

ORIGINAL RESEARCH PAPER

**MULTI-SENSORY EVALUATION OF GAYO ARABICA COFFEE WITH
VARIOUS ROASTING TIMES DURING THE DEVELOPMENT PHASE**

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Received on 4 April 2025

Revised on 2 July 2025

Abstract

The coffee roasting technique consists of three phases, namely the Drying phase, Maillard phase, and Development phase. The Development phase plays an important role in achieving high quality coffee because at this stage the coffee beans begin to develop the desired taste. This research aims to evaluate multi-sensory Gayo Arabica coffee with various roasting times in the Development phase. The roasting process was carried out with the same time variation in the Drying phase and Maillard phase, namely 4:00 minutes each, while in the Development phase a different time variation was applied, namely 2:50 minutes (treatment A1); 3:50 minutes (treatment A2); 4:50 minutes (treatment A3). Research parameters included roasting charts that measured time in the Drying phase, Maillard phase, Development phase, total roasting time, roasting profile, determination of Agtron value, cupping test by Q Grader, and sensory quality testing by identified panelists using the Technique for Order of Preference method by Similarity to Ideal Solution (TOPSIS). TOPSIS is a decision-making method based on various alternatives that are ranked to get the best results with the highest value. The results of the research showed that the best time treatment in the development phase based on cupping scores respectively were treatment A1 which was ranked 1st (score of 85.00), treatment A2 was ranked 2nd (score of 82.00), and treatment A3 was ranked 3rd (score of 81.00). Meanwhile, the sensory assessment by identified panelists using the TOPSIS method showed almost the same results where treatment ranked 1st was occupied by treatment A1 with a value of 0.909. However, rank 2 was occupied by a different treatment, namely treatment A3 with a value of 0.427, and rank 3 was treatment A2 with a value of 0.260. Therefore, it can be concluded that the assessment by certified panelists and identified panelists, who can be considered representative of consumers, showed the same conclusion that coffee roasted with the best treatment in the development phase was 2:50 minutes (treatment A1).

Keywords: arabica coffee, development phase, roasting interval, TOPSIS, sensory.

Introduction

Gayo Arabica coffee is a type of superior coffee from Aceh which is famous for its distinctive taste (Fadhil *et al.*, 2021). One of the factors influencing the quality of coffee taste is the roasting process (Abubakar *et al.*, 2021; Fadhil *et al.*, 2023a). The process of roasting coffee beans has a close relationship with the multisensory experience of coffee which is ultimately enjoyed by the drinkers (Fadhil *et al.*, 2022; and Musika, 2017). The development and application of effective sensors is a key in efforts to improve quality and consumer satisfaction in the modern coffee industry. Coffee roasters use their sensory knowledge to regulate the roasting process, so that the coffee achieves the desired result, making it a balanced, sweet or more bitter taste (Fadhil *et al.*, 2023b). The texture and color of coffee beans are also influenced by proper roasting so that dry, crunchy and shiny dark brown beans can be produced. Finally, in the cupping process, coffee experts use their sensory sense to assess the brightness, clarity and characteristics of the crema in the resulting espresso brew, so that the sensory sense becomes an indicator of the quality of the roasting process. Therefore, roasting coffee beans is not only a technical process, but it is also an art utilizing human sensors to create a rich and multisensory satisfying coffee experience (Abubakar *et al.*, 2020; Yusibani *et al.*, 2023).

The roasting process consists of three phases, namely the Drying phase, Maillard phase, and Development phase. Each phase has an important role in developing the unique taste and aroma of coffee (Fadhil *et al.*, 2023a). The Drying Phase is the initial stage in the coffee roasting process. At this stage, green coffee beans containing 8-12% moisture are dried to evaporate the water. This process takes 4-8 minutes at a temperature of approximately 150 °C (302 °F). The goal is to ensure the coffee beans are evenly dry before entering the next stage of roasting. Next, the Maillard phase, which is key in the development of the coffee's brown color and distinctive aroma, lasts for 3-5 minutes at a temperature of 160-180 °C (320-356 °F). In this phase, Maillard reactions occur between amino acids and sugars which produce caramel, chocolate and nutty flavors, as well as complex aroma compounds that form the basis of the coffee flavor profile (Ezuan *et al.*, 2015; Fadri *et al.*, 2019; Fadhil *et al.*, 2023a).

The Development Phase, or first crack, is the final stage where coffee beans undergo significant physical and chemical changes. In this phase, the coffee beans begin to expand and make a cracking sound at 195-225°C (383-437°F), which signals the start of flavor development. This phase is very important because it determines the final flavor profile of the coffee. Setting the right temperature and time for each phase allows the coffee roaster to achieve the desired flavor profile, producing coffee with dark or light characteristics, as well as influencing the body and aftertaste of the coffee (Choo, 2019; Munchow *et al.*, 2020).

The use of the TOPSIS method in sensory evaluation provides a systematic and quantitative approach to evaluating products based on sensory criteria. According to Fadhil and Agustina, (2019); Mubarak *et al.*, (2021), this method is an alternative for making decisions based on sensory data, which in the end can improve product

quality and consumer satisfaction. The aim of this research is to evaluate multi-sensory Gayo Arabica coffee with various roasting times in the Development phase.

Materials and methods

Materials

This research was conducted at Aromabica Gayo Limited Liability Company and Post-Harvest Engineering Laboratory, Universitas Syiah Kuala. The primary equipment used in this study was a Super Roaster featuring a horizontal centrifuge batch roasting mechanism. The Coffee Roasting Machine, made in Indonesia, is designed for precise roasting of coffee beans with adjustable temperature control, suitable for medium to dark profiles. It has a 5 kg batch capacity, with a stainless-steel body, mild steel frame, and dynamo motor drives for both the drum and cooling system. Heating is provided by an LPG burner, regulated by a thermocontrol and solenoid system. A built-in cooling bin accelerates post-roast handling. Key features include a control panel, automatic ignition, sampling lever, inspection light, and customizable design. Roasting time is 7–10 minutes. Standard accessories include 2 blowers, a cast iron stove, a hose, a regulator, and a timer. Operating Principles of the Super Roaster Horizontal Centrifuge Batch Roasting Machine. The Super Roaster with a horizontal centrifuge batch system operates in discrete roasting cycles by combining conductive and convective heat transfer mechanisms. Green coffee beans are loaded into a horizontally oriented drum, which is typically preheated to approximately 170°C using either gas energy sources. During roasting, the drum rotates horizontally, generating centrifugal force that evenly distributes the beans along the inner drum walls. This ensures uniform heat exposure for each bean, promoting consistent roasting results. Heat is transferred through two primary modes: conduction, via direct contact between the beans and the heated drum surface, and convection, through hot air circulating within the roasting chamber. This dual heating method improves the uniformity and efficiency of the roasting process. The machine is equipped with programmable controls for temperature, drum rotation speed, and roasting duration, often including memory functions to store specific roasting profiles and maintain batch-to-batch consistency. After roasting, the beans are promptly transferred to a cooling tray featuring fans and agitators to rapidly halt the roasting process. This quick cooling preserves the desired flavour profile and prevents overdevelopment. Thanks to its precise control capabilities, uniform heat distribution, and ease of maintenance, the Super Roaster is ideally suited for professional roasteries, speciality coffee shops, and small-scale coffee processing operations that emphasize product quality and consistency.

To support precise control and analysis of the roasting process, Artisan an open-source software compatible with various roasting machines and sensors enables real-time monitoring and recording of key parameters, including bean temperature and rate of temperature change. It also allows for the storage of roasting profiles to maintain flavour consistency and facilitates detailed analysis of critical roasting stages. In addition to digital monitoring through Artisan, conventional instruments such as digital scales, stopwatches, glassware, spoons, measuring cups, and cameras

are utilized to ensure comprehensive and accurate control throughout the roasting procedure. The material used in this study consisted of 6 kg of Gayo Arabica coffee beans with a moisture content of 10.25%, processed using the full-wash method and sourced from Blang Gele Village, Bebesen District, Central Aceh Regency.

This research procedure comprised four sequential stages. The first stage involved the coffee roasting process. The second stage focused on determining the roasting profile using the Agtron scale. The third stage entailed cupping evaluation conducted by certified panellists (Q Graders) to assess the quality of the roasted beans. The final stage consisted of a sensory evaluation by identified panellists, employing the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) method to support decision-making based on three treatment iterations conducted during the development phase.

Roasting process

Roasting of Gayo Arabica coffee beans was conducted for each treatment batch, with 2 kg of green beans per batch. The initial step involved measuring the density of the beans before roasting. The roasting process was performed using a Super Roaster equipped with a horizontal centrifuge batch system, operated at an initial drum temperature of 170 °C and a gas pressure of 3 psi. Throughout the roasting process, Artisan software was employed to monitor and record temperature profiles and related parameters in real-time. A stopwatch was utilized to record the duration of each roasting phase, including the drying phase, Maillard phase, and development phase. Upon completion of the roasting process, a temperature curve was generated for each sample, illustrating the progression of temperature throughout the roasting cycle. The duration of the drying and Maillard phases was consistent across all treatments (A1, A2, and A3), each lasting 4 minutes. However, the development phase varied among treatments: 2 minutes and 50 seconds for treatment A1, 3 minutes and 50 seconds for treatment A2, and 4 minutes and 50 seconds for treatment A3 (Table 1).

Table 1. Time Treatment for Roasting Gayo Arabica Coffee Beans

Sample	Drying (W1)	Maillard (W2)	Development (W3)	Total roasting time
A1	4:00 minutes	4:00 minutes	2:50 minutes	10:50 Minutes
A2	4:00 minutes	4:00 minutes	3:50 minutes	11:50 Minutes
A3	4:00 minutes	4:00 minutes	4:50 minutes	12:50 Minutes

Roasting profile

Following the completion of the roasting process, the roasted coffee beans were evaluated using the Agtron scale to determine their respective roasting profiles. The Agtron scale served as a standardized reference for classifying roast levels, including light, light to medium, medium to dark, and dark profiles.

Cupping test

The cupping score was an assessment carried out by certified panelists (Q graders), namely a group of trained panelists who already have a license from the Specialty Coffee Association (SCA) requirements. In this research, the certified panelists were represented by the Gayo Cupper Team (GCT).

Sensory assessment

The sensory assessment was carried out by 9 identified panelists who had met certain criteria. According to Fadhil *et al.* (2021) and Fadhil *et al.* (2022), the criteria for identified panelists include: a) knowing the types of coffee, b) liking and frequently consuming Gayo Arabica coffee, c) being able to identify the taste of Arabica coffee Gayo, d) willing to be a panelist for the sensory assessment of Gayo Arabica coffee based on the principles of the study conducted, e) in good health, without coughing, canker sores, and the like. Sensory assessment included flavour, aroma, aftertaste, acidity, body and preference level using a scale of 1-5 as an assessment parameter. Scale 1 was the lowest level of preference and scale 5 was the highest level of preference.

TOPSIS method

Data obtained from sensory assessments were processed using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. TOPSIS ranks the available alternatives based on their relative closeness to the ideal solution. The resulting ranking serves as a decision-making preference in selecting the most optimal alternative (Muzakkir, 2017).

The TOPSIS method was selected because it is a widely used multi-criteria decision-making approach characterized by relatively simple mathematical computations. This method can be efficiently implemented with the assistance of computer software, enhancing its practicality and effectiveness. TOPSIS facilitates a compromise among multiple criteria, allowing suboptimal performance in one criterion to be compensated by superior outcomes in others. Consequently, this method has been extensively applied across various sectors as a reliable and effective tool for multi-criteria decision-making (Dandage *et al.*, 2018 and Mijalkovski *et al.*, 2024). The steps of the TOPSIS method to determine the ranking of alternatives in the sensory evaluation of Gayo Arabica coffee taste are as follows:

1. Building a decision matrix

The decision matrix X referred to m alternatives that will be evaluated based on n criteria. The decision matrix X was as follows:

$$X = \begin{matrix} & \begin{matrix} X_1 & X_2 & X_3 & \dots & X_n \end{matrix} \\ \begin{matrix} a_1 \\ a_2 \\ a_3 \\ \vdots \\ a_m \end{matrix} & \begin{matrix} X_{11} & X_{12} & X_{13} & \dots & X_{1n} \\ X_{21} & X_{22} & X_{23} & \dots & X_{2n} \\ X_{31} & X_{32} & X_{33} & \dots & X_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ X_{m1} & X_{m2} & X_{m3} & \dots & X_{mn} \end{matrix} \end{matrix}$$

2. Creating a normalized decision matrix

The equation used to transform each element x_{ij} was:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}} \quad (1)$$

3. Creating a weighted normalized decision matrix
With weights $w_j = (w_1, w_2, w_3, \dots, w_n)$, where w_j is the weight of the j th criterion and $\sum_{j=1}^n w_j = 1$, then the normalized weight matrix V was:

$$v_{ij} = w_j r_{ij} \quad (2)$$

4. Determining the positive ideal solution and negative ideal solution matrices
The positive ideal solution was denoted A^+ while the negative ideal solution was denoted A^- . The following are the equations of A^+ dan A^- :

$$\begin{aligned} a. A^+ &= \{ (\max v_{ij} | j \in J), (\min v_{ij} | j \in J'), i = 1, 2, 3, \dots, m \\ &= \{1^+, v2^+, v3^+, \dots, v_n^+ \} \end{aligned} \quad (3)$$

$$\begin{aligned} b. A^- &= \{ (\min v_{ij} | j \in J), (\max v_{ij} | j \in J'), i = 1, 2, 3, \dots, m \} \\ &= \{1^-, v2^-, v3^-, \dots, v_n^- \} \end{aligned} \quad (4)$$

5. Calculating Separation

- a. S^+ is the alternative distance from the positive ideal solution defined as:

$$s_i^+ = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^+)^2}, \text{ where } i = 1, 2, 3, \dots, m \quad (5)$$

- b. S^- is the alternative distance from the positive ideal solution defined as:

$$s_i^- = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^-)^2}, \text{ where } i = 1, 2, 3, \dots, m \quad (6)$$

6. Calculating the relative closeness to the positive ideal solution.

The relative closeness of each alternative to the positive ideal solution could be calculated with the following equation:

$$c_i^+ = \frac{s_i^-}{(s_i^- + s_i^+)}, 0 \leq c_i^+ \leq 1 \quad (7)$$

where $i = 1, 2, 3, \dots, m$

where c_i^+ was the relative closeness of the i^{th} alternative to the positive ideal solution, s_i^+ was the distance of the i^{th} alternative from the positive ideal solution and s_i^- was the distance of the i^{th} alternative from the negative ideal solution.

7. Ranking Alternatives.

Alternatives were ordered from the largest c_i^+ value to the smallest value. The alternative with the largest c_i^+ value was the best solution.

Results and discussion

This research employed Gayo Arabica coffee beans characterized by a moisture content of 10.25% and a bulk density of 750 g/L. The roasting process was initiated at approximately 170 °C for every 2 kg of coffee beans.

Roasting chart

The development phase starts after the first crack occurs and lasts until the roasting is complete (drop). First crack occurs when a popping sound is heard during roasting.

Coffee roasting graph generated from Artisan software Version 2.4.4 Windows. This application monitors and records temperature changes in coffee beans during the roasting process, providing visualization that allows roasters to understand and analyze the process better.

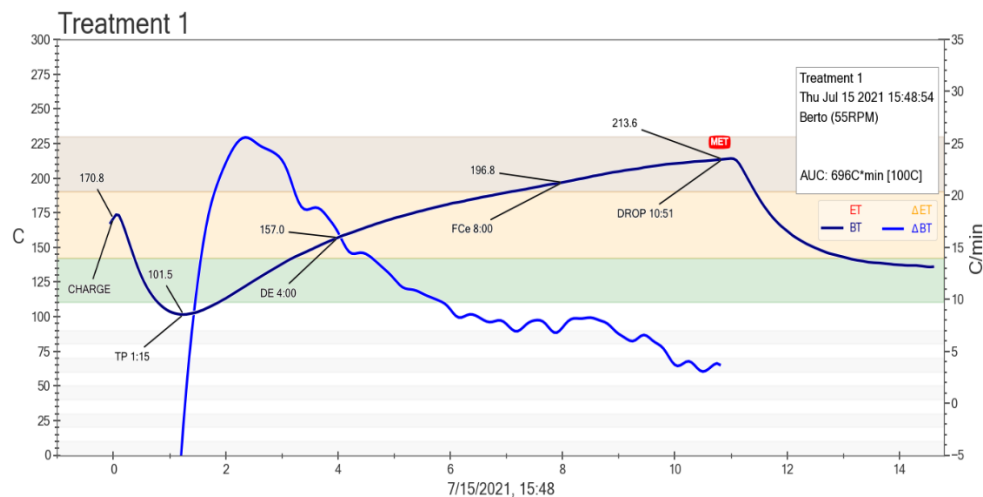


Figure 1. Roasting Chart of Coffee A1

The letter C on the right axis shows temperature, and C/min indicates its rate of change. The chart tracks Coffee A1's roasting, highlighting TP (shift to active roasting), DE (end of drying, rapid temperature rise), and FC (first crack signaling flavor development). ET is elapsed time since start, and BT is bean temperature during roasting. ΔET means Environmental Temperature (roaster drum temperature), and ΔBT means Bean Temperature during roasting. Both track roasting progress, shown in software like Artisan.

Figure 1 illustrates the temperature profile within the coffee roasting drum throughout the roasting process. The dark blue line represents the drum temperature from the initiation to the completion of roasting. The initial drum temperature was 170.8 °C, and the temperature at the turning point was recorded at 101.5 °C. Upon the introduction of green coffee beans into the drum, the temperature dropped to 69.3 °C due to the endothermic nature of the beans.

The drying phase lasted for approximately 4 minutes, during which the temperature rose to 157 °C and the coffee beans began to exhibit a yellow hue. At this stage, the Maillard reaction phase commenced and continued for another 4 minutes until the temperature reached 196.8 °C. This temperature marks the onset of the first crack and the beginning of the development phase. During roasting, coffee beans undergo both endothermic heating and subsequent exothermic reactions, particularly evident during the first crack, which is indicated by audible popping sounds.

The development phase lasted for 2.50 minutes following the first crack, culminating in a total roasting duration of 10.50 minutes with a final temperature of 213.6 °C, at which point the beans were discharged from the roasting drum.

The bright blue line in Figure 1 represents the Rate of Rise (RoR), which denotes the rate of temperature increase in the coffee beans per minute (ΔBT). Monitoring RoR is critical to achieving the targeted roasting profile, as it reflects the thermal momentum of the beans. To ensure consistent results, RoR should be observed at intervals of 30–60 seconds. During the roasting process, the heat source was maintained at a constant level with a gas pressure of 3 psi, indicating that the flame intensity remained unchanged from the charge temperature through to the drop. The observed temperature changes in the coffee beans were as follows: an increase of 24 °C from minute 1 to 3, 12 °C from minute 3 to 5, 7 °C from minute 5 to 7, and 4 °C from minute 9 to 10.50. These gradual changes reflect the controlled progression of heat transfer necessary for producing optimally roasted coffee.

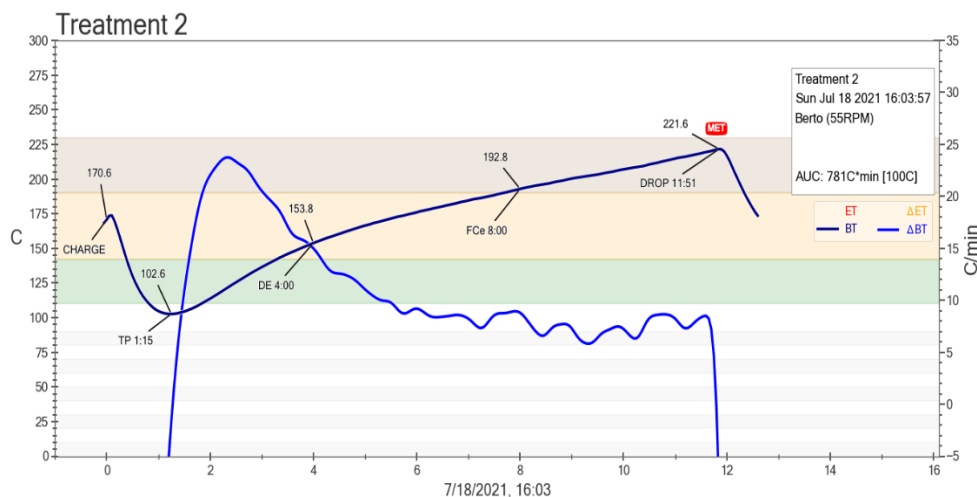


Figure 2. Roasting Chart of Coffee A2

The letter C on the right axis shows temperature, and C/min indicates its rate of change. The chart tracks Coffee A1's roasting, highlighting TP (shift to active roasting), DE (end of drying, rapid temperature rise), and FC (first crack signaling flavor development). ET is elapsed time since start, and BT is bean temperature during roasting. ΔET means Environmental Temperature (roaster drum temperature), and ΔBT means Bean Temperature during roasting. Both track roasting progress, shown in software like Artisan.

The initial temperature at the onset of the roasting process for coffee A2 was 170.6 °C, as shown in Figure 2. The turning point occurred at 1.15 minutes, marked by a temperature of 102.6 °C. This point signifies the lowest temperature after the beans were introduced into the roasting drum and the subsequent commencement of a temperature increase.

The first stage of roasting, known as the Drying phase, lasted for 4 minutes and reached a temperature of 153.8 °C. During this phase, the coffee beans began to turn yellow as a result of moisture loss. This was followed by the Maillard reaction phase, which extended for an additional 4 minutes and culminated at a temperature of 192.8 °C (First Crack entry, FCe). The Maillard phase is critical for the formation of key flavour and aroma compounds in coffee.

Subsequently, the Development phase began with the occurrence of the first crack, during which the beans underwent a series of exothermic reactions. For coffee A2, the Development phase lasted 3 minutes and 50 seconds. The beans were discharged from the roasting drum at 11 minutes and 50 seconds, with a final drop temperature of 221.6 °C. The light blue line in Figure 2 represents the rate of temperature increase in the coffee beans per minute (ΔBT), commonly referred to as the Rate of Rise (RoR). As with coffee A1, the roasting of coffee A2 was conducted using a constant heat source. The RoR provides a crucial indicator of thermal dynamics and must be carefully monitored to ensure optimal flavour development. During the roasting of coffee A2, the following temperature increases were observed in successive time intervals: 22 °C (minutes 1–2), 16 °C (minutes 2–4), 9 °C (minutes 4–6), 9 °C (minutes 6–8), 7 °C (minutes 8–10), and 8 °C (minutes 10–11.50). These values illustrate a relatively stable RoR throughout the process. However, curve analysis of the RoR revealed notable irregularities between minutes 10 and 11.50. During this interval, the rate of temperature increase was more pronounced compared to the preceding segment (minutes 8–10), suggesting fluctuations in temperature regulation in the final phase of roasting. Such fluctuations can impact the consistency and sensory quality of the final product.

In general, a stable and controlled RoR is indicative of effective thermal management throughout the roasting process. This is essential for achieving uniform development of coffee flavour compounds, ultimately influencing the aroma, taste, and overall cup profile. Precise control from the beginning to the end of roasting ensures optimal and consistent outcomes, aligning with the desired characteristics specified by the roaster.

The letter C on the right axis shows temperature, and C/min indicates its rate of change. The chart tracks Coffee A1's roasting, highlighting TP (shift to active roasting), DE (end of drying, rapid temperature rise), and FC (first crack signaling flavor development). ET is elapsed time since start, and BT is bean temperature during roasting. ΔET means Environmental Temperature (roaster drum temperature), and ΔBT means Bean Temperature during roasting. Both track roasting progress, shown in software like Artisan.

Figure 3 shows that the dark blue curve (BT) represents the initial bean temperature of 176.1 °C. At 1.21 minutes, a turning point (TP) occurred at 100.6 °C, revealing the moment when the coffee beans were introduced into the roaster. The Drying phase began at this turning point and lasted for approximately 4 minutes, during which moisture content in the beans was reduced. Following this, the temperature increased to 153.3 °C (DE). Completion of the Drying phase was revealed by the beans turning yellow. Subsequently, the Maillard phase commenced, lasting 4

minutes and reaching a temperature of 193.1 °C (FCe), concurrent with the first crack event. During the Development phase, the beans were roasted for 4.5 minutes until reaching a final temperature of 219.2 °C (DROP).

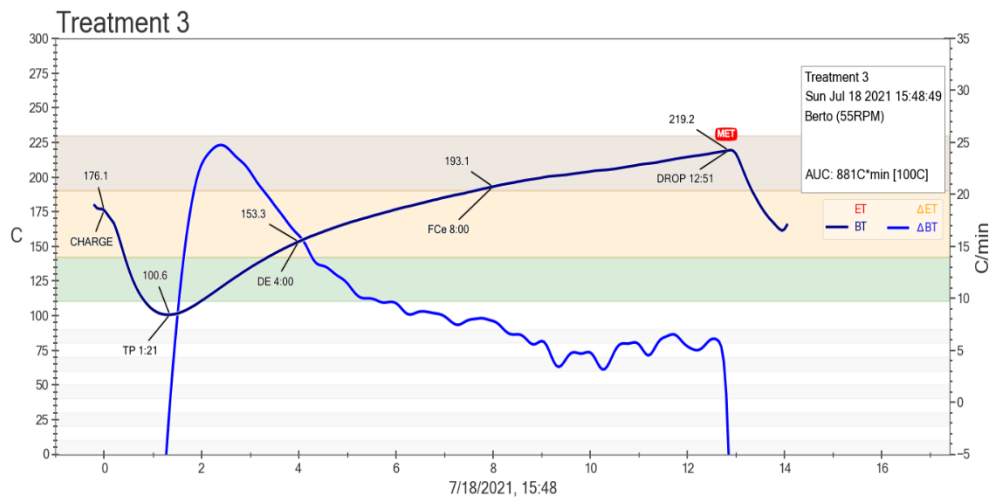


Figure 3. Roasting Chart of Coffee A3

The light blue line reveals the minute-by-minute changes in bean temperature (ΔBT) throughout the roasting process. The roasting of coffee beans in treatment A3 applied constant heat similarly to treatments A1 and A2. The ΔBT curve reveals the Rate of Rise (RoR), with values of 23 °C/min between minutes 1–2, 16 °C/min between 2–4, 10 °C/min between 4–6, 8 °C/min between 6–8, and 5 °C/min between 8–10 and 10–12.5 minutes.

The Development phase begins after the first crack, which occurs at approximately 190 °C. Development time is a critical parameter to control roasting outcomes, set at 2:50 minutes for A1, 3:50 minutes for A2, and 4:50 minutes for A3. This phase continues until the end of roasting (DROP). The first crack is revealed by an audible popping sound during roasting.

The roasting curves were generated using Artisan software (Version 2.4.4, Windows), which reveals temperature changes in coffee beans throughout roasting. This visualization tool enables roasters to better understand and analyze the process. Precise control of roasting parameters allows for achieving desired flavour profiles and quality standards in coffee.

A decreasing RoR (Rate of Rise) curve is an indicator of good roasting quality, where the coffee beans heat up quickly at first and then more slowly over time. This aligns with the findings of Lancashire (2020) and Freitas *et al.* (2024), who state that analyzing a decreasing RoR curve signifies that the coffee roasting process has been properly executed. Initially, the beans experience rapid heating, which gradually slows down as time progresses. This controlled process ensures that the temperature

within the roasting drum is effectively managed to achieve the desired results. Maintaining consistent temperature stability throughout the roasting process, as reflected by a gradual decrease in the RoR curve, is a key indicator of optimal roast quality.

The Development Phase was calculated from the beginning of the first crack to the end of roasting. According to Choo (2019), the Development phase is key in determining the level of coffee roast, such as light, medium or dark roast.

The approach in this research differentiates the Development phase from the general method of roasting coffee beans, where usually the determination of this phase depends on changes in bean color to achieve the desired coffee profile. However, in this research, the Development phase was determined based on the time interval after the first crack occurred. The aim was to evaluate the roasting profile and sensory characteristics of the coffee produced. Apart from that, the distinctive aroma of coffee is greatly influenced by the temperature profile and duration used during the roasting process. This is in accordance with the explanation Gloess *et al.* (2014); Bertone *et al.* (2016); Kim *et al.* (2018); and Alamri *et al.* (2022), stating that the approach to the Development phase in the coffee bean roasting process is emphasized based on the time determined after the first crack occurs. This approach differs from common approaches that rely on visual changes in the color of the coffee beans to achieve the desired roast profile.

Calculating the Agtron Scale of Coffee Beans

The score of agtron on different colour from A1 coffee, A2 coffee and A3 coffee can be seen below.



Figure 4. Agtron Scale Values for the Grounds of A1 Coffee, A2 Coffee and A3 Coffee

Samin *et al.* (2018) found that the Agtron scale is measured manually by an expert and experienced Q-Grader to match the final roasting result with the color of Gayo Arabica coffee powder. The Agtron scale is used to determine the color of coffee beans after roasting. The smaller the number, the darker the color of the coffee beans. According to Choo (2019), scale #55 includes the Medium roast category, scale #45 includes Moderately Dark, and scale #35 includes Dark. The longer the roasting time, the smaller the Agtron value. This indicates that the color of the coffee is

getting darker and has a special flavor profile. Yang *et al.* (2016); Rabbani *et al.* (2021) stated that the smaller the Agtron number, the darker the roasted coffee beans. Nanda *et al.* (2018); Alstrup *et al.* (2020) also added that the Development phase really determines the final taste of the coffee which can be seen from the change in color of the coffee beans during roasting. This color change is used to monitor and stop the roasting process (Schenker *et al.*, 2017).

Cupping score assessment test

The cupping test was carried out by 2 Q-Graders from the Gayo Cuppers Team based on 11 assessment attributes on 3 samples with different roasting times in the Development phase (Table 2). Trained cuppers can identify and understand the sensory aspects that determine coffee quality. Sample A1 was ranked first with a score of 85.00, while coffee sample A2 received a score of 82.00 so it was ranked second, and sample A3 (81.00) was ranked last. The final score was the sum of all attributes assessed by the cupper that represented the overall quality of the coffee.

Table 2. Cupping Results on 3 Samples by Q-Grader

Coffee A1		Coffee A2		Coffee A3	
Attribute	Score	Attribute	Score	Attribute	Score
Aroma	8.00	Aroma	7.75	Aroma	7.50
Flavor	8.00	Flavor	7.50	Flavor	7.50
After Taste	7.75	After Taste	7.25	After Taste	7.00
Acidity	7.75	Acidity	7.25	Acidity	7.25
Body	8.00	Body	7.25	Body	7.50
Balance	7.50	Balance	7.25	Balance	7.00
Uniformity	10.00	Uniformity	10.00	Uniformity	10.00
Clean Cup	10.00	Clean Cup	10.00	Clean Cup	10.00
Sweetness	10.00	Sweetness	10.00	Sweetness	10.00
Overall	8.00	Overall	7.25	Overall	7.25
Final Score	85.00	Final Score	82.00	Final Score	81.00

Evaluation of the quality and characteristics of coffee was carried out through a cupping test. This test is effective for distinguishing the characteristics of different coffees (Yulia, 2018). According to the SCAA protocol (2018), the cupping test is carried out for three purposes, namely: determining sensory differences between samples, describing the taste of the samples, and determining product preferences. The cupping test is important to ensure the quality of the coffee before the coffee is

distributed. The quality of coffee assessed through the cupping test is an international standard recommended by the Specialty Coffee Association of America (SCAA).

Table 2 shows slight differences in each attribute of the coffee samples. These results were affected by treatment in the Development phase during roasting. This treatment has a significant impact on the sensory output. According to Masi *et al.* (2015); Cheng *et al.* (2016); Toledo *et al.* (2016); Giacalone *et al.* (2019); Dong *et al.* (2019); Febrianto *et al.* (2023), differences in each coffee attribute are caused by variations in treatment in the development phase during coffee bean roasting. This phase is very important because it affects the aroma, flavor, aftertaste, acidity and body of the coffee. Even though the differences are small, different treatments can result in changes to the taste of the coffee. Variations in temperature, duration, and roasting method affect how the chemical compounds in coffee beans develop, thus influencing the quality and flavor characteristics of the final coffee.

Respondent data processing

Coffee sensory testing was carried out based on 5 attributes, namely: aroma (C1), flavor (C2), aftertaste (C3), acidity (C4), and body (C5). Testing these attributes produced data from coffee samples A1, A2, and A3 which were averaged for each criterion (Table 3). Next, the data were normalized (Table 4) and converted into weighted normalized values using the TOPSIS formula (Table 5). These weighted normalization values were used to calculate the distance between positive and negative ideal solutions (Table 6). These distances determined the best alternative where the lowest distance from the positive ideal solution and the highest distance from the negative ideal solution showed the relative closeness of the three coffee alternatives (Table 7 and Table 8).

Table 3. Alternative Criteria Data

Code	Criteria	Attribute	Weight
C1	Aroma	Benefit	25
C2	Flavor	Benefit	32
C3	After Taste	Benefit	16
C4	Acidity	Benefit	13
C5	Body	Benefit	14

Table 8 shows that the preference value for A1 treatment was ranked first, namely 0.909. The second rank was obtained by A3 treatment, namely 0.427. A2 Treatment was ranked third with a value of 0.260. These results were in line with the cupping test by experts (Q Grader) who gave coffee A1 the first rank (85.00), coffee A2 the second rank (82.00), and coffee A3 the third rank (81.00).

Table 4. Results of Data Analysis Obtained by Respondents

Alternative	C1	C2	C3	C4	C5
Coffee A1	4.33	4.00	3.78	3.67	4.11
Coffee A2	3.89	3.67	3.33	3.22	3.44
Coffee A3	4.44	3.44	3.44	3.67	3.78

Table 5. Normalized Decision Values

Alternative	C1	C2	C3	C4	C5
Coffee A1	0.5914627	0.622403	0.6196646	0.600863	0.626666
Coffee A2	0.5313603	0.571055	0.5458950	0.527188	0.524509
Coffee A3	0.6064883	0.535267	0.5639276	0.600863	0.576350

Table 6. Weighted Normalized Values

Criteria	C1	C2	C3	C4	C5
Weight	25	32	16	13	14
Coffee A1	14.786568	19.9169	9.9146342	7.811221	8.773329
Coffee A2	13.284007	18.27376	8.7343206	6.853442	7.343127
Coffee A3	15.162208	17.12854	9.0228417	7.811221	8.068902
Max	15.162208	19.91690	9.9146342	7.811221	8.773329
Min	13.284007	17.12854	8.7343206	6.853442	7.343127

Table 7. Distance Values for Positive and Negative Ideal Solutions

Alternative	Positive	Negative
Coffee A1	0.375640	3.793236
Coffee A2	3.253233	1.145222
Coffee A3	3.011063	2.248327

Table 8. Preference Values for Relative Closeness of Positive Ideal Solutions

Alternative	Positive	Negative	Preference	Ranking
Coffee A1	0.375	3.793	0.909	1
Coffee A2	3.253	1.145	0.260	3
Coffee A3	3.011	2.248	0.427	2

Coffee A1 was rated the most preferred by the panelists based on 5 assessment criteria. Both groups, namely Q Graders and identified panelists, assessed coffee based on the same five attributes, namely: aroma, flavor, aftertaste, acidity, and body. Even though they used the same criteria, their assessment results could be different. This difference was caused by various factors, especially differences in perspective and experience in evaluating coffee characteristics.

According to Chamber *et al.* (2016); Zavadskas *et al.* (2016); Fadhil *et al.* (2023c), Q Grader is an expert who has certification in assessing coffee professionally. They have in-depth knowledge of various aspects of coffee and are trained to recognize and assess coffee quality to a high standard. Their assessments tend to be objective and based on very specific parameters. On the other hand, identified panelists consisting of consumers or coffee lovers have different experiences and preferences. Although they also rate aroma, flavor, aftertaste, acidity, and body, their ratings may be more subjective and influenced by personal taste. They may focus more on personal preferences than high industry standards. Consequently, these differences in perspective may result in variations in final judgments between the two groups. Q Graders may provide more technical and detailed assessments, while identified panelists provide ratings based on their taste preferences.

Conclusions

Based on the research findings, it can be concluded that roasting Gayo Arabica coffee beans with a Development phase duration of 2 minutes and 50 seconds and a total roasting time of 10 minutes and 50 seconds yielded the best sensory quality in sample A1. This was evidenced by the highest cupping score (85.00) and the highest sensory preference value (0.909) compared to the other samples. These findings indicate that the Development phase duration plays a crucial role in determining the flavor characteristics and overall profile of the coffee. Therefore, these parameters can be recommended as a reference for roasting Gayo Arabica coffee beans to achieve optimal product quality.

Acknowledgments

The authors appreciate the Ministry of Education, Culture, Research, and Technology of Indonesia, Directorate of Research and Community Service (DRTPM-DIKTI), Research and Community Service Institution (LPPM)

Universitas Syiah Kuala for supporting Fundamental Research Grant Scheme (FRGS) 2024 with the contract number: 094/E5/PG.02.00.PL/2024. To our beloved mother, father, wife/husband, and big family may Allah subhaanahu wata'aala always gather us together in goodness and reunite us in His Jannah (heaven) later. O Allah, let our love, and the love of people who love each other because of You, be eternally in Your way.

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