Chemical characteristics of Indonesian single-origin cocoa beans and the effect of tempering treatments on dark chocolate - a preliminary study

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Abstract. The aim of this study was to investigate the effect of geographical origin on the chemical characteristics of cocoa beans and to determine the effect of tempering treatment on the glossiness of dark chocolate. In this study, three roasted single-origin cocoa nibs, i.e., single-origin Kulon Progo, Aceh, and Gunung Kidul, were analysed to determine their moisture content, ash, crude protein, total fat, and pH value, as well as their sensory properties. Kulon Progo cocoa nibs were mostly preferred and further processed into dark chocolate using three tempering variations and analysed to determine their glossiness, texture, and colour. The glossiness level of dark chocolates under different tempering treatments was ranked using RedJade Sensory Software. Data were analysed using Minitab 17.0 Statistical Software. The results show that single-origin cocoa beans from Kulon Progo had the lowest moisture content (1.33 ± 0.015 %) and the highest fat content (54.01 ± 0.434 %). Dark chocolate tempered at 50:32:27:32°C had the most preferred glossy appearance (2.59 out of 3.00).

1. Introduction
Cocoa beans harvested from cocoa trees (Theobroma cacao L.) have become one of Indonesia's vital agricultural commodities. The Indonesian cocoa beans are produced from plantations across various regions, such as Sumatra, Java, Sulawesi, and Bali, with a total production of around 750,000 tons in 2019[1]. This has made Indonesia become the third-largest cocoa-producing country after Côte d'Ivoire and Ghana [2].

Chocolate is one of the most popular confectionery products in the world. Global premium chocolate market, including single-origins, has grown significantly over the last decade [3]. One of the reasons that drive consumers to choose chocolate and other cocoa products is the uniqueness of their sensory profiles [4]. Single-origin chocolates have specific and unique flavor [4,5]. The genotypes of cocoa beans, geographical origins, post-harvest processing (fermentation and drying), as well as chocolate manufacturing processes (roasting, conching, and tempering) are factors that influence chocolate quality [6].

Among different quality parameters, flavor is one of the most significant attributes of chocolate quality considered by consumers [7]. Raw cocoa beans have an unpleasant astringency and bitterness. The flavor precursors of chocolate are generated during fermentation and drying, while the development of flavors occurs during the roasting process. To better understand the quality of cocoa products, it is
essential to identify the chemical characteristics that are likely to play an important role in shaping the sensory profile of chocolate, which may influence the acceptance of consumers [8].

In chocolate manufacturing, tempering is an essential procedure to ensure that fat sets in the correct crystal form [9]. Although there are different methods to temper chocolate, all focus to create the desirable \(\beta\)-V crystal form [10]. Well-tempered chocolate results in a product with glossy appearance, good snap, good contraction from the mold, and resistance to bloom during storage [11]. This preliminary study aims to investigate the effect of geographical origins on the chemical characteristics of cocoa beans and evaluate the effect of tempering on the glossiness, colour, and texture of dark chocolate.

2. Materials and methods

2.1. Raw materials

Single-origin roasted cocoa nibs (Figure 1) and cocoa masses were purchased from Pawon Gendis (Kulon Progo) and Cokelat nDalem (Aceh and Gunung Kidul). Sucrose was purchased from Prima Food. Cocoa butter (Mycryo Barry Callebaut) and soy lecithin were purchased from Master Bahan Kue.

![Figure 1. Roasted cocoa nibs from (a) Kulon Progo, (b) Aceh, and (c) Gunung Kidul.](image)

2.2. Sample preparation

2.2.1. Sensory evaluation. The preference ranking test was conducted by serving 5 g of each sample (single-origins from Kulon Progo, Aceh, and Gunung Kidul) in clear plastic pouch. Panellists were asked to evaluate the colour and aroma of the samples by ranking them from most preferred (score of 3.00) to least preferred (score of 1.00) [12]. Sensory evaluation design and data collection were performed using RedJade Sensory Software (Martinez, CA, US).

The preference ranking test of dark chocolate was conducted by preparing a bar (9 cm x 3.5 cm x 0.5 cm) of each tempered chocolate (tempered 1, tempered 2, and tempered 3, described later in the text) and serving them in a plastic container. Panellists were asked to evaluate the glossy appearance based on the ranking method as described previously [12]. Sensory evaluation design and data collection were performed using RedJade Sensory Software (Martinez, CA, US).

2.2.2. Dark chocolate processing. The most preferred roasted cocoa nib from the sensory evaluation was then further processed into dark chocolate. The dark chocolate was formulated following a previous method [13] with modification. Cocoa mass (70%), sugar (18.88%), cocoa butter (10.72%), and lecithin (0.4%) were mixed at 70°C for 60 minutes. Following the mixing process, the chocolate was conched at 70°C for 90 minutes.

The tempering of the chocolate was performed following a previous method [14] with different end temperatures. Tempering 1 was performed at 50:32:27:32°C, tempering 2 at 50:32:27:34°C and tempering 3 at 50:32:27:36°C. The objective of these different endpoint temperatures was to obtain a
glossy appearance. The tempered chocolates were poured into a 9 cm x 3.5 cm x 0.5 cm polycarbonate mold and manually vibrated for 3 minutes to release air bubbles. The molded chocolates were then refrigerated at 14°C for 2 hours. After that, chocolates were stored at room temperature.

2.3. Analytical methods

2.3.1. Proximate analysis and pH value. The moisture content, total fat, protein, and ash were determined following the procedures in the AOAC methods [14]. pH value was determined following a previous method [16] by grinding 2.5 g of roasted cocoa nibs and mixing them into 2.5 mL of demineralized water (Hydrobat) for 5 minutes using a magnetic stirrer (MS-H-Pro GSA). The mixture was centrifuged at 3200 x g for 10 minutes at room temperature. The pH of the supernatant was measured using a pH meter (Mettler Toledo GmbH, Giessen, Germany).

2.3.2. Colour. The colour of the dark chocolate was measured using a colorimeter (Precise Color Reader WF30). Colour parameters were expressed using the CIELAB and CIELCH systems. L* indicates lightness, ranging from 0 (black) to 100 (white), C* (chroma) indicates the degree of saturation, and h° (hue) indicates hue luminance [17].

2.3.3. Texture. The texture of the dark chocolate was determined using a Texture Analyzer (Brookfield, TexturePro CT V1.4 Build 17, United States) equipped with a 1000 g load cell and a TA39 probe. The pre-test speed was set at 2 mm/s, test speed at 1 mm/s, load cell at 1000 g, and trigger load at 6.8 g. The hardness of the dark chocolate was expressed as grams. All measurements were conducted at room temperature [15].

2.3.4. Data analysis. All experiments were conducted in three replicates and all values are reported as the means ± standard deviations (SD). All data were collected and tabulated in Microsoft Excel 2013. Proximate and pH value were analysed using a one-way analysis of variance (ANOVA), colour and texture data were statistically analysed using General Linear Model (GLM), and the ranking data were analysed using nonparametric statistics (Friedman Test, Chi-square). Post-hoc analysis (Fisher Test) at 95% confidence interval was performed using Minitab 17.0 Statistical Software (Minitab Inc., State College, Pennsylvania, USA).

3. Results and discussions

3.1. Proximate composition and pH value of single-origin cocoa nibs

Table 1 shows the result of the pH value and proximate data of three roasted cocoa nibs. One-way ANOVA showed significant differences (α=0.05) in the pH value and proximate data. Cocoa nibs from Gunung Kidul had the lowest pH value (4.86 ± 0.057) compared with cocoa nibs from Aceh and Kulon Progo. The pH value of cocoa nibs appears to be affected by their origins. Different geographical locations will have different conditions that affect the biochemical compositions of the cocoa beans, including their acid contents [16]. In addition to geographical origins, the pH of the cocoa nibs can be affected by roasting as it facilitates the evaporation of the acid contents of the cocoa beans. [17].

Single-origin cocoa nibs from Kulon Progo had the lowest moisture content (1.33 ± 0.015%) compared with those from Aceh and Gunung Kidul. This might result from higher roasting levels as it allows moisture content to be reduced from 7% to 1–5% [16]. The minimum moisture content of the cocoa nibs from Kulon Progo could impart an increased quality as microbial and enzymatic reactions would be more limited compared with the other samples [18]. Single-origin cocoa nibs from Kulon Progo had the highest total fat (54.01 ± 0.434%), a parameter associated with good quality chocolate [18]. The different compositions of protein, fat, and ash content might be explained by several different factors such as botanical origin, location of growth and growing conditions [19].


Table 1. Chemical characteristics of roasted cocoa nibs.

| Origin          | pH       | Moisture (%) | Ash (%)    | Protein (%) | Total fat (%) |
|-----------------|----------|--------------|------------|-------------|---------------|
| Gunung Kidul    | 4.86 ± 0.057<sup>a</sup> | 4.15 ± 0.080<sup>a</sup> | 2.30 ± 0.175<sup>b</sup> | 9.82 ± 0.352<sup>b</sup> | 21.50 ± 0.286<sup>a</sup> |
| Aceh            | 5.26 ± 0.115<sup>b</sup> | 3.52 ± 0.190<sup>b</sup> | 3.25 ± 0.230<sup>a</sup> | 14.63 ± 0.125<sup>a</sup> | 48.51 ± 0.176<sup>b</sup> |
| Kulon Progo     | 5.04 ± 0.015<sup>c</sup> | 1.33 ± 0.015<sup>c</sup> | 3.03 ± 0.025<sup>a</sup> | 14.64 ± 0.170<sup>a</sup> | 54.01 ± 0.434<sup>c</sup> |

Notes: Values are the mean ± SD (n=3). Significant differences (α=0.05) are indicated with different superscript letters. Percentages are reported on a dry weight basis.

3.2. Preference ranking of the colour and aroma of single-origin cocoa nibs

Preference ranking is intuitively simple for consumers since it can be done quickly with a relatively small effort [12]. In this preference ranking test, single-origin roasted cocoa nibs from Kulon Progo ranked the most preferred both in colour and aroma (Table 2) attributes. In contrast, single-origin roasted cocoa nibs from Gunung Kidul ranked the least preferred in colour and aroma due to its undesirable aroma and pale appearance. The colour and aroma of different single-origins had a significant difference (S value > Chi-square) in consumer preference.

Table 2. Result of preference ranking test of colour and aroma.

| Origin          | Attribute | Ranking average | df  | S value | Chi-square<sup>2</sup> (Chi<sub>table</sub>) |
|-----------------|-----------|-----------------|-----|---------|---------------------------------------------|
| Kulon Progo     | Colour    | 2.6             | 26.00 | 5.99    |
| Aceh            |           | 2.2             | 1.2  | 5.99    |
| Gunung Kidul    | Aroma     | 2.68            | 24.56 | 5.99    |
|                 |           | 2.04            | 1.28  |         |

Notes: most preferred = 3, preferred = 2, least preferred = 1.

3.3. The effect of tempering on the texture and appearance of dark chocolate

Single-origin cocoa nibs from Kulon Progo was selected to be further processed into dark chocolate based on its chemical characteristics and its preference ranking. Statistical analysis using GLM showed that tempering resulted in significantly different hardness level. Figure 2 shows that the hardness level of dark chocolate significantly decreased from 107.80 ± 17.70 g (tempered 1) to 45.40 ± 7.33 g (tempered 2). The texture (hardness) of chocolate determine its physical structure and mechanical surface properties [15], and in turn will determine the quality of the chocolate. This is because good quality chocolate is often associated with good snapping, a property that relies on texture. In addition to tempering, the total fat content, moisture, and particle size affect the hardness of chocolate [21].
Figure 2. Hardness level of dark chocolate with different tempering treatments. Values are the mean ± SD (n=3). Significant differences (α=0.05) are indicated with different letters.

Figure 3. Appearance of dark chocolate in three different tempering treatments (a) tempered 1, (b) tempered 2, and (c) tempered 3.

Table 3 shows that tempered 1 chocolate had the lowest $L^*$ value (29.49 ± 0.39), indicating a colour darker than tempered 2 chocolate (30.81 ± 0.97) and tempered 3 (31.49 ± 1.28). As shown in Figure 3, related with the result of $L^*$, $C^*$ and $h^\circ$ value, tempered 3 had a poor appearance which indicates blooming process. Different tempering levels result in different glossiness, which refers to the shininess, smoothness, and uniformity of the chocolate surface [20]. The level of glossiness appears to significantly affect the preference of consumers (Table 4), with tempered 1 chocolate being the most preferred (2.59 out of 3.00).

Table 3. Colour measurement of dark chocolate with different tempering treatments.

| Tempering treatment | Colour measurement |
|---------------------|--------------------|
|                     | $L^*$               | $C^*$               | $h^\circ$            |
| Tempered 1          | 29.49 ± 0.39$^a$    | 19.19 ± 0.76$^a$    | 84.99 ± 0.52$^a$    |
| Tempered 2          | 30.81 ± 0.97$^a$    | 15.84 ± 1.03$^b$    | 82.32 ± 0.77$^a$    |
| Tempered 3          | 31.49 ± 1.28$^a$    | 16.88 ± 1.74$^a$    | 82.00 ± 1.10$^a$    |

Notes: Values are the mean ± SD (n=3). Significant differences (α=0.05) are indicated with different superscript letters.
Table 4. Result of preference ranking test of glossiness.

| Treatment     | Ranking average | df | S value | Chi-square ($\chi^2_{Table}$) |
|---------------|-----------------|----|---------|-----------------------------|
| Tempered 1    | 2.59<sup>a</sup> |    |         |                             |
| Tempered 2    | 2.05<sup>b</sup> | 2  | 22.46   | 5.99                        |
| Tempered 3    | 1.36<sup>c</sup> |    |         |                             |

Notes: most preferred = 3, preferred = 2, least preferred = 1. Significant differences ($\alpha=0.05$) are indicated with different superscript letters.

4. Conclusions

This study shows that the geographical origins of cocoa nibs appear to affect their chemical characteristics. Single-origin cocoa nibs from Kulon Progo ranked the most preferred in colour and aroma. Tempered dark chocolate 1 had the highest hardness level, the lowest $L^*$ value (lightness), and the highest $C^*$ value (chroma). Tempering conditions affected the glossiness of the dark chocolate and panellists ranked tempered dark chocolate 1 the most preferred glossy surface.

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