

Production and Characterization of Cocoa (*Theobroma cacao* L) Juice Candy

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*Abstract- This study aimed to produce and characterize candy from cocoa juice extracted from *Theobroma cacao* L. (cocoa) fruits collected from a cocoa farm in Ilara-Mokin, Ifedore Local Government Area of Ondo State. The fruits juice was extracted using three distinct methods (M1-manual draining with applied pressure, M2-adding 60oC warm water with manual draining, M3-separately blending the cocoa placenta without the beans before mixing with beans and draining the juice) followed by pasteurization and crystallization. Proximate composition analysis revealed CJ6 had the highest moisture, ash, fat, and mineral and antioxidant activity emphasizing its nutritional superiority. Sensory evaluations results indicated CJ1 and CJ4 had the best aroma and texture. The best taste was noted in CJ1, CJ5, and CJ6, with CJ5 and CJ6 being most acceptable overall. Antinutrients levels were below WHO standards. The developed cocoa juice-based candies would offer healthier nutritional benefits for consumers and useful information for food industry.*

Keywords: *Theobroma cacao* L., proximate, antinutrient, antioxidant, concentrated juice.

I. INTRODUCTION

The confectionery industry is at a pivotal point, facing the dual challenges of adapting to increasingly health-conscious consumers and addressing environmental sustainability concerns (Dong & Rashkova, 2024). Traditional candy production, heavily reliant on refined sugars and artificial additives, is undergoing significant transformation as consumer preferences shift towards natural ingredients and environmentally friendly products (Ozel et al., 2024). This evolution in consumer behaviour is driving the industry to innovate, not just to align with these new consumer demands but to thrive in a competitive market that values both health and sustainability (Marturano et al., 2023). Innovation within the candy industry is critical as it enables manufacturers to introduce unique flavours,

textures, and nutritional benefits that meet modern consumer expectations (Selvakumar and Manjunath, 2025). Incorporating non-traditional ingredients such as plant-based or by-product-derived components is one innovative strategy because this approach not only satisfies the consumer's palate but also contributes to reducing environmental waste, aligning product development with the principles of a circular economy (Campos-Vega et al., 2018).

Cocoa juice, a by-product from the cocoa fruit, traditionally underutilized in chocolate production which focuses primarily on the beans (Guirlanda et al., 2021), offers significant potential as an innovative ingredient in candy production. Rich in natural sugars, antioxidants, and minerals (Soares and Oliveira, 2022), cocoa juice can enhance the nutritional profile of candies and provide a unique flavour that could increase consumer appeal. Additionally, utilizing cocoa juice aligns with the growing consumer preference for "clean label" products-foods that are free from artificial additives and perceived as healthier (Figueroa et al., 2020). Moreover, the use of cocoa juice in candy production offers an opportunity to innovate in a manner that supports sustainability. By valorising this by-product, the industry can reduce waste and enhance the environmental stewardship of cocoa farming (Queiroga et al., 2021). This sustainable approach not only meets consumer expectations but also addresses the environmental impact associated with traditional candy production processes.

The integration of cocoa juice into the confectionery industry could transform candy production by providing a new use for a cocoa by-product, promoting sustainability, and potentially enhancing the nutritional value of the products. This initiative would utilize the entirety of the cocoa fruit, reducing waste and making full use of its economic value.

Research has shown that cocoa pod husk and other by-products can be repurposed for various uses, such as animal feed, which contributes to sustainable agricultural practices (Wahyudi et al., 2023). Further, cocoa by-products have been used in the production of activated carbon and even in crafting alcoholic beverages, showcasing the versatility and potential economic benefits of these materials (Figueroa et al., 2020; Klis et al., 2023).

The primary aim of this research is to produce and characterize candies utilizing cocoa (*Theobroma cacao* L.) juice, exploring innovative uses of this by-product in candy production. To achieve this, the study is structured around several key objectives: optimizing the extraction methods of juice from the cocoa fruit to ensure efficient recovery; determining the qualitative and quantitative sugar profiles essential for developing the candy formulations; conducting sensory evaluations to assess consumer acceptance based on taste, texture, and overall satisfaction; performing detailed proximate analysis and determining the mineral composition to establish the nutritional content of the cocoa candy; and evaluating its antioxidant and anti-nutrient activities to understand potential health benefits. This comprehensive approach aims to provide valuable insights into the feasibility of incorporating cocoa juice in candy production, potentially leading to healthier and more sustainable confectionery products that align with current consumer trends and environmental initiatives.

II. MATERIALS AND METHODS

2.1 Cocoa Collection

The cocoa fruits used in this study were sourced from Ilara-Mokin, located in the Ifedore Local Government Area of Ondo State, Nigeria. This region is known for its rich agricultural land and favourable climate conditions for cocoa cultivation, which ensures the availability of fresh and high-quality cocoa fruits essential for the extraction of cocoa juice. Figure 1 shows the flow diagram of the cocoa juice candy production.

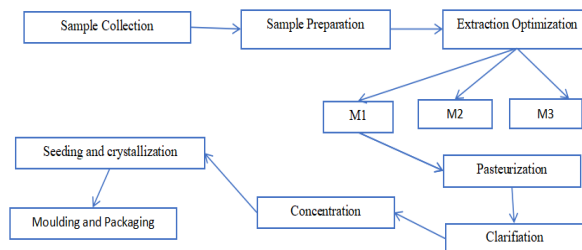


Figure 1: Flow Diagram of Cocoa Juice Candy Production

2.2 Extraction Methods

The extraction of cocoa juice was meticulously executed through a series of steps to maximize the yield and maintain the integrity of the juice's flavour and nutritional properties. Initially, the cocoa pods were thoroughly washed using both tap water and distilled water to remove any dirt and impurities. This cleaning process ensures that the quality of the cocoa juice is not compromised by external contaminants. After washing, the pods were carefully broken using a club. Special attention was given to ensure that the beans inside were not damaged, as the integrity of the beans is crucial for maintaining the quality of both the beans and the juice.

Three different methods were employed to optimize the juice extraction from the cocoa pods, reflecting techniques outlined by Mian et al., (2022) and Nunes et al. (2020):

- Method 1 (M1): Involved breaking opens the pods, pulping the contents, and then manually draining the beans and pulp through a sieve while applying pressure to extract the juice effectively.
- Method 2 (M2): Consisted of adding warm water at 60°C to the pulped contents of the broken pods and then draining the mixture through a sieve to extract the juice.
- Method 3 (M3): Entailed separately blending the cocoa placenta without the beans, mixing the ground placenta back with the remaining pulped content, and finally draining the juice through a sieve.

The effectiveness of each method was assessed by measuring the sucrose concentration using a refractometer and identifying the types of sugars

present using a UV spectrophotometer. The method that yielded the highest sucrose concentration was selected for further use in candy production. Plate 1 shows the concentrate of the juice.



Plate 1: Concentration of Juice

2.3 Quantitative and Qualitative Determination of Sugar Content

The juice extracted using the optimal method was then freeze-dried using a freeze dryer at -57.2°C (DRAWELL DW -12N Freeze Dryer). Post freeze-drying, the dried juice was analysed using ultraviolet spectrometry to determine the precise sucrose content (Chienet al., 2023).

2.4 Candy Production Procedure

The candy production process was meticulously designed to evaluate the potential of using cocoa juice as the primary ingredient in confectionery. Here is a detailed breakdown of the entire procedure:

Initially, approximately 1500 mL of the extracted cocoa juice was pasteurized to ensure microbial safety and prolong shelf life. The pasteurization was conducted at 72°C for 15 seconds in a water bath. This brief exposure to heat was sufficient to eliminate pathogenic bacteria without significantly affecting the flavour or nutritional content of the juice.

After pasteurization, the juice was allowed to settle to facilitate the natural separation of particulates. The supernatant was then carefully decanted and sieved to further clarify the juice. This step was crucial to ensure that the resulting candy would have a smooth texture without any fibrous materials or undissolved particles. The clarified juice, approximately 600 mL, was then centrifuged at 5000 rpm to separate any remaining solids from the liquid. The clear

supernatant obtained was subsequently concentrated using an electric heater equipped with a magnetic stirrer. The concentration process was conducted at 80°C and continued until the juice reached a concentration of 79.9 oBrix. This high concentration was necessary to achieve the desired sweetness and texture in the final candy product.

Once concentrated, the cocoa juice was divided into six separate portions to explore different ratios of sugar and pectin, which are crucial for initiating crystallization:

- CJ1: Concentrated juice seeded with 40 g of granulated sugar and 1 g of pectin.
- CJ2: Concentrated juice seeded with 30 g of granulated sugar and 1 g of pectin.
- CJ3: Concentrated juice seeded with 20 g of granulated sugar and 1 g of pectin.
- CJ4: Concentrated juice seeded with 10 g of granulated sugar and 1 g of pectin.
- CJ5: Concentrated juice seeded with 1 g of pectin only.
- CJ6 (control): Concentrated juice alone.

Each mixture was carefully heated, with a gradual increase in temperature while continuously stirring to ensure the complete dissolution of sugar and pectin into the juice. The heating was maintained until the temperature reached 115°C - a critical point to achieve the right viscosity for molding. Once the desired temperature and consistency were reached, the molten candy mixtures were immediately poured into pre-oiled molds. The filled molds were set aside to cool and solidify at room temperature, a process that took approximately 24 hours. This slow cooling allowed the pectin and sugar to form a gel matrix, which is essential for the candy to achieve the desired firmness and texture. The candy samples are shown in plate 2 below:



Plate 2: Samples of produced Candy

2.5 Characterization of Produced Cocoa Candy

2.5.1 Candy sensory Evaluation:

The resulting candies were evaluated based on texture, sweetness, and overall sensory attributes. The different formulations allowed an assessment of how variations in sugar and pectin concentrations influenced the properties of the final product (Farhan et al., 2024; Pathak et al., 2021)

2.5.2 Proximate Analysis

This involves determination of crude protein, carbohydrate (by difference), moisture, ash, crude fiber, and crude fat which was done according to the standard method of AOAC, (1990).

2.5.3 Antioxidant Evaluation

Antioxidant properties of the candy were assessed through various biochemical assays to determine its potential health benefits:

- **Total Phenol Content:** Utilizing Folin-Ciocalteu reagent, the phenolic content was measured, providing insight into the antioxidant capacity of the candy (Khadiri et al., 2023).
- **Total Flavonoid Content:** Flavonoids were quantified using a colorimetric assay, reflecting their role in combating oxidative stress (Bala et al., 2021).
- **Ferric Reducing Ability:** This assay evaluated the reducing power of the candy extracts, an indicator of potential antioxidant activity (Pulido et al., 2000).
- **DPPH Free Radical Scavenging Activity:** The ability to neutralize DPPH radicals was assessed, showcasing the candy's capability to mitigate radical-induced damage (Gerometta et al., 2020).
- **ABTS Radical Scavenging Assay:** The effectiveness of the candy in scavenging ABTS radicals was examined, further underscoring its antioxidant properties (Bibi Sadeer et al., 2020).

2.5.4 Anti-nutrients Evaluation

The evaluation of anti-nutrients in the cocoa candy involved the quantification of tannins, phytates, oxalates, alkaloids, and saponins, utilizing various

analytical methods to understand their concentrations and potential impacts on the nutritional quality of the product:(Amooet al., 2023; Bloot et al., 2023).

2.5.4.1 Tannin determination

Tannin content was analysed using a modified version of the Folin-Ciocalteu method as described by Galvao et al., (2018). Approximately 0.2 g of the finely ground sample was extracted with 10 mL of 70% aqueous acetone for 2 hours at 30°C in a bath shaker. After centrifugation, 0.2 mL of the supernatant was reacted with Folin-Ciocalteu's reagent and 20% Na₂CO₃. The mixture was incubated at room temperature for 40 minutes and the absorbance was measured at 725 nm. The tannin concentration was obtained from a standard curve prepared with known concentrations of tannic acid.

2.5.4.2 Phytate determination

Phytate levels were quantified following the procedure outlined by Bloot et al., (2023). Four grams of the sample were treated with 100 mL of 2% HCl for three hours, then filtered. The filtrate was titrated with a standard iron (III) chloride solution in the presence of ammonium thiocyanate as an indicator, until a persistent brownish-yellow color was achieved, indicating the end-point. The phytate content was expressed as percentage phytate in the sample (Amooet al., 2023).

$$\text{Phytate (\%)} = (T \times 0.00195 \times 1.19) / 2 \times 100$$

Where: T- Volume of standard iron (iii) chloride solution used for titration.

2.5.4.3 Oxalate determination

Oxalate content was determined by extracting 1 g of sample in 75 mL of 1.5 M H₂SO₄, followed by heating and titration with 0.1 M KMnO₄ at 80-90°C until a stable pink color persisted for 15 seconds (Yoshida and Delafontaine, 2020).

2.5.4.4 Alkaloid determination

Alkaloid concentration was assessed using the method described by Maggio et al., (2013). The sample was extracted with 10% acetic acid in ethanol, filtered, and the filtrate was concentrated. Alkaloids were precipitated by adding concentrated

ammonium hydroxide, collected by filtration, dried, and weighed.

2.5.4.5 Saponins determination

Saponins extraction was performed according to Obadoni and Ochuko (2002). The sample was extracted twice with 20% aqueous ethanol under heat. The extracts were concentrated, and saponins were further extracted with petroleum ether in a separating funnel. The aqueous layer was separated, dried, and the saponin content was quantified by weighing the dry residue.

III. RESULT AND DISCUSSION

3.1 Extraction Method Optimization

The experiment focused on identifying the method that results in the highest concentration of sucrose, alongside the concentrations of other sugars such as fructose, galactose, and lactose, which play significant roles in determining the sweetness and texture of the final candy product. The results revealed significant variations among the methods. M1 extracted the highest sucrose concentration at 307.45 mg/g, significantly outperforming M3 (305.83 mg/g) and M2 (264.44 mg/g), which suggested a potential measurement error or scale issue in M3 that might require further verification. In terms of fructose, M1 again led with 176.06 mg/g, followed by M3 and M2, indicating a trend where M1 consistently provided higher sugar concentrations. Galactose results followed a similar pattern with M1 at the top, further confirming the effectiveness of this method.

These differences in sugar concentrations can be attributed to various factors including the inherent sucrose content in the cocoa fruit, the extraction temperature, and the duration of the extraction process. According to Meilianti (2018), the conditions of the cooking process, particularly the temperature and duration, can cause partial inversion of sucrose into glucose and fructose. This reaction not only increases the solubility of these sugars but also alters their concentration profiles, which can significantly impact the taste and texture of the final candy product.

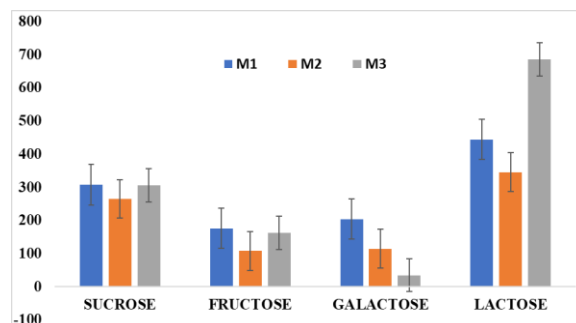


Figure 2: Extraction Method Optimization

The findings underscore the importance of selecting an appropriate extraction method to optimize sucrose yields for candy production. This selection is critical as it affects the sweetness, texture, and overall quality of the candy, making it essential for manufacturers to carefully consider the specific characteristics and efficiencies of different extraction techniques to achieve the desired product outcomes. This consideration ensures that the final candies not only meet quality standards but also align with consumer preferences for taste and texture.

3.2 Characterization of Produced Cocoa Candy

3.2.1 Sensory evaluation in seeded and non-seeded cocoa candy

Sensory evaluation is an essential aspect of food product development, particularly for confectionery items like jelly candies, where consumer first impressions can significantly dictate their market success. In our study, Figure 4 showcases the results of sensory evaluations that focused on attributes such as odour, texture, taste, colour, and overall appearance, each graded on a scale of 10. These sensory parameters are critical as they directly influence consumer preferences and reflect the product's quality and acceptability.

3.2.1.1 Odour evaluation

The evaluation of odour across the samples showed varied consumer perceptions. CJ3 received the lowest odour score at 4.67, indicating a less appealing aroma. In contrast, CJ2, CJ5, and CJ6 were perceived to have average odours with scores of 5.67. However, CJ1 stood out with the highest odour score at 7.00, suggesting that its formulation might be optimally balanced to enhance aromatic properties. Texture Analysis: Texture is another crucial sensory attribute,

with CJ6 and CJ4 providing the most satisfying mouth feel, both scoring 7.00. This indicates a well-accepted texture that likely contributes positively to the overall eating experience. In comparison, CJ2 and CJ3 had more moderate texture ratings at 5.33, suggesting less consumer satisfaction with these variants. CJ5 and CJ1 scored slightly better at 5.67 and 6.00, respectively, demonstrating that slight adjustments in the formulation can improve textural perception.

3.2.1.2 Taste evaluation

Taste evaluations highlighted CJ1, CJ5, and CJ6 as the top performers, each scoring a solid 7.00, indicative of a well-received flavour profile among consumers. CJ2, however, was less favoured, with a taste score of 5.33, reflecting the impact of different sugar compositions, pectin contents, and other ingredients on flavour. This variance underscores the importance of ingredient balance in achieving desired taste profiles in jelly candies.

3.2.1.3 Colour

Colour appearance can be significantly affected by natural and processing-induced changes, such as the oxidative breakdown of anthocyanins and the Maillard reaction during heating. These processes typically lead to darker, less vibrant products. CJ3, for instance, scored the lowest in colour at 5.00, while CJ4 and CJ5 showed relatively higher colour appeal with scores of 6.33, possibly due to specific ingredient ratios and processing conditions that mitigated some browning effects.

3.2.1.4 Overall appearance

The overall appearance, which aggregates the perception of all sensory attributes, was rated highest in CJ5 and CJ6, both achieving a score of 7.00. This suggests that despite the individual sensory variations, the final visual and perceptual integration of these samples was favourable, aligning closely with consumer expectations and preferences.

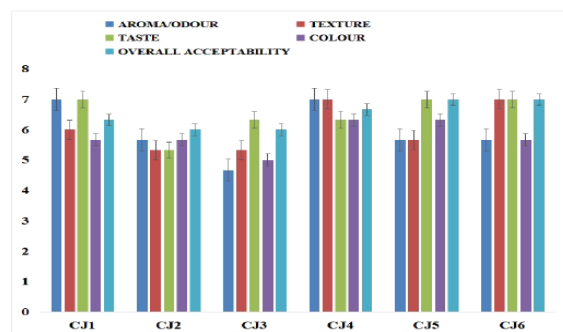


Figure 3: Sensory Evaluation in Seeded and Non-Seeded Cocoa Candy

3.2.2 Proximate analysis

3.2.2.1 Moisture content

The proximate Analysis results for the candy formulation are provided in Table 1, highlighting the nutritional dynamics as affected by varying amounts of sugar and pectin. The results from the study demonstrated a clear relationship between the moisture content and the varying levels of sugar and pectin in the candy formulations. For example, the CJ1 formulation, which contained 40 g of sugar and 1 g of pectin, had the lowest moisture content at 3.24%. This moisture content progressively increased with reductions in sugar content; CJ2 with 30g of sugar had 6.42% moisture, and further reductions led to even higher moisture contents in CJ3 and CJ4. The highest moisture content was observed in CJ5 at 18.03%, which contained only pectin without any added sugar. This trend underscores the role of sugar and pectin in water retention and texture management in candy production, aligning with findings by Meilianti (2018) who noted similar effects in jelly candies.

These findings contrast with studies like Yadav et al., (2021), who reported much higher moisture levels in candies made from different fruit pulps. The unique properties of cocoa juice, combined with the water-binding capacity of pectin, explain the lower moisture levels observed compared to other fruit-based candies.

Table 1: Proximate Composition (%) in the Candy and Seeded Candy

Sa mp le	Moistur e content	Ash	Fat	Crud e Fibre	Prote in	Carbo hydrat e
		1.61 ^b			1.68 ^c	
CJ ₁	3.24 ^a ± 0.01	± 0.01	6.92 ^a ± 0.32	0.00	± 0.02	86.50 ^d ± 0.30
CJ ₂	6.42 ^e ± 0.01	± 0.02	7.09 ^a ± 0.57	0.00	± 0.04	83.21 ^c ± 0.62
CJ ₃	9.98 ^e ± 0.01	± 0.01	7.36 ^a ± 0.34	0.00	± 0.07	78.57 ^b ± 0.49
CJ ₄	9.11 ^d ± 0.01	± 0.01	7.62 ^a _b ± 0.01	0.00	± 0.01	79.12 ^b ± 0.16
CJ ₅	18.03 ^g ± 0.01	± 0.01	6.93 ^a ± 0.01	0.00	± 0.02	71.18 ^a ± 0.64
CJ ₆	13.23 ^f ± 0.01	± 0.52	8.27 ^b ± 0.56	0.00	± 0.01	72.33 ^a ± 0.79

Values are means of three replicates ± standard deviation. Column means followed by different letters are significantly different at P < 0.05.

3.2.2.2 Fat content

The study highlighted trends in fat content that corresponded with sugar reductions. As sugar decreased, fat content increased, peaking in CJ4 at 7.62%. This suggests changes in the candy matrix affecting fat distribution.

3.2.2.3 Protein content

Conversely, protein content showed less variability, ranging from 1.34% to 2.42% across the samples. This indicates a minor but noticeable impact of the formulation changes on protein levels.

3.2.2.4 Carbohydrate content

Carbohydrate levels varied inversely with sugar content; the highest carbohydrate content was in CJ1 at 86.50%, which progressively decreased as sugar was reduced, aligning with the expected role of sugar as a primary carbohydrate source. These results are consistent with the research by Posadino et al., (2024) on quince candy, further illustrating the predominant role of carbohydrates in such confections.

The proximate composition analysis of cocoa juice-based candies offers valuable insights into how adjustments in sugar and pectin not only affect moisture content but also impact the overall nutritional quality of the candies. This knowledge is crucial for optimizing candy formulations to enhance their appeal, nutritional value, and shelf life, potentially leading to more innovative and health-conscious products in the confectionery industry.

3.2.3 Antioxidant properties of seeded and non-seeded cocoa candy

The evaluation of antioxidant properties in cocoa candy variants is critical in understanding how different formulations influence the effectiveness of bioactive compounds in mitigating oxidative stress. This aspect of food science, highlighted by Amoo et al., (2023); Ayoade et al., (2022) and Yadav et al. (2022), emphasizes the health implications of dietary antioxidants. The results, depicted in Figure 4, detail the antioxidant capacities of both seeded and non-seeded cocoa candies, providing a comparative insight based on changes in the recipe.

The analysis measured total phenolic content, flavonoid levels, Ferric Reducing Antioxidant Power (FRAP), DPPH radical scavenging activity, and ABTS radical scavenging capacity. Notably, phenolic concentrations showed a direct correlation with reduced sugar content, with the lowest sugar variant (CJ6, no sugar or pectin) displaying the highest phenolic value at 33.13 mg/g. This trend suggests that reducing sugar not only influences the sensory attributes but also enhances the phenolic content, consistent with findings from Cedeño-Pinos et al. (2023). Flavonoid content varied across the samples, starting at 8.01 mg/g in CJ1 and peaking at 11.87 mg/g in CJ2. A surprising decrease to 3.62 mg/g in CJ6 suggests that the absence of sugar and pectin impacts the stability or extraction efficiency of flavonoids within the candy matrix, possibly due to changes in the physical structure of the candy.

The FRAP results aligned with the increase in phenolic content, rising progressively from 27.23 mg/g in CJ1 to 35.30 mg/g in CJ6. This pattern reinforces the hypothesis that lower sugar formulations enhance antioxidant power, offering a nutritional advantage in candy production. The DPPH

assay results indicated a complex relationship between sugar content and free radical scavenging ability. While there was an initial decrease in antioxidant capacity with sugar reduction from CJ1 to CJ3, this trend reversed from CJ4 to CJ6, suggesting that factors other than sugar concentration may influence antioxidant activities in these candies. The ABTS assay provided insights into the antioxidant capacities with a varied pattern of results. Starting at 185.64 mM Trolox in CJ1, the levels fluctuated across the formulations, reaching a high in CJ3 (364.01 mM Trolox), dropping in CJ4, and then rising again in CJ5 and CJ6. These fluctuations highlight the dynamic interactions between ingredients that affect the antioxidant potential of the candies.

The study of antioxidant properties in cocoa juice-based candies reveals that ingredient modifications, particularly sugar and pectin adjustments, significantly impact the antioxidant profiles. These results provide valuable insights for the confectionery industry, suggesting that lower sugar candies not only meet consumer preferences for healthier options but also offer enhanced nutritional benefits. This research contributes to the broader understanding of how ingredient selection can influence the health-promoting qualities of food products, aligning with current trends towards more health-conscious food choices.

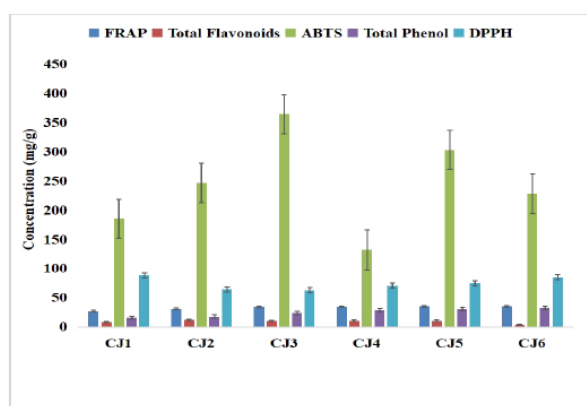


Figure 4: Antioxidant Concentration in Seeded and Non-Seeded Cocoa Candy

3.2.4 Antinutrients composition in seeded and non-seeded cocoa candies

The analysis of antinutrients components in various formulations of cocoa candy, as detailed in Figure 6, reveals significant insights into the levels of oxalates, phytate, alkaloids, saponins, and tannins present in these products. Antinutrients, while often considered inhibitors of nutrient absorption, can also provide health benefits, creating a nuanced impact on diet and health (Amooet al., 2023; Ajayi et al., 2022).

Oxalate levels varied across the candy samples, with the highest level recorded in CJ1 (1.51 mg/g) and the lowest in CJ6 (0.48 mg/g). The trend of decreasing oxalate content from CJ1 to CJ6 suggests that adjustments in the candy formulation can effectively reduce the potential risks associated with oxalate consumption, such as reduced mineral bioavailability and kidney stone formation. The findings corroborate research by Bargagli et al. (2020), which discusses the negative impact of dietary oxalates on calcium absorption and the associated health risks.

Similarly, phytate levels showed a descending pattern from CJ1 (7.90 mg/g) to CJ6 (4.90 mg/g). Phytates, known for chelating essential minerals like iron and zinc, can hinder their absorption. The observed reduction in phytate content across the samples suggests an improved nutritional profile of the candies, potentially enhancing the bioavailability of these important minerals. This aligns with studies like Zhang et al. (2022), which emphasize the importance of reducing phytate levels in foods to improve mineral uptake.

Alkaloid content also decreased from CJ1 to CJ6, highlighting the impact of specific processing or formulation techniques in minimizing their presence in the final product. While alkaloids can be toxic in high quantities, they also possess medicinal properties, making their controlled presence in foods significant. Bhambhani et al. (2021) explore the dual nature of alkaloids, emphasizing the need for a balanced approach in food manufacturing to harness their benefits while avoiding potential risks. The study noted an increase in saponin levels, particularly in CJ6 (33.14 mg/g), which may be attributed to formulation changes aimed at enhancing certain health benefits, such as cholesterol reduction. Research by Luo et al. (2020) supports the beneficial role of saponins in lowering cholesterol levels,

indicating a positive impact on cardiovascular health. Tannins, which increased from CJ1 to CJ6, are recognized both for their antioxidant properties and their ability to inhibit protein and nutrient digestion. The increase in tannin content could enhance the antioxidant capacity of the candies, though it may also reduce the bioavailability of certain nutrients. Oluwole et al. (2022) discuss the complex role of tannins, noting both their health-promoting and inhibiting effects on nutrient absorption.

The detailed assessment of antinutrients levels in cocoa candies illustrates the delicate balance between maximizing health benefits and minimizing dietary risks through careful formulation adjustments. This study highlights the potential for candy manufacturers to develop products that not only satisfy consumer tastes but also contribute positively to health, aligning with growing consumer interest in functional and healthful foods. The findings underscore the importance of understanding both the beneficial and adverse effects of antinutrients, guiding the development of confectionery products that are both enjoyable and nutritionally advantageous.

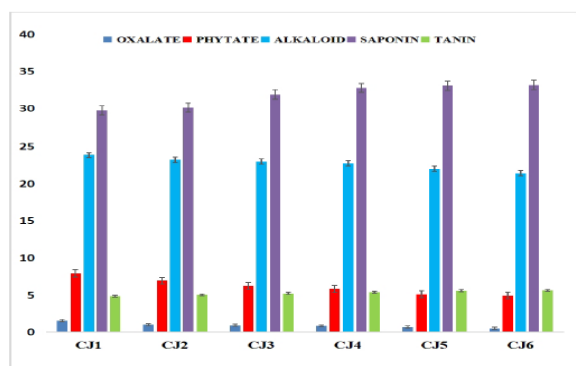


Figure 5: Antinutrient Composition in Seeded and Non-Seeded Cocoa Candy

3.2.5 Mineral composition of cocoa candy variants

The detailed analysis of the mineral content in different cocoa candy variants, as depicted in Table 2, underscores the significant contribution of essential minerals to the nutritional profile of these candies. Calcium and potassium, key minerals for bone health and cellular functions, respectively, are found in the highest concentrations in CJ6, with calcium at 20.91 mg/g and potassium at 22.97 mg/g. This high concentration in CJ6 suggests potential health benefits, particularly for bone strength and cardiovascular function. However, CJ2 shows notably lower levels of these minerals, potentially making it less beneficial in these specific areas. Magnesium, which is vital for numerous enzymatic reactions within the body, is also most concentrated in CJ6 at 16.71 mg/g. This suggests that CJ6 may be particularly beneficial for metabolic health and anti-inflammatory benefits. Trace minerals such as copper and chromium, which play roles in antioxidant deficiencies and glucose metabolism, respectively, are similarly highest in CJ6, indicating its potential utility in enhancing these physiological processes.

Table 2: Mineral Composition (mg/g) of Cocoa Candy

Sample	MINERALS											
	Ca	K	Mg	Cu	Cr	Na	Fe	Zn	P	Mn	Se	
CJ ₁	8.09 ^b ± 0.61	8.89 ^b ± 0.83	6.47 ^a ± 0.32	0.07 ^c ± 0.01	0.03 ^b ± 0.01	11.92 ^a ± 0.02	0.39 ^b ± 0.01	0.4 ^a ± 0.01	4.77 ^b ± 0.12	0.04 ^a ± 0.02	0.01 ^a ± 0.00	
CJ ₂	3.47 ^a ± 0.21	3.81 ^a ± 0.12	6.82 ^a ± 0.51	0.03 ^b ± 0.01	0.03 ^b ± 0.01	12.11 ^a ± 0.03	0.4 ^b ± 0.01	0.93 ^b ± 0.01	5.43 ^b ± 0.22	0.07 ^c ± 0.02	0.02 ^a ± 0.01	
CJ ₃	9.19 ^b ± 0.63	10.1 ^b ± 0.42	7.35 ^a ± 0.21	0.08 ^c ± 0.00	0.04 ^b ± 0.01	13.54 ^b ± 0.02	0.44 ^b ± 0.01	1.06 ^b ± 0.03	2.04 ^a ± 0.04	0.05 ^a ± 0.01	0.02 ^a ± 0.01	
CJ ₄	13.17 ^c ± 0.45	14.47 ^c ± 0.71	10.52 ^b ± 0.62	0.11 ^c ± 0.01	0.05 ^b ± 0.01	19.39 ^c ± 0.01	0.64 ^c ± 0.01	1.52 ^b ± 0.04	7.77 ^c ± 0.03	0.01 ^a ± 0.01	0.03 ^a ± 0.01	
CJ ₅	14.48 ^c ± 0.76	15.9 ^c ± 0.26	11.57 ^b ± 0.52	0.13 ^c ± 0.01	0.06 ^b ± 0.02	21.32 ^d ± 0.02	0.71 ^c ± 0.02	1.67 ^b ± 0.05	8.54 ^c ± 0.04	0.08 ^c ± 0.02	0.03 ^a ± 0.01	
CJ ₆	20.91 ^d ± 1.32	22.97 ^d ± 1.89	16.71 ^c ± 0.99	0.19 ^c ± 0.01	0.09 ^c ± 0.01	30.79 ^e ± 1.21	1.02 ^d ± 0.01	2.41 ^c ± 0.01	12.33 ^d ± 0.21	0.11 ^c ± 0.01	0.05 ^b ± 0.01	

Value are means of triplicate ± standard deviation. Column means followed by different letters are significantly different at P < 0.05

The sodium content in CJ6, at 30.79 mg/g, is the highest among the samples. While sodium is crucial for maintaining proper fluid balance, its elevated levels in CJ6 could pose risks for individuals with conditions such as hypertension or cardiovascular diseases, highlighting a potential dietary concern. Iron and zinc, essential for oxygen transport and immune function, respectively, also peak in CJ6, with iron at 1.02 mg/g and zinc at 2.41 mg/g. These concentrations suggest that CJ6 could effectively support energy production and bolster immune health. Phosphorus, manganese, and selenium, which are important for bone health, enzyme functions, and combating oxidative stress, respectively, also show their highest levels in CJ6. This pattern suggests a comprehensive mineral profile in CJ6 that could significantly contribute to dietary quality and address common nutritional deficiencies. The consistent high levels of minerals in CJ6 could be attributed to specific ingredient differences or processing methods that enhance its mineral content. While the nutritional benefits of such a rich mineral profile are clear, the high sodium content necessitates a cautious approach to its consumption, especially for individuals with specific health considerations.

Table 2 not only highlights the potential of cocoa-based candies as a source of essential minerals but

also underscores the importance of careful formulation. Manufacturers must consider both the health benefits and potential risks associated with mineral concentrations, especially sodium, to tailor products that meet nutritional goals while ensuring consumer safety. This comprehensive mineral profile provides valuable insights for both manufacturers aiming to enhance their product offerings and consumers seeking nutritious additions to their diet.

CONCLUSION

This research embarked on a comprehensive exploration to produce and characterize candy derived from cocoa (*Theobroma cacao* L.) juice. The study aimed to optimize various aspects of production to enhance the end product's quality and appeal, successfully achieving significant advancements in cocoa candy production. The findings offer deep insights into practical manufacturing aspects and have potential implications for industrial applications and consumer health. The study identified the most effective extraction method for maximizing essential sugar yields from cocoa juice, with Method 1 providing the highest sucrose concentration. This is crucial for manufacturers seeking to refine extraction processes to enhance product sweetness and texture efficiently.

Through quantitative and qualitative sugar analyses, the study revealed diverse sugar compositions within cocoa juice, including sucrose, fructose, galactose, and lactose, enabling manufacturers to tailor recipes for improved taste and texture.

Sensory evaluation provided insights into consumer perceptions regarding odor, taste, texture, and overall appeal, which are essential for aligning candy formulations with consumer expectations in a competitive market. Additionally, proximate and mineral composition analysis demonstrated how variations in formulations could influence nutritional content, suggesting pathways to fortify candies with minerals like calcium, potassium, and magnesium without compromising taste. The evaluation of antioxidant properties and anti-nutrient activities offered a nuanced view of the health impacts of cocoa candies. Some formulations enhanced antioxidant levels, providing protective benefits against oxidative stress, while reductions in anti-nutrients like oxalates and phytates in specific samples improved the nutritional value by enhancing mineral bioavailability.

Building on these findings, the study suggests several avenues for further research to deepen insights and enhance confectionery products. These include exploring alternative extraction techniques, conducting longitudinal sensory analyses, integrating natural sweeteners, and adding nutritional fortifications. Comparative studies with other fruit juices and market-oriented research tailored to consumer demographics and preferences could also expand product lines and diversify the range of flavored candies. Additionally, assessing the environmental impact of production and conducting a techno-economic analysis would ensure the sustainability and economic viability of new production methods. Ultimately, this research not only advances the boundaries of candy production by integrating health considerations into traditionally indulgent food products but also enriches consumer choices, providing a foundation for producing healthier, more appealing cocoa-based candies. The detailed findings and recommendations contribute significantly to the confectionery industry, offering valuable insights for food scientists and

manufacturers aiming to innovate and improve their offerings.

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