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# Roasting variations and brewing methods in the preparation of clear Coffee Beverages from Gayo Arabica Coffee

Ismail Sulaiman[1], Marsyanda[1], Cut Erika[1]

[1]Universitas Syiah Kuala (USK), Department of Agricultural Product Technology, Indonesia
Contact authors: Ismail.sulaiman@usk.ac.id; marsyandaunggul@gmail.com; cut.erika@usk.ac.id
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## ABSTRACT

Coffee beverages are popular worldwide, and they typically contain caffeine. This research, however, focuses on the creation of low caffeine content and clear coffee, so that individuals with caffeine sensitivities can savor it. The resultant coffee product is a colorless, clear coffee. While the coffee production process initially yields a dark-colored drink, it can be transformed into a transparent beverage via distillation and chemical methods. This study aims to investigate the process of producing clear coffee by varying roasting and brewing methods, employing various techniques to achieve a colorless coffee with low caffeine content. The preparation of clear coffee beverages involves the brewing of espresso and Tobruk, followed by an analysis of pH, caffeine levels, and color attributes in the resulting clear coffee. Based on ranking tests conducted for each parameter in clear coffee beverages, the most favorable approach involves using the distillation method, espresso brewing, and medium roasting. The analysis of this chosen formulation yields a transparent beverage with a pH of 3.5 and caffeine levels measuring 4.639 mg/mL.

**Key words:** Coffee; Clear coffee; Destination; Chemical reaction; Caffeine.

## 1 INTRODUCTION

Coffee (*Coffea* sp.) is one of Indonesia's foremost agricultural commodities with significant economic value (Siagian, 2020). Data from the Central Statistics Agency (BPS) reveals an 12.92% increase in Indonesian coffee exports in 2022 compared to 2023. In 2023, the export value of Indonesian coffee reached USD 1.13 billion, with an export volume of 434.198 thousand tons (BPS, 2023). In the preceding year, 2020, Indonesia recorded coffee exports worth USD 990.19 million and an export volume of 375.60 thousand tons (BPS, 2021). Moreover, the distinctive flavor of coffee has been endeared by many people, making it a promising avenue for development. Indonesia predominantly cultivates three coffee varieties: arabica (*Coffea arabica*), robusta (*Coffea canephora*), and liberica (*Coffee liberica*) (Abdullah, 2019). Among these, arabica and robusta are the most consumed globally, with arabica accounting for 70% of total coffee consumption and robusta making up the remaining 30% (Dairobbi et al., 2018).

Indonesia, particularly Aceh Province, is renowned for its production of Arabica coffee, notably Gayo Arabica coffee. Arabica coffee is classified as a specialty coffee due to its distinct sweet, slightly sour, and bitter notes. In addition, it has a strong aroma, reminiscent of fruits and spices (Meisetyani et al., 2021). Evaluated by the Specialty *Coffee Association of America*, Gayo Arabica coffee is categorized as a complex, robust-bodied coffee, rendering it a high-quality coffee cherished by coffee connoisseurs and the global coffee market (Fadhil et al., 2017).

In Indonesia, coffee consumption has become an integral part of daily life. This is evident in the proliferation of coffee shops, ranging from small roadside vendors to large cafes. Coffee consumption has evolved into a longstanding tradition, passed down through generations (Satyajaya et al., 2014). Over the last 5 years, coffee consumption in Indonesia has increased by 5.63%, going from 4,550 sacks (equivalent to 273,000 tons) in 2015 to 4,806 sacks (equivalent to 288,360 tons) in 2019. Coffee beverages have transcended being mere accompaniments, emerging as prominent choices (Saputera, 2021).

The era of globalization has encouraged innovation in various industries, including the coffee industry. Despite its popularity, the range of coffee products has traditionally been limited to brewed coffee, coffee powder, and instant coffee. However, one innovative product gaining traction is clear coffee. Clear coffee is a colorless coffee beverage that retains the aroma, flavor, and freshness of traditional coffee (Hanna, 2017). This concept was introduced by David Nagy and his brother Adam Nagy from Slovakia with the intention of allowing people to enjoy coffee without worrying about teeth discoloration (Wardhana; Irwan, 2020b).

The process of preparing clear coffee involves clarification, which entails the removal of particles, sediment, oils, natural organic matter, and water color to achieve a clear appearance (Kawakatsu et al., 2014). There are four primary methods for producing clear coffee: distillation, centrifugation, sedimentation, and chemical treatment. A review of the literature suggests that distillation and chemical methods are the most effective in producing clear coffee, whereas the others may be feasible but often do not yield optimal clarity.

According to the research conducted by Wardhana and Irwan (2020a), clear coffee is typically prepared using the distillation method, involving two key factors: the degree of roasting (light, medium, dark) and the quantity of spring water used (50, 100, and 150 mL). Their study revealed that the best formulation resulted from coffee roasted at 195°C (medium) and a ground coffee to spring water ratio of 10:50 (g/mL). This formulation yielded coffee with the highest ratings for taste, color, and aroma, while also having a lower caffeine content.

On the other hand, the chemical coffee-making process involves the combination of coffee, milk, and lemon, followed by filtration using a filter paper (Yuliandri, 2022). In a previous study, the coffee mixture consisted of 60 g of coffee powder, 600 mL of water, 20 mL of lemon juice, and 50 mL of milk. The results demonstrated that the coffee changed color, resulting in a thinner appearance, similar to that of clear tea water.

## 2 MATERIAL AND METHODS

The tools used in this research included a Wiliam Edison brand roasting machine (model: W3100 IR), an espresso machine, a TA417D grinder, a V60 brewing kit, distillation apparatus, a pH meter, digital scales, measuring cups, containers, measuring flasks, refrigerators, cuvettes, a Shimadzu UV-Vis spectrophotometer (model: UV-1900i), digital scales, color analysis tools, paper filters, glasses, and sensory test assessment forms.

The materials used in this study comprised Gayo Arabica coffee beans grown at an altitude ranging from 1,000–1,400 m above sea level (masl). These beans were roasted to medium (211°C for 11.30 min) and dark (223°C for 12.30 min) levels and ground to different consistencies (coarse -15 and fine - 5). Additionally, hot water at 98°C, fresh milk, lemon fruit from Banda Aceh, Indonesia, unsalted crackers, water, calcium carbonate, and chloroform were employed.

A randomized group design experimental setup was adopted, comprising three factors: Method (M), Brewing (B), and Roasting (R). Method (M) consisted of two levels: chemical (M1) and distillation (M2). Brewing (B) had two levels: espresso (B1) and Tobruk (B2), whereas Roasting (R) had two levels: medium (R1) and dark (R2). This design resulted in eight treatment combinations, each replicated three times, yielding a total of 24 experimental units.

### 2.1 Procedure

#### 2.1.1 Preparation of Clear Coffee Beverage with the Distillation Method using Espresso Brewing

A total of 16.5 g of finely ground Gayo Arabica coffee bean powder (grind number 5) was placed in a filter port, tamped using a tamper, and positioned in the filter port on the machine (Presso skirt). Subsequently, 85 °C hot water was introduced from the top. The process involved gently pulling both levers upward and then pressing down in a balanced motion (Syarifuddin; Yusriyani, 2022). The brewed coffee was then subjected to distillation for 1 h.

#### 2.1.2 Preparation of Clear Coffee Beverage using the Distillation Method with Tobruk Brewing

For this method, 8.25 g of coffee were combined with 150 mL of 93°C water. The brewed coffee was then distilled for 1 h.

#### 2.1.3 Preparation of Clear Coffee Beverage using the Chemical Method with Espresso Brewing

A total of 16.5 g of finely ground Gayo Arabica coffee bean powder (grind number 5) was placed in a filter port, tamped using a tamper, and positioned in the group head of the machine (Presso skirt). Hot water at 85 °C was added from the top, and both levers were gradually pulled upward and pressed down in one balanced movement. Subsequently, 210 mL of water, 20 mL of lemon, and 160 mL of milk were added (Marsyanda et al., 2022). After sedimentation and coagulation occurred in the liquid, it was filtered using a filter paper.

#### 2.1.4 Preparation of Clear Coffee Beverage using the Chemical Method with Tobruk Brewing

In this method, 8.25 g of coffee were mixed with 150 mL of 93 °C hot water. To the brewed coffee, 70 mL of milk and 10 mL of lemon were added. After sedimentation and coagulation took place in the liquid, it was filtered using a filter paper (Specialty Coffee Association of America - SCAA, 2015; Sulaiman et al., 2022).

### 2.2 Parameter observation

Following the preparation of clear coffee drinks through distillation and chemical methods, several parameters, including pH acidity, caffeine content, and color analysis, were observed and analyzed (Farida et al., 2013; Riyanti et al., 2020; Hartuti et al., 2019). Descriptive tests were conducted to evaluate the sensory attributes of the coffee, such as flavor, acidity, aftertaste, and sweetness, using a method adapted from Kinasih et al. (2021). Ratings were given on a scale ranging from 1–5, as outlined in Table 1.

### 2.3 Statistical Analysis

The obtained data were analyzed using analysis of variance (ANOVA). If there was a significant effect between treatments ($\alpha < 0.05$), then Duncan's multiple range test (DMRT) was used.

## 3 RESULTS

### 3.1 Acidity Level (pH)

The research revealed a pH range of 3.40–4.46, with an average pH value of 4.00. The ANOVA results indicated a highly significant effect ($p \leq 0.1$) of the clear coffee preparation method on the pH levels, as depicted in Figure 1.

### 3.2 Caffeine Content

This research involved several stages, including creating a standard curve with a specific concentration at a wavelength of 274 nm using a UV-VIS spectrophotometer. The standard curve equation obtained was $y = 2.4222x - 0.0507$ with an R2 value of 0.9874 with 86% accuracy. This value was compared with literature data (Sulaiman, 2023), which reports the maximum caffeine wavelength as 272–276 nm. The caffeine value obtained was 272.5, with an absorbance of 0.193. The caffeine standard curve is presented in Figure 2.

The standard curve results, generated with various concentrations dissolved in distilled water, provided concentration and absorbance values that align with the linear equation. This calibration curve serves as a basis for determining caffeine concentration (x) in the sample with a clear measurement of absorbance (y) (Figure 3).

**Table 1:** Descriptive test rating scale.

| Scale | Clarity | Color | Aroma | Coffee Flavor | *Acidity* | *Aftertaste* |
|---|---|---|---|---|---|---|
| 1 | Very turbid | Dark | Very weak | Very weak | Very not acidic | Very weak |
| 2 | Turbid | Brown | Weak | Weak | Not acidic | Weak |
| 3 | Somewhat turbid | Tea color | Neutral | Neutral | Moderately acidic | Neutral |
| 4 | Clear | Clear tea color | Strong | Strong | Acid | Strong |
| 5 | Very clear | Clear | Very strong | Very strong | Very acidic | Very strong |

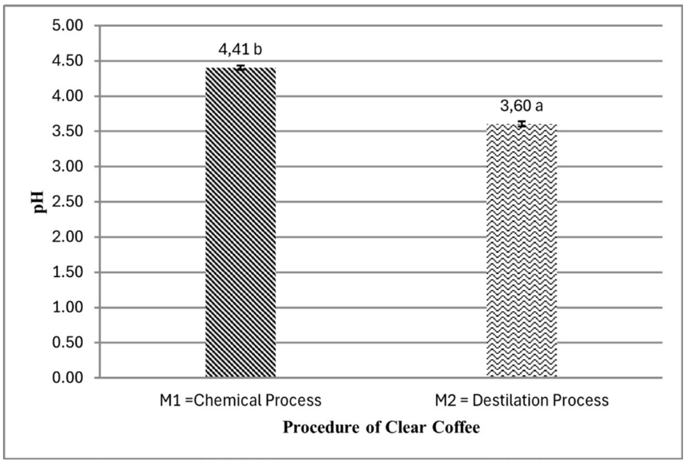


**Figure 1:** Effect of clear coffee preparation on the pH of clear coffee beverages in DMRT0.05 test (values followed by different letters indicate significant differences).

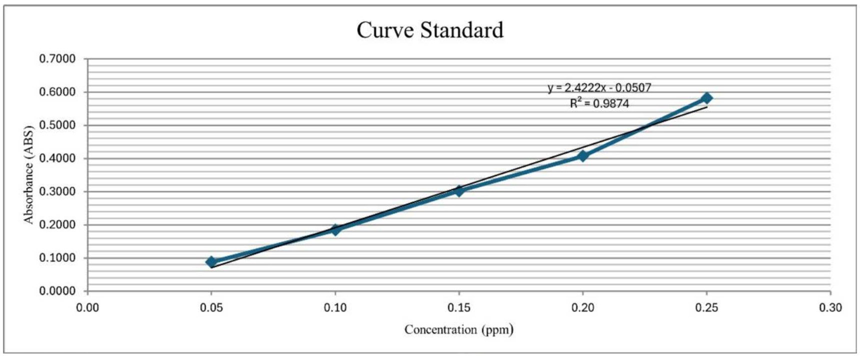


**Figure 2:** Standard curve of caffeine.

Caffeine levels in the chemical method for each sample were 0.052 mg/mL, 0.052 mg/mL, 0.051 mg/mL, and 0.054 mg/mL, respectively. In the distillation method, the caffeine levels of each sample were 0.046 mg/mL, 0.047 mg/mL, 0.048 mg/mL, and 0.049 mg/mL, respectively.

### 3.3 Color Analysis

Color testing was conducted on espresso and Tobruk coffee brews, as well as clear coffee beverages using the chemical method. No color testing was performed on the distillation method. The analysis of L*, a*, and b* values is presented in Table 2. The L* value represents the reflected light that creates achromatic colors, including white, gray, and black. The L* value for brewed Tobruk and espresso was 0.0, whereas the L* value for clear coffee prepared using the chemical method ranged from 38.57–59.77, with an average of 50.66.

### 3.4 Optimal Treatment Selection

The determination of the best sample in this study was based on the assessment of caffeine and pH levels in clear coffee beverages, as summarized in Table 3.

## 4 DISCUSSION

### 4.1 Acidity Levels (pH)

Different coffee varieties contain various types of acids that influence the acidity, aroma, and flavor of the coffee product. Coffee beans contain carboxylic acids such as acetic acid, formic acid, lactic acid, malic acid, pyruvic acid, quinic acid, and citric acid (Panggabean, 2011). Figure 1 illustrates that M1, employing the chemical method, yields significantly different results from M2, which uses the distillation method. M1 exhibits a higher pH value of 4.41 compared to M2, which has a pH value of 3.60. Clear coffee produced through the distillation method has a lower pH than the chemical method. This discrepancy arises because the distillation method produces clear coffee without the addition of other ingredients. In contrast, the chemical method involves additional ingredients, including milk, which can increase its pH. According to Basheer et al. (2022), different coffee types with varying additives can alter the pH of a solution. Among the beverages tested, black coffee added with added milk was the least acidic. The addition of milk to black coffee increases its pH.

### 4.2 Caffeine Content

The results of the study are summarized in Table 4. It is evident that coffee brewed through the distillation method contains lower caffeine content compared to the chemical method or the control group without treatment. This can be attributed to the distillation process, which involves heating the liquid to the vapor phase and then condensing it back into a liquid state. In the context of coffee beverages, distillation tends to produce beverages with reduced caffeine levels because caffeine has a higher boiling point than many other components in coffee. The boiling point of caffeine found in coffee beans is approximately 178–180°C (352–356°F) at standard atmospheric pressure (1 atm or 101.3 kPa).

Caffeine possesses a relatively high boiling point when compared to other constituents of coffee and water. During the distillation process, as coffee is heated, components with lower boiling points tend to evaporate earlier than caffeine. Since caffeine has a higher boiling point, it remains in the liquid phase and does not evaporate. When the vapor is condensed back into a liquid, components with lower boiling points are present in the resulting vapor, whereas caffeine, with its higher boiling point, remains in the liquid. Consequently, coffee beverages

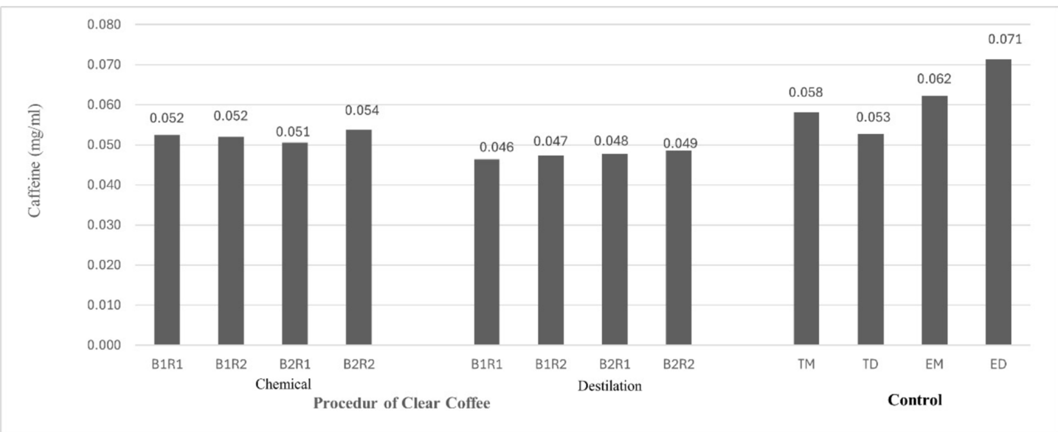


**Figure 3:** Caffeine content (mg/mL) in the sample and control.

subjected to the distillation process exhibit lower caffeine levels. This observation aligns with the research published by Wardhana and Irwan (2020b) and Sulaiman et al. (2022) on the production of clear coffee via the distillation method. In this study, variations in the formulation ratio between ground coffee and spring water were investigated, with a ratio of 10:50 (g/mL), resulting in coffee beverages with low caffeine content.

**Table 2:** L* (brightness), a* (redness), and b* (yellowness) values of brewed coffee and chemically clear coffee drinks.

| Metode (M) | Brewing (B) | Roasting (R) | L* | a* | b* | Color |
|---|---|---|---|---|---|---|
| Kimiawi (M1) | *Espresso* (B1) | Medium (R1) | 47.23 | 20,47 | 40.20 | |
| | | Dark (R2) | 38.57 | 29.10 | 38.40 | |
| | Tobruk (B2) | Medium (R1) | 59.77 | 10.60 | 62.50 | |
| | | Dark (R2) | 57.07 | 14.93 | 59.93 | |
| Brewing | | *Espresso* | 0 | 1.30 | 0 | |
| | | Tobruk | 0 | 4.10 | 0.90 | |

The a* value, indicative of red-green color levels, for clear coffee beverages produced via the chemical method ranged from 10.60 to 29.10, with an average of 18.78.

The b* value, representing the yellow to blue color range, for clear coffee beverages prepared using the chemical method ranged from 38.40 to 62.50, with an average of 50.25.

**Table 3:** Optimal treatment slection.

| Sample | Caffeine | | pH | | Total | Rank |
|---|---|---|---|---|---|---|
| | Average | Value | Average | Value | | |
| Espresso Medium - Chemical | 0.52 | 6 | 4.40 | 7 | 13 | 6 |
| Espresso Dark - Chemical | 0.52 | 6 | 4.47 | 8 | 14 | 7 |
| Tobruk Medium - Chemical | 0.51 | 5 | 4.37 | 5 | 10 | 5 |
| Tobruk Dark - Chemical | 0.54 | 8 | 4.38 | 6 | 14 | 7 |
| Espresso – Medium Distillation | 0.46 | 1 | 3.52 | 1 | 2 | 1 |
| Espresso – Dark Distillation | 0.47 | 2 | 3.60 | 2 | 4 | 2 |
| Tobruk – Medium Distillation | 0.48 | 3 | 3.66 | 4 | 7 | 3 |
| Tobruk – Dark Distillation | 0.49 | 4 | 3.63 | 3 | 7 | 3 |

**Table 4:** Caffeine content in 100 mL.

| No | Sample | Caffein (mg/mL) | Caffeine content 100 mL (mg) |
|---|---|---|---|
| 1 | Tobruk Medium (TM) | 0.058 | 5.809 |
| 2 | Tobruk Dark (TD) | 0.053 | 5.272 |
| 3 | Espesso Medium (EM) | 0.062 | 6.222 |
| 4 | Espresso Dark (ED) | 0.071 | 7.130 |
| 5 | Espresso Medium - Chemical (M1B1R1) | 0.052 | 5.245 |
| 6 | Espresso Dark - Chemical (M1B1R2) | 0.052 | 5.203 |
| 7 | Tobruk Medium - Chemical (M1B2R1) | 0.051 | 5.052 |
| 8 | Tobruk Dark - Chemistry (M1B2R2) | 0.054 | 5.382 |
| 9 | Espresso Medium - Distillation (M2B1R1) | 0.046 | 4.639 |
| 10 | Espresso Dark Distillation (M2B1R2) | 0.047 | 4.735 |
| 11 | Tobruk Medium - Distillation (M2B2R1) | 0.048 | 4.777 |
| 12 | Tobruk Dark - Distillation (M2B2R2) | 0.049 | 4.859 |

## 4.3 Color Analysis

In this study, color tests using the chemical method were exclusively conducted on espresso and Tobruk coffee brews, as well as clear coffee drinks. No color testing was conducted for the distillation method. This is because clear coffee, by its nature, lacks significant color or exhibits an extremely minimal level of color. Colorimeters are typically designed to measure color parameters in solutions, including color, luminance, and color components such as CIE a* and CIE b*. Clear coffee typically exhibits color values that are nearly transparent or lack noticeable color in the color system measured by the colorimeter. Consequently, using this instrument may yield minimal results or fail to distinguish between clear coffee and plain water. As indicated by Selby (2023), colorimeters are primarily engineered to measure colors within the visible light spectrum, which typically ranges from approximately 380–750 nanometers (nm). This spectrum aligns with the range of light visible to the human eye. Colorimeters are not designed to measure colors beyond the visible light spectrum, such as ultraviolet (UV) or infrared, unless specialized devices are created for these spectra.

The results presented in Table 2 indicate that the highest L* value was observed in the M1B2R1 treatment, exceeding the brewed coffee beverage. Coffee brews have lower brightness levels than clear coffee produced through the chemical method. This is because coffee brews generally contain more solids or dissolved particles than clear coffee produced by the chemical method. Furthermore, the density of brewed coffee can also influence the L* value. Thicker or more concentrated coffee may exhibit a lower L* value due to the higher absorption of light by the denser liquid.

The highest a* value was found in the M1B1R2 treatment, where an increase in the a* value in clear coffee drinks produced by the chemical method using espresso brewing and a higher degree of dark roasting was observed, which occurs due to several factors.(acid and milk content) As noted by Nurba (2019), roasting coffee to higher levels, such as a dark roast, tends to result in higher a* values. This is due to the formation of chemical compounds during the roasting process that impart red or brown hues to the coffee. Additionally, the concentration and density of coffee during the brewing process play a crucial role. A denser or more concentrated coffee contains more compounds that contribute to color, resulting in a higher a* value, in line with the findings of Kinasih et al. (2021).

The highest b* value was recorded in the preparation of clear coffee beverages through the chemical method using Tobruk brewing and medium roasting (M1B2R1). The chemical method for making clear coffee involves the application of specific chemical principles. One of these principles is the combination of milk and acidic ingredients, which initiates a process known as "curdling" or clumping. This process is pivotal in binding soluble substances and particles in the coffee brew. The preparation of clear coffee via the chemical method using brewed coffee can be considered an effective approach to binding soluble particles in coffee. An indicator of the success of this process is the change in coffee color from its initial solid black state to a yellowish hue. According to Kinasih et al. (2021), Tobruk is a straightforward coffee-making method that involves mixing coffee grounds with boiling water without the use of high pressure. Consequently, Tobruk typically results in a more diluted extraction and exhibits a lighter texture or body than espresso.

## 4.3 Selection of the Optimal Treatment

According to Tarwendah (2017), treatments can be ranked based on quality parameters and consumer preference levels to identify the most favorable treatment and eliminate the rankles favorable ones. The aim of determining the optimal sample is to identify the superior treatment within the clear coffee beverage product. In this study, the selection of the best sample is predicated on an evaluation of caffeine and pH acidity tests for clear coffee drinks. The ranking test results revealed that M2B1R1 is the optimal treatment for clear coffee drinks, including a medium roasting level, espresso brewing, and distillation.

# 5 CONCLUSIONS

The results of research on clear coffee-making studies involving roasting variations and brewing levels on Gayo Arabica coffee lead to the conclusion that the method of preparing clear coffee significantly affects the resulting pH. Furthermore, data analysis on caffeine levels in clear coffee drinks using the distillation method indicates lower caffeine content compared to the chemical and control methods. Regarding the production of clear coffee drinks using the chemical method, it is noteworthy that the sample with the most favorable color characteristics is the one produced through the chemical method with Tobruk brewing and a medium roasting level, yielding values of L* (59.77), a* (+10.6), and b* (+62.5). Through comprehensive ranking tests on each parameter assessed for clear coffee beverages, according to the conditions under which this work was developed, it is evident that the superior treatment is M2B1R1, which involves the distillation method, espresso brewing, and a medium roasting level.

# 6 AUTHORS CONTRIBUTION

Conceptual idea: Sulaiman, I; Methodology design: Sulaiman, I.; Marsyanda. Erika, C; Data collection: Marsyanda, Data analysis and interpretation: Sulaiman, I.; Marsyanda. Erika, C, and Writing and editing: Sulaiman, I.

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