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Development of a local single-origin dark chocolate based on consumer preferences

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Abstract

Chocolate, derived from cocoa, is a widely enjoyed product, with numerous small and medium enterprises in Indonesia processing local single-origin cocoa such as that from Kulon Progo to cater to domestic tastes. This study aims to develop a local single-origin dark chocolate based on consumer preferences for specific attributes and to determine their willingness to pay (WTP). The developed chocolate was then profiled and compared with a commercial dark chocolate. A discrete choice experiment (DCE) was conducted to evaluate consumer preferences for attributes including cocoa content, sugar type, and price (per 50 g), using levels informed by a preliminary survey. The online survey was carried out using Lighthouse Studio 9.12.0, with data analyzed via Hierarchical Bayes (HB). The results revealed that consumers preferred dark chocolate with 80% cocoa content and palm sugar and were willing to pay IDR 48,904.48 for this variant. Based on these preferences, the product was further evaluated for physicochemical properties, including moisture, fat content, hardness, and color. The product is compared to a commercial alternative. Significant differences were observed in adhesiveness, cohesiveness, gumminess, glossiness, and in the L* and a* color values, indicating the need for further development to improve the quality of locally produced dark chocolate.

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1. Introduction

Cocoa (*Theobroma cacao* L.) is a key estate crop that plays a strategic role in the global economy. According to FAOSTAT (1), Indonesia ranks as the third-largest cocoa producer in the world, following Côte d'Ivoire and Ghana, with a production volume of 641,741.02 tons. Cocoa cultivation in Indonesia is concentrated in five major provinces: Central Sulawesi (19.92%), Southeast Sulawesi (16.09%), South Sulawesi (12.62%), West Sulawesi (10.62%), and Lampung (7.22%) (2). In Java, Kulon Progo stands out as a leading cocoa-producing region within the Yogyakarta Special Region Province. The district has shown a relatively consistent increase in productivity over the years, with production increasing from 1,357.45 tons in 2019 to 1,384.00 tons in 2021 (3). This potential warrants further development, particularly through improving cocoa bean quality and increasing the value of derived chocolate products, to foster greater consumer interest in locally produced single-origin chocolate.

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Single-origin chocolate has the potential to offer distinctive characteristics, especially in terms of flavor profile. Unlike conventional chocolate, which is typically made from blended beans sourced from multiple regions, single-origin chocolate is gaining popularity as a premium product (4). A study by Callebaut (5) reported that 55% of respondents believed that single-origin chocolate possesses a refined and distinctive taste. These sensory attributes shape consumer perceptions and significantly influence product acceptance (6). As a result, understanding consumer preferences on the basis of perceived product attributes is essential.

This study aims to develop a local single-origin dark chocolate made from Kulon Progo cocoa beans on the basis of consumer preferences for various product attributes and to determine their willingness to pay (WTP). This study stems from an established collaboration with local small and medium enterprises (SMEs) in Kulon Progo, focusing on their regional chocolate production. Previous research by Wahyuni et al. identified Kulon Progo cocoa as the most preferred origin in terms of color and aroma compared to other studied regions (7). Developing a commercializable chocolate product that aligns with consumer needs is therefore essential. Consequently, a preliminary consumer survey was conducted to evaluate critical product attributes, including sugar type, cocoa content, shape, packaging, appearance, and branding. The primary attributes identified from this survey were subsequently utilized as the foundation for the current study. Consumer preferences were translated into product development and used to create a dark chocolate variant, which was then profiled for its physicochemical characteristics and compared with a commercial product. The discrete choice experiment (DCE) method was employed to identify key consumer preferences and price sensitivity. On the basis of the findings, the resulting product concept provides a reference for SME in the production of market-aligned dark chocolate. Ultimately, this study offers valuable insights for stakeholders in Indonesia's single-origin cocoa and chocolate sector to support product development and quality improvement in line with consumer expectations.

2. Materials and Methods

2.1. Materials and Tools

The primary ingredient used in this research was single-origin fermented cocoa beans (*Forastero*) sourced from Kulon Progo. These beans were roasted and processed into cocoa paste by Pawon Gendis, which is located in Kulon Progo, Yogyakarta. The additional ingredients used in the formulation of the dark chocolate included palm sugar, cocoa butter, and soy lecithin. A commercial dark chocolate product (single origin: Cangkreng, Purworejo) with comparable ingredients (80% of cocoa content and sweetened by palm sugar) was utilized as a reference for comparison.

The materials used for chemical analyses included distilled water (Waterone), n-hexane p.a., acetone (Merck), acetic acid, Folin-Ciocalteu reagent, sodium carbonate (Na_2CO_3 ; Merck), methanol (Merck), petroleum ether p.a. (Merck), silica gel, and gallic acid. All materials and reagents were supplied by the Biochemistry and Food Analysis Laboratory, Department of Food Science and Biotechnology, Faculty of Agricultural Technology, Universitas Brawijaya. The analytical instruments used in the study included an analytical balance (Ohaus), a UV–Vis spectrophotometer (Thermo Scientific–Genesis 20), a magnetic hotplate stirrer (Thermo Scientific), a centrifuge (Hermle), an electric oven (RedLine), a desiccator (Nucelite), a Soxhlet apparatus (Gerhardt), an ultrasonic vortex probe (Thermo

Scientific; Cole Parmer, 20% amplitude), a color reader (CR-10, Konica Minolta), a Glossmeter AMN60 and standard laboratory glassware.

2.2. Methods

2.2.1. Chocolate production

For the chocolate production process, single-origin cocoa is roasted and processed into cocoa paste by Pawon Gendis, a small- to medium-sized cocoa enterprise located in Kulon Progo, Yogyakarta. The dry-fermented cocoa beans (with a moisture content of 7–8%) were roasted via a local roasting machine at 150 °C for 30 minutes. Following roasting, the beans were broken into nibs with the removal of the epidermis, and the nibs were then crushed to form cocoa paste. The pasting process was carried out for 1 hour at room temperature (20–25 °C). The resulting cocoa paste was analyzed for moisture and fat content in accordance with the Indonesian National Standard (SNI) Cocoa Mass 3749:2009 (8). According to the formulation, the cocoa paste was used in dark chocolate production by incorporating additional ingredients, namely, cocoa paste, cocoa butter, palm sugar, and soy lecithin. The ingredients were mixed at 70 °C for 60 minutes, followed by conching at the same temperature for 90 minutes. Tempering was conducted via the double-boiler method at 50 ± 5 °C for 9 minutes, after which the samples were cooled to 32 °C for 32 seconds in a water bath maintained at 15 °C. The mixture was further cooled and mixed at 27 ± 1 °C for 9 minutes. The chocolate was subsequently reheated using a bowl placed over simmering water until it reached a temperature of 32 °C. The final processing steps included molding, cooling, and demolding. Molding was followed by an initial cooling phase at 12 °C for 2 hours and a secondary cooling phase at 14 °C for 24 hours. The finished chocolate was stored at 20 °C until further analysis.

2.2.2. Discrete choice experiment (DCE) method for consumer study

The discrete choice experiment (DCE) consumer study was conducted in four key stages: identifying product attributes and corresponding levels; constructing choice sets; designing the questionnaire; and analyzing individual consumer preference data. The attributes and levels were determined through a preliminary online survey conducted via Google Forms, which involved 203 respondents. The survey collected data on demographic characteristics, health history (including allergies), motivations for consuming dark chocolate, frequency of consumption, purchasing channels, and perceptions of important dark chocolate attributes. Baseline levels for the DCE were established on the basis of attributes commonly found in dark chocolate products currently available on the market. The results of this preliminary survey were used to define the experimental design of the formal DCE evaluation. The number of respondents for DCEs was determined (9). The minimum sample size required for the study was calculated to be 74.074. However, the study was conducted with a total of 241 respondents, who were selected on the basis of specific criteria: they must be consumers of dark chocolate products, have no history of allergies to chocolate or its derivatives, and must not be colorblind. In the discrete choice experiment (DCE), the attribute levels with the highest utility values were identified and applied in the formulation of a newly developed dark chocolate product. The physicochemical characteristics of this product, particularly the cocoa solid content (percentage of cocoa) and type of sugar, were subsequently compared with those of commercial dark chocolate products.

2.2.3. Physicochemical analysis

Cocoa paste and dark chocolate products were analyzed for moisture content (10), fat content(10), color analysis (CR-10 Konica Minolta) with color parameters based on CIELAB, texture (i.e., hardness, cohesiveness, adhesiveness, and gumminess) via a texture profile analyzer (TPA) brand CT-3 texture analyzer (AMETEK Brookfield, Middleboro, USA) modified from Fibrianto et al. (11), and glossiness via a Glossmeter AMN60 (12).

2.2.4. Statistical analysis

The consumer study data were analyzed via the hierarchical bayes (HB) method, which estimates the utility values of attribute levels for individual respondents and calculates the average utility values for key attributes such as cocoa content, sugar type, and product price. Attribute preference analysis was performed via Lighthouse Studio version 9.12.0 (Sawtooth Software Inc.). The willingness to pay (WTP) for the dark chocolate variants was calculated via Microsoft Excel 2013 (Microsoft Corp.). To compare the physicochemical characteristics of the consumer-preferred dark chocolate product with those of the commercial control, a paired t-test was conducted via Minitab 17 (Minitab, LLC).

3. Results and Discussion

3.1. Determination of Dark Chocolate Product Attributes and Levels

A preliminary survey (Figure 1) was conducted to identify relevant attributes and levels for dark chocolate products. The findings revealed that the three most important attributes according to the respondents were cocoa solids content, brand, and sugar type. On the basis of these results, the product development phase focused on two key attributes: cocoa content (i.e., dark chocolate percentage) and sugar type.

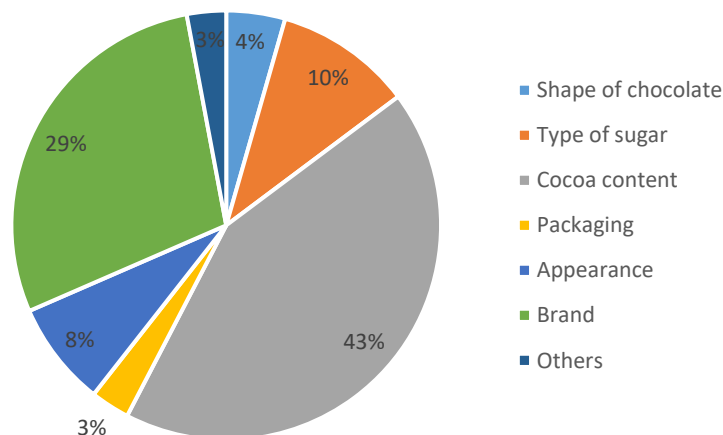


Figure 1. Important attributes of dark chocolate products.

The selection of levels for each attribute was informed by a review of the relevant literature and observations of the current market. To assess consumers' willingness to pay (WTP) for dark chocolate products, price was included as an additional attribute. Price levels were determined through a survey of comparable dark chocolate products available on the market. According to Wongprawmas & Canavari (13), the price attribute level can be determined by subtracting 50% and adding 50% of the average price. The average market

price identified through the survey was IDR 38,000. The attributes and level selections derived from the preliminary survey are presented in Table 1. Baseline values were determined on the basis of attribute levels common in existing dark chocolate products on the market.

Table 1. Dark chocolate attributes and levels.

Attribute	Level
Cocoa content	64% (baseline)
	72%
	80%
Type of sugar	Granulated sugar (baseline)
	Coconut sugar
	Palm sugar
Price (per 50 g)	IDR 19,000
	IDR 38,000 (baseline)
	IDR 57,000

On the basis of the preliminary study, the discrete choice experiment (DCE) design included nine choice sets (t), each consisting of three product concepts (a) and a fourth option representing “no choice” (c). The experimental design incorporated three attributes: dark chocolate cocoa content (64%, 72%, and 80%), sugar type (granulated sugar, coconut sugar, and palm sugar), and price point (IDR 19,000 as the lowest price, IDR 38,000 as the midrange price, and IDR 57,000 as the highest price).

3.2. Demographic distribution of the respondents

A total of 241 respondents participated in this consumer study (Table 2). The sample consisted of 79.25% female and 20.75% male participants. The majority (53.94%) resided outside Malang city or the district. In terms of age distribution, the largest respondent groups were from the 18–25, 26–30, and 31–35-year age brackets. Most participants held a bachelor's or master's degree.

The predominant occupations among the respondents were private-sector employees and students. In terms of monthly income, the largest proportion (27.39%) earned between IDR 1,600,000 and IDR 3,500,000, whereas 19.50% reported an income of less than IDR 1,000,000.

Table 2. Respondent demographics.

Respondent Categories		Amount	Percentage (%)
Gender	Male	50	20.75
	Female	191	79.25
Domicile	Malang City/Regency	111	46.06
	Other Cities/Regencies	130	53.94
Age	18–25 years	63	26.14
	26–30 years	56	23.23
	31–35 years	74	30.71
	36–40 years	32	13.28
	>40 years	16	6.64
Education level	Senior High School or equivalent	27	11.20
	Diploma	12	4.98
	Bachelor’s Degree	161	66.80
	Master’s Degree	38	15.78
	Doctorate	2	0.83

Respondent Categories		Amount	Percentage (%)
Occupation	Others	1	0.41
	Student	46	19.09
	Civil Servant	21	8.71
	Private Employee	56	23.24
	Entrepreneur	28	11.62
	Freelancer	16	6.64
	Housewife	41	17.01
	Unemployed	9	3.73
Income	Others	24	9.96
	<IDR 1,000,000	47	19.50
	IDR 1,000,000	26	10.79
	IDR 1,500,000		
	IDR 1,600,000	66	27.39
	IDR 3,500,000		
	IDR 3,600,000	44	18.26
	IDR 6,500,000		
	IDR 6,600,000	18	7.47
	IDR 10,000,000		
>IDR 10,000,000	40	16.60	

3.3. Dark Chocolate Product Consumption

According to the consumer study, approximately half of the respondents (50.62%) reported consuming dark chocolate one to three times per year. The majority (52.69%) purchased dark chocolate products from supermarkets. The primary motivations for purchase included use in baking and beverages (35.68%) and an appreciation for dark chocolate’s distinctive aroma and flavor (24.46%).

Although Indonesia is the world’s third-largest cocoa producer, the domestic consumption of chocolate products remains relatively low compared with that in European countries. According to Sabarisman and Purwaditya (14), this trend may be attributed to the limited availability of chocolate products that align with local consumer preferences. Additionally, cultural perceptions contribute to the low consumption rate, as many Indonesian consumers associate chocolate with negative health outcomes, particularly weight gain and diabetes (15).

3.4. Dark Chocolate Attribute Preferences

Dark chocolate consumption levels and preferences for product attributes (Figure 2) revealed that respondents who consumed dark chocolate daily or one to three times per week strongly preferred the 80% cocoa content level. This was reflected in the highest and most positive average utility value among all attribute levels, indicating a strong alignment with consumer preferences. In contrast, the 64% cocoa content level consistently received negative utility values, suggesting lower appeal across consumption frequency groups.

For the sweetener attribute, palm sugar yielded the highest average utility value and was particularly favored by respondents who consumed dark chocolate monthly or once every three months. Moreover, the "none" or "do not choose" option received negative utility values overall, implying that respondents were generally inclined to select one of the available product concepts rather than opt out.

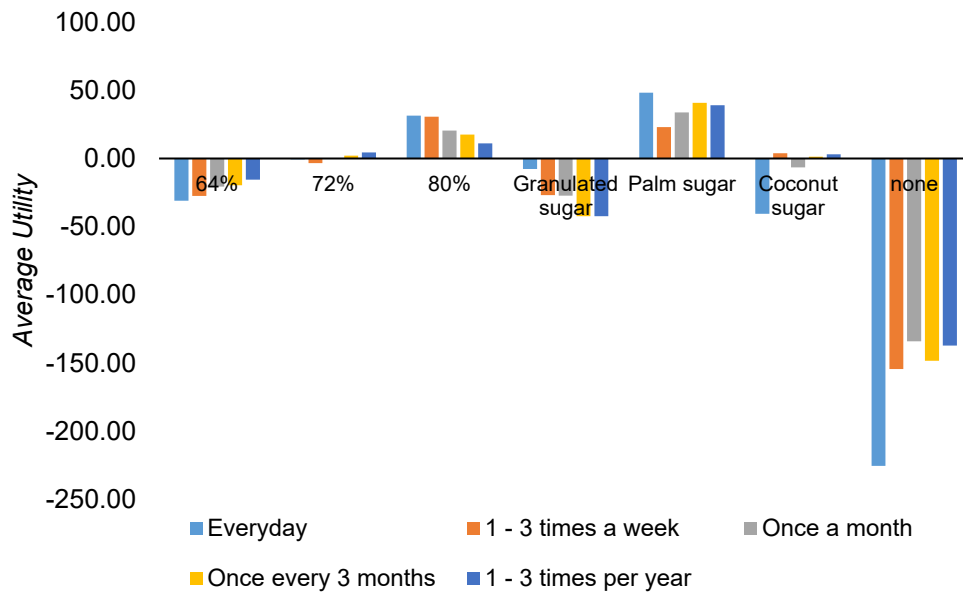


Figure 2. Frequency of consumption against dark chocolate attribute level preference.

3.5. Consumer Preferences for Dark Chocolate Products

The importance analysis of dark chocolate attributes (Figure 3) indicated that sugar type held the greatest significance, with an importance value of 41.01, followed by price at 33.17 and cocoa content at 25.82.

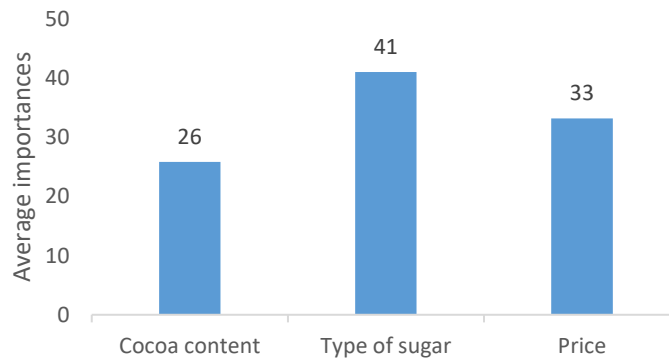


Figure 3. Respondents' preferences for dark chocolate attributes.

The analysis of the preference data (Table 3) indicated that all the evaluated attributes and their corresponding levels significantly influenced consumer choices ($p < 0.05$). A deeper evaluation of cocoa content and sugar type attributes (Figure 4) revealed that 64% of the cocoa content had a negative utility value (-18.40), whereas both 72% and 80% of the cocoa content was associated with positive utility values. Notably, the 80% cocoa content had the highest positive utility value (15.91), indicating that it was the most preferred level among consumers. According to Orme (16), a positive utility value reflects a favorable attribute, reinforcing the strong consumer preference for higher cocoa content.

Despite its more bitter taste, 80% dark chocolate offers several health benefits. Montagna et al. noted that chocolate with 80% or more cocoa is rich in antioxidants, particularly flavonoids (17). These compounds help neutralize harmful free radicals, thereby

reducing oxidative stress and cellular damage and contributing to the prevention of chronic diseases such as cardiovascular conditions, cancer, and neurodegenerative disorders (18). Additionally, dark chocolate with high cocoa content has been linked to improved emotional regulation and a reduction in negative emotional states (19).

Table 3. Respondent preference data for dark chocolate attribute levels.

Attribute	Level	P value
Cocoa content	64%	5.32×10^{-12}
	72%	1.66×10^{-2}
	80%	2.06×10^{-8}
Type of sugar	Granulated sugar	3.12×10^{-17}
	Coconut sugar	1.52×10^{-27}
	Palm sugar	8.32×10^{-1}
Price	IDR 19,000	2.28×10^{-11}
	IDR 38,000	4.37×10^{-26}
	IDR 57,000	1.45×10^{-27}

Although some studies do not explicitly focus on the 80% level, global and regional consumer trends reflect a growing preference for dark chocolate with high cocoa content (70%–90%), including within the Indonesian market. In fact, the Asia–Pacific region, including Indonesia, is projected to experience a compound annual growth rate (CAGR) of approximately 4.25% for this market segment through 2033 (20).

The second key attribute examined in the study was the type of sugar used as a sweetener in dark chocolate products, which was assessed across three levels: granulated sugar, palm sugar, and coconut sugar. As shown in Figure 7, both palm sugar and coconut sugar yielded positive utility values, whereas granulated sugar presented a negative utility value (-37.62). This suggests that consumers view palm and coconut sugars as preferable alternatives to conventional sweeteners in chocolate products (21). Among the two products, palm sugar had the highest utility value (37.24), indicating a stronger consumer preference relative to coconut sugar.

Research by Ibrahim et al. (22) supports the sensory appeal of palm sugar, noting that it enhances the aroma and flavor of dark chocolate through the Maillard reaction during crystallization. The mineral and protein contents of palm sugar likely contribute to the formation of volatile compounds that increase its aromatic profile. Additionally, palm sugar offers a complex sweetness and distinct caramel aroma that evokes a warm, traditional sensory experience. Consumers also favor its dark brown to black coloration, which reinforces perceptions of naturalness and a strong connection to locally sourced, artisanal products (23). Cultural heritage further influences this preference, as palm sugar consumption is deeply rooted in the traditions of many local communities (24).

From a nutritional standpoint, palm sugar provides 368 kcal per 100 grams, whereas coconut sugar provides 386 kcal (25). It also has a lower glycemic index (62.47) than both coconut sugar (67) and granulated sugar (100), making it a more suitable option for managing blood sugar levels (26–28). Statistically, the palm sugar level had a significant effect (p value <0.05) on respondent preference, reinforcing its potential as a consumer-preferred sweetener in dark chocolate formulations.

3.6. Willingness to Pay (WTP) for Dark Chocolate Products

Willingness to pay (WTP) represents an estimated value indicating a consumer's maximum willingness to pay for a given product. It is closely linked to consumer perceptions and perceived product value (29). In this study, WTP values were derived by converting the utility value associated with each attribute level. The results of these conversions are presented in Table 4.

Table 4. WTP value of dark chocolate.

Level Attribute	WTP (IDR)
Cocoa content 64%	<i>Baseline</i>
Cocoa content 72%	13,638.49
Cocoa content 80%	22,412.74
Granulated sugar	<i>Baseline</i>
Palm sugar	48,904.48
Coconut sugar	24,828.13

The willingness to pay (WTP) for various dark chocolate product attributes showed consistently positive values. For the cocoa content attribute, the 72% cocoa level yielded a WTP value of IDR 13,638.49, indicating that consumers are willing to pay this amount more for 72% cocoa dark chocolate than for the baseline 64% cocoa product. The 80% cocoa content level had an even greater utility-derived WTP value of IDR 22,412.74, indicating a strong preference and greater willingness to pay for higher cocoa concentrations.

For the sugar type attribute, palm sugar generated the highest WTP value at an IDR of 48,904.48, which was based on its utility value of 37.24. This suggests that consumers are willing to pay nearly IDR 49,000 more for dark chocolate sweetened with palm sugar than for chocolate made with granulated sugar. Coconut sugar, while also positively received, yielded a WTP value of IDR 24,828.13, which is notably lower than that of palm sugar, in line with its lower utility value of 0.38. Overall, these results reflect a marked consumer preference and premium willingness to pay for products with higher cocoa contents and alternative natural sweeteners, especially palm sugar.

3.7. Newly Developed Dark Chocolate Product Characteristics in Comparison with Commercial Products

The results of the utility analysis (Figure 4) revealed that the respondents clearly preferred dark chocolate formulated with 80% cocoa content and sweetened with palm sugar. Accordingly, a dark chocolate product was developed using an 80% single-origin cocoa paste and palm sugar formula. The cocoa paste used had a moisture content of $1.27 \pm 0.05\%$ and a fat content of $49.71 \pm 0.27\%$. The final formulation included 18.5% palm sugar, 1% cocoa butter, and 0.5% soy lecithin.

The physicochemical properties of the resulting single-origin dark chocolate were then evaluated and compared with those of commercially available dark chocolate products. A paired *t*-test was conducted to assess significant differences in physical and chemical characteristics between the consumer-preferred product and the commercial counterpart (Table 5).

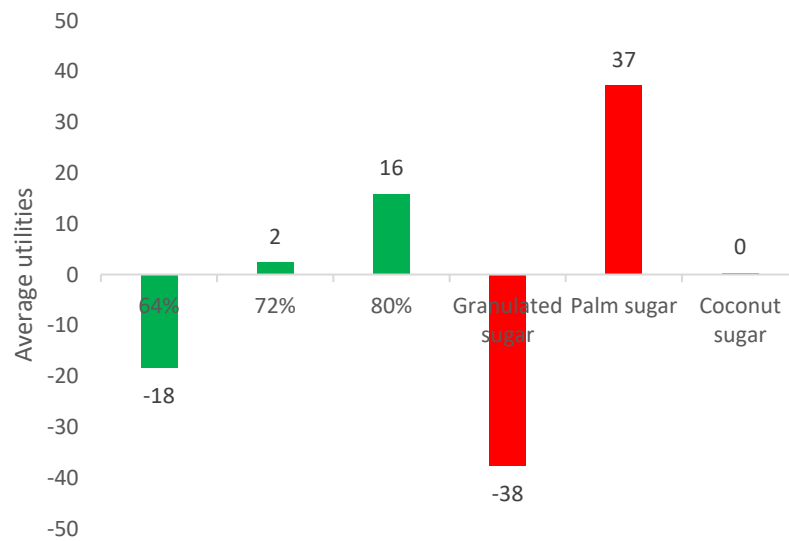


Figure 4. Respondents' preferences for dark chocolate attribute levels.

Table 5. Characteristics of developed single-origin dark chocolate products vs commercial dark chocolate products.

Parameter	Commercial dark chocolate	Developed single-origin dark chocolate	Significance ($\alpha=0.05$)
Moisture content (%)	2.43±0.01	2.35±0.10	Ns
Fat content (%db)	60.54±7.86	54.95±4.73	Ns
Hardness (g)	693.6±116.3	619.3±60.2	Ns
Adhesiveness (mJ)	0.54±0.05	0.24±0.03	S
Cohesiveness	0.15±0.00	0.11±0.01	S
Gumminess (g)	94.22±6.97	70.88±5.10	S
Glossiness	19.55±0.17	18.25±0.63	S
L* value	45.53±0.15	41.03±0.76	S
a(+) value	2.13±0.17	0.45±0.28	S
b(+) value	4.28±0.32	4.25±1.57	Ns

Data mean ± SD (n=4); S= significant; Ns = not significant

Table 5 shows that there were no significant differences ($\alpha = 0.05$) between the developed single-origin dark chocolate and the commercial product in terms of moisture content, fat content, hardness, or b* (yellowness) value. The moisture content is a critical parameter in dark chocolate, as it affects crystallization, texture, rheological properties, and shelf life (22). According to Saputra et al. (21), moisture content also influences fat retention, which is another key quality factor in chocolate. The fat content typically ranges between 50–60% in both commercial and formulated products, contributed by cocoa paste and added cocoa butter. The species or variety of cocoa and the specific processing formulation further impact this parameter.

In addition to fat content, particle size distribution and tempering conditions contribute significantly to chocolate hardness (30,31), as do other sensory characteristics, such as melt-in-mouth quality and smoothness. Fat functions as a lubricant within the chocolate matrix, reducing particle friction; thus, lower fat levels tend to increase hardness. Amariei and

Mancas (32) reported that dark chocolate with 85% cocoa content had a greater fat concentration (55.9 g/100 g) but exhibited lower hardness (53.56 N) than did 75% cocoa chocolate (fat 50.5 g/100 g, hardness 66.26 N).

The particle size and uniformity also play synergistic roles in determining hardness. Finer and more evenly distributed particles enhance particle interactions, resulting in a denser, more compact microstructure. A tightly packed structure with minimal fat voids tends to increase hardness. Ramadhan et al.(33)confirmed that chocolate with a compact microstructure and smaller particle size exhibited greater hardness. Furthermore, an optimal tempering process promotes the formation of stable and uniform cocoa butter crystals, which improves both the texture and hardness of dark chocolate (34).

The textural parameters of adhesiveness, cohesiveness, and gumminess were found to differ significantly ($\alpha = 0.05$) between the developed dark chocolate product and its commercial counterpart, with the developed product exhibiting higher values across all three products. These physical discrepancies are likely attributable to processing factors, particularly those governing particle size and distribution. Adhesiveness, for instance, is highly sensitive to particle size, where smaller particles typically increase the stickiness of dark chocolate. Similarly, particle size plays a critical role in determining cohesiveness. Although particle size distribution was not empirically measured in the present study, Afoakwa et al. (35), noted that larger particles may diminish cohesiveness by creating internal voids that are only partially occupied by smaller particles, thereby resulting in a less integrated internal structure. This highlights the critical importance of precise particle size control in achieving desirable textural properties, which should be a key consideration in industrial dark chocolate production.

The conching process, which refines chocolate by reducing particle size and enhancing flavor development, is a key determinant of final product texture (36). Therefore, the conching technique and the specific equipment employed during processing are crucial to optimizing chocolate quality, particularly in terms of structural and sensory attributes.

In addition to the previously discussed parameters, significant differences were observed in glossiness, the L^* value (lightness), and the a^* value (red–green chromaticity) between the developed dark chocolate and the commercial product. Glossiness refers to a smooth, uniform chocolate surface free of bubbles or white spots, contributing to an attractive visual appeal(30). This property is highly influenced by the tempering process, which governs cocoa butter crystallization and polymorphism (37). Proper tempering promotes the formation of stable type V cocoa butter crystals, which are responsible for a glossy, bright finish (38,39). In contrast, undertempering can result in fat blooms, producing a dull surface with a whitish coating, whereas over-tempering may lead to excessive hardness and a diminished gloss with a darker appearance. In this study, the tempering procedure was rigorously controlled based on established temperature-time profiles. The observed differences in glossiness compared to the commercial benchmark may be attributed to the manual nature of the tempering process or inherent variations in fat composition between the samples (40).

Storage conditions also play a key role in maintaining gloss. Exposure to temperature fluctuations or excessive heat can trigger fat migration to the surface, leading to blooms and reduced luster (41). The variations in the L^* and a^* values between the developed and commercial products may be attributed to differences in particle size distribution and the resulting fat crystal formation. A smoother surface, achieved through a finer particle size and

uniform distribution, enhances light reflection and contributes to a higher L* value, yielding a shinier appearance (21,42).

4. Conclusions

In conclusion, this study demonstrates that consumer preferences, as identified through the discrete choice experiment (DCE), play a valuable role in guiding the development of single-origin dark chocolate products. The results indicated that sugar type, price, and cocoa content were attributes with positive utility values, indicating their importance in shaping consumer choice. Among the options presented, dark chocolate with 80% cocoa content and sweetened with palm sugar emerged as the most preferred combination. This preference was also reflected in the willingness to pay (WTP) analysis, where consumers showed a greater willingness to pay for products with these attributes. Compared with commercially available dark chocolate, the developed single-origin variant displayed no significant differences in several chemical or physical parameters, such as moisture content, fat content, and hardness. However, significant differences were observed in other physical characteristics, including glossiness and certain textural properties.

These findings suggest that while the developed product meets several essential quality benchmarks, further improvements particularly in surface gloss and appearance may be needed to increase its competitiveness with commercial products. Nevertheless, if a product aligns with consumer expectations in terms of taste, quality, and price, it holds strong potential for market acceptance. Future research should include comparative consumer acceptance tests and broader product evaluations to validate market readiness and refine formulation strategies.

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Author Contributions

W.B.S. was responsible for the overall conceptualization and research design. A.Y.M.N. designed the discrete choice experiment (DCE) used in the study. N.L.W. collected the data and performed the analysis. A.D.C. wrote the original draft of the manuscript. S.S.Y. and T.T. contributed to the review and editing of the paper.

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Institutional Review Board Statement

This research was conducted in accordance with the Declaration of Helsinki and was approved by the Research Ethics Review Committee (POLKESMA) (Reg.No. :008/KEPK-POLKESMA/2021).

Data availability statement

Data will be made available upon request.

Conflicts of interest

The authors declare that they have no conflicts of interest. The funders have no role in any of the related stages.

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