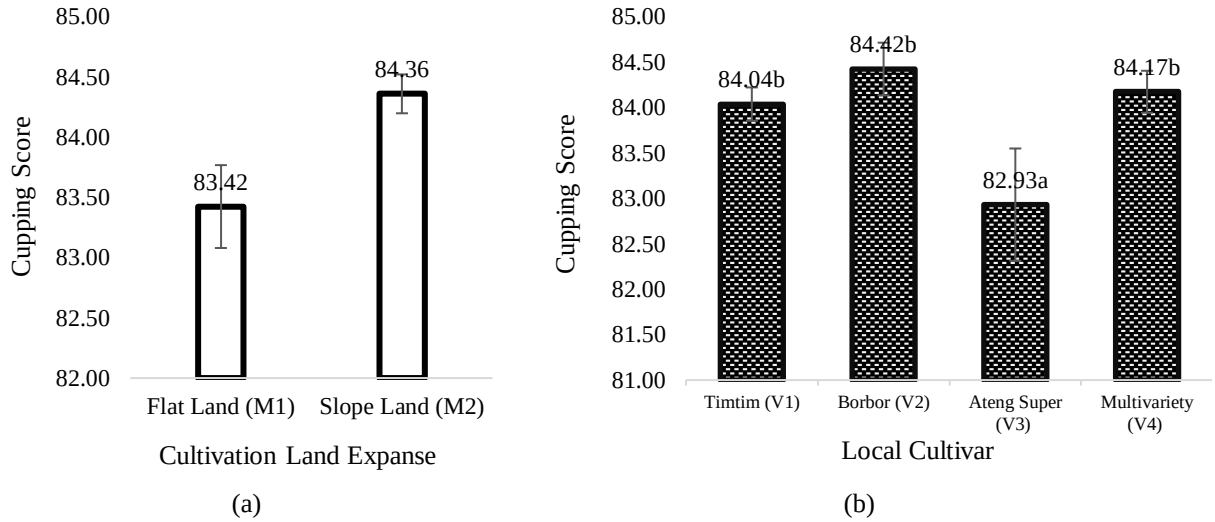

Figure 2. Effect of Cultivation Land Expanse (a) $LSD_{0.05}$ = 0.694 and Local Cultivar Type (b) $LSD_{0.05}$ = 0.801 on the Cupping Score of Gayo Arabica Coffee Brewing (Values Followed by the Same Letters Show Unsignificant Differences), N= 24.

Figure 2a shows that flat cultivation land expanses produce coffee with lower cupping scores and are significantly different from those of sloping areas. The cupping score shows that the sensory quality of coffee grown on sloping land is better than the others. The sensory quality of coffee is a complex manifestation of the entire process of cultivation, post-harvest handling, and processing until it is brewed. Therefore, the expanse of the cultivation area is thought to influence the ripening process of the coffee cherries, thereby influencing the chemical composition of the coffee cherries before they are picked.

Coffee plants on sloping land expanse (M2) generally receive 6-8 hours of direct sunlight daily, while those on flat land (M1) receive 9-10 hours of sunlight daily.

Figure 2b shows the influence of each type of local cultivar found in the Gayo Highlands on the cupping score. The cupping scores of Timtim, Borbor, and multivariety cultivars do not have any significant differences. Multivariety (V4), a mixed cultivar coffee, has the highest cupping score because each cultivar's sensory characteristics can synergize with each other to produce better coffee sensory quality. This cupping score is also in line with research by Abubakar et al. (2017), who studied the influence of farm elevation and varieties on the sensory quality of Gayo arabica coffee. The cultivation area of Timtim and Borbor cultivars are divided naturally based on the Gayo farmer's local wisdom (natural suitability). Coffee farmers in Central Aceh commonly cultivate Timtim, while the Borbor cultivar are generally grown in Bener Meriah Regency (Widayat et al., 2015).

Fragrance, Flavor, Acidity, Aftertaste, Balance, Overall

The ANOVA results show that the cultivation land expanse and local cultivars of Gayo coffee significantly influence six sensory attributes (fragrance, flavor, acidity, aftertaste, balance, and overall) out of ten according to SCAA standards. The influence of the cultivation land expanse factor on the six sensory attributes can be seen in Figures 3a to 3f, while the influence of local cultivars on the four sensory attributes can be seen in Figures 4a to 4d.

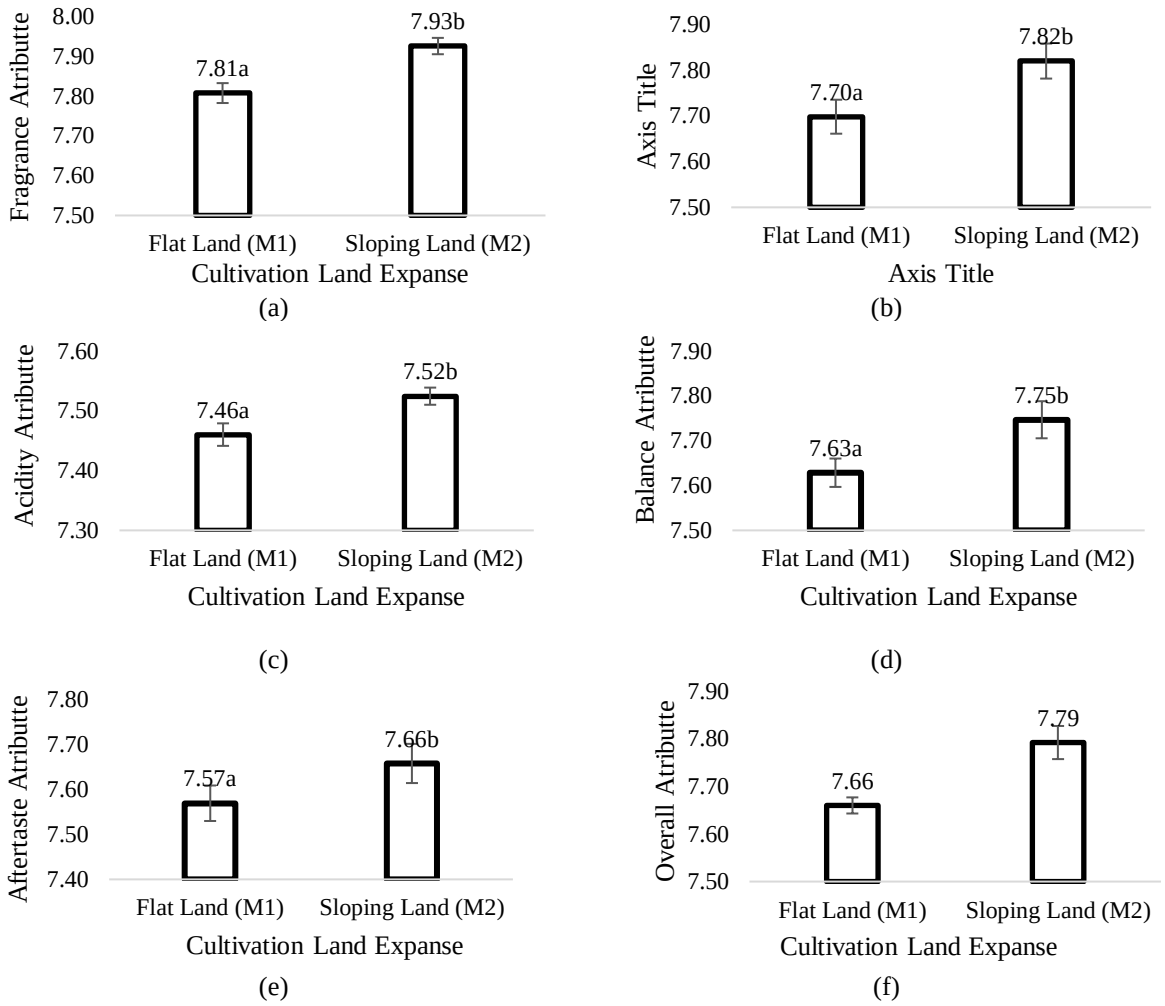

Figure 3. Effect of Cultivation Land Expanse (Flat/Sloping) on Sensory Attributes of Gayo Arabica Coffee Brewing Based on SCAA (a) Fragrance, $LSD_{0.05} = 0.090$ (b) Flavor, $LSD_{0.05} = 0.092$ (c) Acidity, $LSD_{0.05} = 0.062$ (d) Balance, $LSD_{0.05} = 0.108$ (e) Aftertaste, $LSD_{0.05} = 0.095$ and (f) Overall, $LSD_{0.05} = 0.093$ (Values Followed by the Same Letters Show Unsignificant Differences).

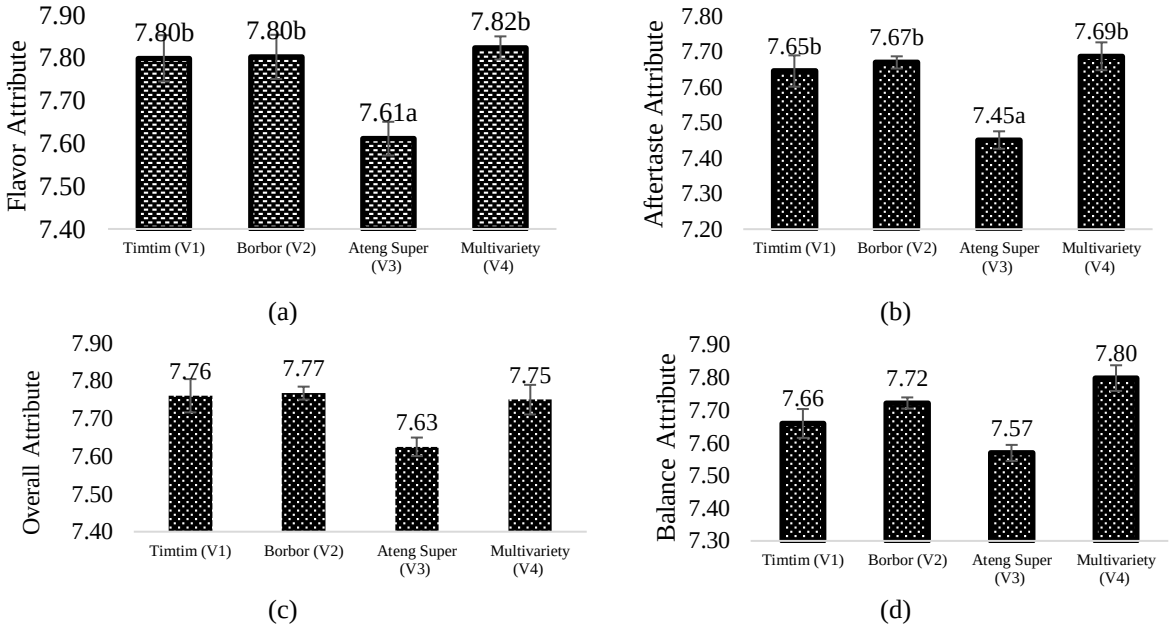

Figure 4. Effect of Local Cultivar Type (Timtim, Borbor, Ateng Super, Multivarieties) on Sensory Attributes of Gayo Arabica Coffee Brewing Based on SCAA (a) Flavor, $LSD_{0.05}$ = 0.107 (b) Aftertaste, $LSD_{0.05}$ = 0.104 (c) Overall, $LSD_{0.05}$ = 0.107 (d) Balance, $LSD_{0.05}$ = 0.124 (Values Followed by the Same Letters Show Unsignificant Differences).

Fragrance is an attribute tested within 3 to 5 minutes after the coffee is brewed to identify and assess the aroma intensity of the brewed coffee using nasal (Specialty Coffee Association of America, 2015). Flavor, acidity, balance, and aftertaste are assessed when the brewing temperature reaches 71 °C, approximately 8 to 10 minutes after brewing. Brewing coffee using the brew method is conducted by adding water to ground coffee at a temperature of 93-95 °C. A thick layer on the surface of the glass is then formed to trap volatile compounds released due to interaction with hot temperatures. The Q-grader removed the thick layer when testing the fragrance and inhaled the aroma. The flavor is assessed using the retronasal technique, where the coffee is sipped vigorously so that the coffee's aroma and taste can be assessed simultaneously (Specialty Coffee Association of America, 2015). The intensity of these two attributes is greatly influenced by the content and type of volatile components contained in coffee beans. Sloping land expanse is reported to produce brewed coffee with better fragrance and flavor values than flat land expanse.

The formation of volatile compounds generally occurs during roasting (Diviš et al., 2019) due to the Maillard reaction and the release of beans fatty components onto the surface of the coffee (Schenker & Rothgeb, 2017), but precursors of volatile compounds, such as organic acids and sucrose, formed during the ripening process of coffee cherries. Diego et al. (2016) reported that the sloping land expanse affects the chemical composition of coffee cherries. Sloping coffee farm exposed to direct sunlight tend to produce coffee with lower sucrose content (67.87%) and a cupping score (84.84), than those of coffee cherry from sloping land with indirect sunlight exposure (shading), with sucrose content of 70.63%, and the cupping score of 85.34. Coffee grown on sloping land and exposed to indirect sunlight are reported to photosynthesize twice as much as coffee plants that exposes directly to sunlight (or at a loonger expose duration). The photosynthetic productivity is studied through the stomatal conductance value, which is a measure of gas exchange rate (CO_2 uptake) and transpiration (water loss as water vapor) through the leaf stomata to indicate the photosynthesis rate (Ayalew, 2018). The range of direct sun exposure on sloping land (on the mountain side) is shorter, so the environmental temperature is lower, but photosynthesis results are still available in large quantities, therefore coffee cherries could grow and ripe optimally (Piato et al., 2020).

Acidity is a trained panelist's perception of the brewed coffee's sour taste intensity. Acidity refers to the pleasant acidity of coffee and is one of superior sensory quality components in brewed coffee. Sloping land expanse tends to produce better brewed coffee acidity than that of flat land expanse, as shown in

Figure 2c. This result aligns with coffee pH value measured in this study, as shown in Figure 1. Coffee grown in sloping land is thought to have better cherry maturity. Ripe coffee cherries tend to produce coffee brew with solid acidity with a positive impression (Abubakar et al., 2022). Many studies report that panelists' assessments of the fragrance, flavor, and acidity quality are determinants of balance, aftertaste, and overall quality (Diego et al., 2016). Balance attribute measures the balance between sour taste, flavor, and body. Aftertaste measures the period of coffee's positive impressions, such as acidity and body (viscosity), that remain in the oral cavity and after being swallowed. The aftertaste score will be higher if the panelists record a longer positive impression. Overall is an attribute that allows expert panelists to provide an individual and subjective assessment of how the coffee brew being tested compares to other brews they have tasted before. This research shows that the sloping land expanse produces better coffee brewing in regard to sensory balance, aftertaste, and overall attributes.

Figures 4a, 4b, 4c, and 4d show the influence of local cultivars of arabica coffee in the Gayo Highlands on flavor, aftertaste, overall, and balance scores. The influence of arabica coffee cultivar on these four sensory attributes has the same trend. Ateng Super has the lowest value on the four attributes and is significantly different from Timtim, Borbor, and multivarieties coffee brews. Meanwhile, flavor, aftertaste, balance, and overall score of Timtim, Borbor, and multivarieties brews do not have any significant differences among each other. This result is in agreement with several previous studies which stated that the sensory quality of Ateng Super was lower than that of Timtim and Borbor (Abubakar et al., 2017), though it is still meet specialty coffee requirement. The sensory quality of Ateng Super is considered better than that of other local cultivars, such as Lini S 288 (Hulupi et al., 2013). The Timtim and Borbor cultivars that have been successfully cultivated in the Gayo Highlands have the potential to produce 1,180 and 1,109 kg of coffee beans/ha, respectively. Both can adapt to the environment and climate of the Gayo Highlands, and have been reported to be quite resistant to diseases, such as leaf rust, compared to Ateng Super. Althoug the productivity of Ateng Super reaches 1,760.4 kg/ha, this kind of dwarf stature tend to have unstable productivity and quality, and have a shorter productive period (Hulupi et al., 2013).

CONCLUSIONS

The sloping land expanses (at the mountain side facing east or west) influence coffee brew's acidity degree and cupping score. Coffee grown on sloping land tends to produce coffee beans with a lower pH, better fragrance, flavor, acidity, balance, and overall quality than coffee grown on flat land. The local Timtim and Borbor cultivars are reported to produce coffee with a superior taste compared to Ateng Super. The total cupping score results for all treatments (80,04 - 85,08) with average score 83,89 show that the coffee in this study (Timtim, Borbor, and Ateng Super cultivars) meets the requirements for specialty coffee according to SCAA standards. The Timtim and Borbor cultivars have better quality if planted on sloping land expanse at 1,000 to 1,600 meters above sea level. Future research should be directed to identify volatile components and organic acids from local cultivars planted on sloping and flat land expanses, to ensure that sloping land expanse could optimize the coffee plants photosynthesis process and produce better quality Gayo arabica coffee brews.

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