Sensory characteristic of espresso coffee prepared from Gayo arabica coffee roasted at various times and temperatures

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Abstract. Gayo Arabica Coffee cultivated in mountainous area of Central Aceh has a distinctive, fruit-like aroma and a delicate flavor. Therefore, it is very popular among coffee drinkers, and Baristas. However, information about relation between degree of roasting and organoleptic quality of Gayo Arabica espresso is very limited. The aim of this research was to evaluate sensory quality of Gayo Arabica espresso. Factorial Randomized Block Design consisting of two factors was employed in this study. The first factor was roasting temperature (with three levels), i.e. 193°C, 204°C and 213°C, while the second factor was roasting time (with three levels) i.e. 9 minutes, 12 minutes and 15 minutes. Results show that roasting temperature has a very significant effect, while roasting times has a significant effect on sensory quality of Gayo Arabica espresso. As roasting temperatures and roasting times increase, pH values also increase. The highest cup score (85.08) was obtained from coffee roasted at 204°C for 12 minute. The Gayo coffee espresso had nutty, floral and spicy characters. Nevertheless, hedonic test showed that local customers prefer espresso coffee prepared from the bean roasted at 213 °C for 12 minutes, giving nutty, fruity, herby, floral, spicy and grassy characters.

1. Introduction
Arabica coffee (Coffeea arabica) and Robusta (C. canephora) are important commodities for farmers and business actors in Indonesia. As for Aceh, Arabica coffee is grown more than robusta coffee, especially in the Gayo Highlands region (Central Aceh, Bener Meriah and Gayo Lues districts). Arabica coffee generally has a distinctive aroma and unique taste, according to the location where it grew. Likewise, Gayo Arabica coffee also has a distinctive taste that is different from other Arabica coffees [1],[2]. Furthermore, Gayo Arabica coffee processed by full and semi wash has distinguished flavors, namely chocolate, dark-chocolate, caramel, nutty and spicy [2].

The distinctive flavor of coffee products is influenced by several factors including temperature and roasting time. In general, roasting temperature is divided into 3 levels, namely light roast with a temperature of 193 °C to 199 °C, medium roast with a temperature of 204 °C and dark roast with a temperature of 213 °C to 221 °C. The temperature and duration of roasting also affect the quality of coffee and espresso coffee [3]. Roasting triggered the formation of compounds responsible for coffee taste and flavor. More than 1000 volatile compounds have been identified in coffee gaseous phase, which contribute directly and indirectly to the aroma and flavor [4]. As roasting time is prolonged, coffee bean color will turn gradually to brown, and then to dark brown [3], [5].
Another factor that also affects the quality of coffee drink is its brewing technique. In general, the brewing of coffee is divided into two, namely soaking and rinsing. Immersion methods include “ibrik” (boiling), press, and coffee bag techniques. Rinsing method for brewing includes percolation techniques, drip brewing, low pressure techniques (vacuum brewing) and high pressure techniques or espresso [6], [7].

Espresso comes from the Italian word for "fast". Espresso coffee is a drink that is extracted from coffee grounds using hot water with high pressure in about 30 seconds. The pressure used can reach 9 atm, while the water temperature is around 90 °C. Baristas generally use espresso coffee as a basic ingredient in serving various types of coffee to produce better quality drinks [6]. Therefore, the quality of the espresso coffee will determine the quality of the coffee drink served.

Gayo Arabica coffee is very popular among baristas to be used as a raw material for espresso. However, information on the influence of various factors such as roasting variations on the quality of Gayo Arabica espresso coffee is still limited. Therefore, there is a need for more complete research on the effect of the degree and duration of roasting of Gayo Arabica coffee on the sensory quality of espresso coffee in order to produce espresso coffee that meets consumer preference. The purpose of this study was to determine the effect of variations in temperature and duration of roasting of Gayo Arabica on the sensory quality of espresso coffee. The results of this study are expected to provide information to public, farmers and entrepreneurs or producers regarding an appropriate roasting process especially on the variations of temperature and length to produce the best espresso made from Gayo Arabica coffee.

2. Materials and methods

2.1. Materials and equipment

The coffee beans used were obtained from several randomly selected farmers in Kute Panang District, Central Aceh, in 2017. The weight of total sample collected was about 50 kg (8.75% moisture content). Other materials used in this study were unsalted crackers and distilled water. The equipment used is a laboratory scale roaster with a capacity of 200 g with dimensions (mm) LxWxH = 662x513x544, an espresso coffee machine, grinder, pH meter, 100 ml beaker glass and a scale. The tools used for the organoleptic test were coffee cups, stationery, stopwatches, measuring cups and spoons. The research was conducted at the laboratory of PT. Volkopi Indonesia, Bener Meriah and the Laboratory of Food and Agricultural Product Analysis, Faculty of Agriculture, Universitas Syiah Kuala, Banda Aceh.

2.2. Research procedure

The experimental design used in this study was a factorial randomized block design consisting of 2 factors. The first factor is the roasting temperature (cut off temperature) which consists of 3 levels, namely 193°C (light – T1), 204°C (medium – T2) and 213°C (dark – T3). The roasting temperature was started from 185 °C (charge temperature), and then was rise to the targeted roasting temperatures. The second factor is the total roasting time which consists of 9 minutes (W1), 12 minutes (W2) and 15 minutes (W3). The treatment combination in this study was 3 x 3 = 9 (nine) with 3 replications (27 units of experiment).

About 150 g of Arabica coffee beans were roasted in a hot air laboratory roaster at intended temperatures and times. After cooling, the bean was stored in a tight container waiting for analysis. An espresso machine with a steam pressure of 9-10 atm was employed to produce an espresso drinks. As many as 15 g of ground coffee was needed to make 30 ml espresso brew which was immediately tested.

Analysis carried out on the espresso coffee brew were acidity level (pH) [8], hedonic test and cup test based on the standard method of Specialty Coffee Association of America (SCAA). Cupping parameters tested include fragrance/aroma, flavour, aftertaste, acidity, body, balance, uniformity, clean cup, sweetness, defects and overall [9]. The cup test was carried out by three trained panellists (Q-Graders) from the Gayo Cupper Team who are well known to international buyers. The cupping procedure used was adopted from [2]. The hedonic test (aroma, acidity, and body) was carried out by 25 semi-trained panellists.
ANOVA (Analysis of variance) was used to test the effect of the two factors and their interactions on the sensory quality parameters of the coffee brew. If the given treatment affects the parameters significantly, then it was tested further with the LSD (Least Significant Difference) test.

3. Results and discussion

3.1. Acidity level (pH value) of espresso coffee

The pH value of Gayo Arabica espresso coffee roasted at 193 °C (light roast) ranges from 5.11 - 5.19 (average 5.16), roasted at 204 °C (medium roast) ranges from 5.18 - 5.23 (average 5.22), and those roasted at 213 °C (dark roast) ranged from 5.47 to 5.65 (average 5.54). According to [7], pH value of Arabica coffee steeping is around 5, while robusta coffee ranges from 5.4 - 5.50.

Analysis of variance for pH value showed that the roasting temperature had a very significant effect on the pH value of arabica espresso coffee, while length of roasting had no effect on the value. Moreover, interaction between the two factors has a significant effect on the pH value. Figure 1 shows that the pH of coffee beans roasted at 213 °C is higher than the pH of the beans roasted at the other two temperatures. The LSD test shows that a roasting temperature of 213 °C (with a 15 minutes roasting time) gives the highest pH value, namely 5.65, which is significantly different from all pHs from other treatments. So that, the higher the roasting temperature, the higher the pH value of the coffee brew. [10] also reported that the pH of the coffee brew will increase in line with the increase in roasting temperature of the beans.

The degree of acidity (pH) of coffee drinks greatly affects its taste. The sour taste detected in coffee brew comes from simple aliphatic acid compounds such as acetic acid, citric acid, malic acid and pyruvic acid. These aliphatic acid compounds come from chlorogenic acid which is broken down in the roasting process [3],[7]. The dominant sour taste is usually obtained in coffee with a light roast (low temperatures), in which the acidic compounds has not yet broken down further. Besides temperature and duration of roasting, the acidity of coffee is also influenced by the fermentation process, the type of plant, the growing environment and the brewing technique. Wet coffee processing has a more acidic taste due to the aliphatic acid residue obtained from the fermentation process [7]. Meanwhile, arabica coffee originating from a higher altitude farm have a higher degree of acidity than that of coffee grown in a lower altitude lands [11].

![Figure 1. Effect of temperature and length of roasting on the pH of espresso arabica coffee](image-url)
3.2. Sensory characteristics

Total cupping score of Gayo Arabica coffee roasted at 193 °C (light roast) ranged from 82.25 - 83.58 (average 82.91), while the one that roasted at 204 °C (medium roast) ranged from 82.75 - 85.08 (average 83.72), and those roasted at 213 °C (dark roast) ranged from 80.67 to 82.42 (average 81.53). The results of ANOVA showed that roasting temperature and roasting time had a very significant effect on the taste of Arabica coffee, while the interaction between the two factors had no significant effect.

The LSD test showed that coffee roasted at temperature of 213 °C (dark roast) gave the lowest total cupping score (81.53), which was significantly different from those roasted at 193 °C and 204 °C (i.e. 82.92 and 83.72). Figure 2 shows that coffee roasted at 204 °C gave a slightly higher cupping score (83.72) than that of coffee roasted at 193 °C (82.92), although it was not significantly different from the other. Roasting temperatures that slightly above 200 °C have an advantage, because they can trigger a further maillard reaction between monosaccharides and amino acids to form new flavors. At the same time there is also a caramelization reaction among monosaccharide compounds so that a sweet taste sensation appears at this roasting temperature and there is less acidity and less bitterness in coffee beans [12], [13].

In term of length of roasting, a 12 minutes roasting time gave the highest cupping score (83.69), which was significantly different from the other two roasting times (9 and 15 minutes). It means that a 12 minutes roasting time can provide the best taste and flavor. This finding is consistent with the [9] recommendation which suggests that roasting times should not be less than 8 minutes and no more than 12 minutes. If it is less than 8 minutes, it can cause an uncomfortable sour taste. Muzaifa and Hasni [14] reported that a typical gayo arabica coffee usually has a cupping score equal to or more than 80.

![Figure 2](image1.png)  **Figure 2.** Effect of roasting temperature on total cupping score of espresso arabica coffee (number followed by similar alphabet shows no significant difference).

![Figure 3](image2.png)  **Figure 3.** Effect of length of roasting total cupping score of espresso arabica coffee (number followed by similar alphabet shows no significant difference).

Influence of temperature and length of roasting on intensities of coffee taste and flavor are shown in Figure 4. Medium roast (at 204 °C) produces the best sensory attributes intensity (its value is closer to 8) compared to other two roasting temperatures. Moreover, coffee bean roasted for 12 minutes have the highest sensory attribute intensity, except for acidity attribute (which gave the highest acidity score when roasted at 193 C, and for 9 minute. This indicates that a too short roasting process can reduce the sensory quality of the bean, while a too long roasting process also can reduce the quality of the coffee. Sunarharum et al., [15] mentioned that degree and length of roasting are among factors influencing coffee quality.
Figure 4. Influence of roasting temperature (a) and roasting time (b) on intensities of coffee taste and flavor attributes (fragrance, flavor, after taste, acidity, body, balance, and overall).

The taste and flavor characteristics of Gayo Arabica espresso coffee roasted at different degrees and lengths, are presented in Table 1, which also illustrates the variation in the characteristics of the brew.

Table 1. Description of taste and flavour characteristics of espresso prepared from Gayo Arabica coffee.

| Sample | Taste and flavor characteristics |
|--------|----------------------------------|
| T1W1   | nutty, garden peas, short finish, fruity, citrusy, herby, greenish, corn like, tarty, high acid, bright nutty, corn, floral, sweet, spicy, toasty |
| T1W2   | soft nutty, palm sugar, floral, herby, spicy, grassy, vegetable, sweet, spicy, toasty, citrusy, nutty, greenish |
| T1W3   | garden peas, sugar cane, butternut, floral, fruity, nutty, sweet, grassy, metallic, tea like |
| T2W1   | nutty, sweet caramel, floral, long finish, citrusy, spicy, grassy, corn like, chocolaty, fruity, caramel, herby, acid, slightly smoky |
| T2W2   | palm sugar, long finish, potato like, sweet floral, caramel, chocolaty, nutty, spicy, floral, creamy, honey, sweet potato, fruity, spicy, herby, honey like |
| T2W3   | nutty, sweety caramel, floral, toasty, slightly smoky, spicy, dark chocolaty, metallic, smoky, ashy, burn, biscuit, toasty, dark caramel |
| T3W1   | soft, smoky, bitter, tarty, grassy, metallic, rubbery, strawy, ashy, tobacco |
| T3W2   | sweet creamy, floral, tea like, astringency, bitter, dark caramel, cook beef, smoky, low acidity, tobacco, ashy |
| T3W3   | sweet, herby, smoky, fruity, heavy body, bitter, ashy, metallic, burn, dark nutty, rubbery, tarty, tobacco |

Note: T = roasting temperature (T1= 193 °C; T2 = 204 °C; T3 = 213 °C).
W= roasting time (W1 = 9 minutes; W2 = 12 minutes; W3 = 15 minutes).

The distinctive and pleasant flavors that appear in coffee roasted at 193 °C (light roast) are nutty, floral, and sweet. The characters that appear at a medium roasting temperature (204 °C) are nutty, floral and spicy. Meanwhile, the bean roasted at 213 °C (dark roast) produces coffee brew with nutty, fruity, herby, floral, spicy and grassy characters.

In addition to the distinctive and pleasant taste characteristics appearing in the coffee brew, there are also flavor defects such as ashy, bitter, and rubbery at roasting temperature of 204 °C with 15 minutes.
roasting time, and at roasting temperature of 213 °C with all roasting time. This flavor defect usually appears because coffee beans have been exposed to fungi, fruit borer (berry borer), harvest of unripe cherry and unappropriated beans drying [7]. Based on table 1, it can be inferred that coffee bean roasted at 193 °C and 204 °C (with 12 minutes roasting time) can provide a distinctive and pleasant coffee aroma and taste. Meanwhile, roasting the bean at 213 °C could produce some flawed flavors in the coffee brew.

3.3. Hedonic test of espresso coffee
Hedonic test (aroma, acidity, body) was carried out on three samples with the best total cup score for each roasting level. The hedonic test results showed that the most favored aroma, acidity, and body of arabica espresso coffee by the panelists were the one roasted at 213 °C (dark roast) with 12 minutes roasting time. One of the most important step in coffee bean processing is roasting. The aroma compounds formed during this process are volatile organic compounds mainly originated from carbohydrate and lipid matrices. During brewing, the matrix will split and form aromatic compounds that evaporate into air so that they can be detected by human sensory [3]. Bhumiratna et al., [16] mentioned that fragrance and aroma are among the most important marks of the origin of a coffee.

The aroma of espresso coffee is formed during the roasting process starting at a temperature of 160 °C to 175 °C [7]. Meanwhile, the sensation of body attribute is influenced by fat, protein and complex hydrocarbons in coffee, which begin to appear in the medium-dark roasting process. A higher body sensation (thickness) begins to form at a roasting temperature of 210 °C (medium-dark roasting), which can trigger the release of lipid compounds from the cell walls of the coffee. The brewed coffee roasted at medium-dark temperatures has a higher body (thickness) than those roasted at light roasting temperatures [6], [7]. High intensity of body can provide a pleasant taste and flavor in the mouth and at the same time can describe the character of coffee originating from Sumatra [9].

Acidity is a taste that can provide a sensation of brightness if the brewed coffee served is delicious. On the other hand, acidity can also give a sour sensation if the coffee brew is not so tasty. The characters of espresso coffee which are pleasant, sweet and fresh fruit can only be felt if the coffee brew is in the best condition and extracted with a proper equipment [17]. Bad acidity taste in coffee brew is usually caused by too high or dominant level of acidity [9].

Based on the hedonic test, it can be concluded that consumers prefer espresso coffee with dark roast (213 °C) and 12 minutes roasting time, than those of light roast (193 °C) and medium roast (204 °C). Consumers favor espresso coffee that has a soft flavor, low acidity, but has a thick body. This finding differs from organoleptic/descriptive test results of the coffee brew described earlier. However, this might happen due to the habit of consumers who most likely often consume coffee brew prepared from the bean roasted at high temperatures (dark roast).

4. Conclusions
Roasting temperature and roasting time have a very significant effect on the flavor quality of espresso made from Gayo Arabica coffee. The interaction between temperature and roasting time had a very significant influence on the pH of arabica espresso coffee. The higher the temperature and the longer the roasting time, the higher the pH value of the coffee brew (the lower the degree of acidity). The best cupping score (85.08) was obtained from a coffee roasted at 204 °C (medium roast) with 12 minutes roasting time, which gave nutty, floral and spicy characters. Based on the hedonic test, the most preferred Gayo Arabica espresso coffee by consumers (in Aceh) is the one roasted at 213 °C (dark roast) with a 12 minutes roasting time, producing a nutty, fruity, herby, floral, spicy and grassy characters. Further research, should be aimed to investigate the effects of roasting degree on coffee espresso prepared from different variety of Gayo Arabica coffee.
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Acknowledgements

Authors and other researchers involved in this study are pleasurably acknowledge Ministry of Research and Higher Education under University of Syiah Kuala for supporting valuable facilities and funding this research (additional topics) through program Penelitian Unggulan Unsyiah, in 2017. The acknowledgements also go to member of Gayo Cupper Team, (Takengon, Aceh Province), for their beneficial support in performing the cupping test.