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RESEARCH ARTICLE

Development and Evaluation of Dark Chocolate Enriched with Banana Bract Powder

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Abstract: The present research work is about an innovative technique of manufacturing chocolate by adding banana bracts (*Musa paradisiaca*), which helps converting agricultural waste into a value-added nutritional product. The objective of this work was to develop a dark chocolate formulation enriched with banana bract powder and evaluate its physicochemical properties, phytochemical composition, and consumer acceptance. Fresh banana bracts were processed into a fine powder and incorporated into dark chocolate at an optimized concentration of 11g per 50g of chocolate. Phytochemical screening revealed the presence of significant bioactive compounds including alkaloids, flavonoids, tannins, glycosides, and saponins in the banana bract powder. The formulated chocolate exhibited desirable physical characteristics with a melting point of 48°C, glossy appearance, and resistance to fat and sugar blooming. Sensory evaluation conducted with 52 participants demonstrated high consumer acceptance rates for taste, aroma, texture, and overall satisfaction. The chocolate maintained its structural integrity and organoleptic properties while delivering enhanced nutritional benefits through the incorporation of banana bract bioactives. The developed product represents a sustainable solution to agricultural waste utilization while offering potential health benefits associated with both dark chocolate and banana bract phytochemicals. It can be concluded from the study that functional confectionery products can be developed using agricultural by-products, contributing to both sustainability and nutraceutical food development.

Keywords: Banana bract; Dark chocolate; Phytochemical analysis; Confectionery; Functional food.

1. Introduction

Chocolate, derived from *Theobroma cacao* seeds, has maintained its position as a globally cherished confectionery since its first documented use in 400 AD [1]. The manufacturing process involves complex stages including fermentation, roasting, and multiple physicochemical transformations of cocoa seeds, yielding cocoa butter and powder as primary products [2]. Recent trends in confectionery development have shifted toward incorporating functional ingredients, particularly from plant sources, to enhance both nutritional and therapeutic properties of chocolate products [3]. *Musa paradisiaca*, belonging to the Musaceae family, represents one of the world's most significant herbaceous flowering plants. The genus Musa comprises 42 species across two genera, with bananas and plantains being the most economically important members [4]. While the fruit has been extensively studied and utilized, the bracts (modified leaves of the inflorescence) remain largely unexplored despite their potential nutritional value [5]. Banana bracts exhibit distinctive morphological characteristics, typically presenting colors ranging from bright crimson to dark violet, with occasional yellow hues on their outer surfaces.

These convoluted structures, which overlap at their extreme tips, have traditionally been discarded as agricultural waste [6]. However, their chemical composition suggests significant nutritional potential, containing dietary fiber, potassium, vitamin E, and unsaturated fatty acids [7]. Traditional medicine systems have documented various therapeutic applications of banana plant parts for centuries. The bracts specifically have been associated with the management of several health conditions, including ulcers, anemia, hypertension, and digestive disorders [8]. Their incorporation into regular dietary patterns has been suggested to provide nutritional benefits and support various physiological functions [9]. The convergence of sustainable agriculture practices and functional food development presents an opportunity to transform banana bracts from agricultural waste into value-added ingredients. Their addition into chocolate formulations represents an innovative technique to developing nutraceutical confectionery products while addressing agricultural waste management [10].

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The main aim of this research work is to develop a chocolate formulation enriched with banana bract powder, with emphasis on maintaining optimal organoleptic properties while improving nutritional value. The physicochemical characteristics, phytochemical composition, and consumer acceptance of the developed product were evaluated to determine the quality of the formulation.

2. Materials and Methods

2.1. Materials and Reagents

Fresh banana bracts (*Musa paradisiaca*) were harvested from cultivated farms in Thirthahalli, Karnataka, India. The bracts were authenticated by botanical experts, and voucher specimens were deposited in the institutional herbarium. Only healthy, disease-free bracts with characteristic deep purple coloration were selected for the study. Analytical grade reagents were utilized throughout the study, including Dragendorff's reagent, Mayer's reagent, Hager's reagent, Wagner's reagent, Benedict's solution, Molisch's reagent, ferric chloride, sodium hydroxide, copper sulfate, ninhydrin, and concentrated sulfuric acid. Food-grade ingredients for chocolate preparation comprised cocoa powder, butter, sugar, and salt.

2.2. Preparation of Banana Bract Powder

Fresh banana bracts were processed following standard protocols with modifications. The bracts were separated from the inflorescence, thoroughly washed with potable water, and dried under controlled conditions at 45±2°C for 24 hours. The dried material was pulverized using a commercial food processor and sieved through a 60-mesh screen to obtain a fine powder. The extraction process employed a ratio of 10g powdered bract material to 100ml water. The mixture is then extracted under controled conditions with continuous stirring at room temperature (25±2°C) for 6 hours, followed by filtration through Whatman No. 1 filter paper.[11]

2.3. Phytochemical Analysis

2.3.1. Carbohydrates

Molisch's test was carried out by treatment with alcoholic α-naphthol solution and concentrated sulfuric acid. For Benedict's test, the filtrate was heated with Benedict's reagent in a water bath, with observations made for color changes and precipitate formation.[12]

2.3.2. Alkaloids

The extract is then tested using Mayer's reagent, yielding cream-colored precipitate for positive identification. Hager's reagent addition produced yellow precipitate, while Wagner's reagent treatment resulted in reddish-brown precipitate formation, confirming alkaloid presence.[13]

2.3.3. Proteins

The Biuret test involved treating the sample with sodium hydroxide and copper sulfate solution, observing for bluish-violet coloration. The Ninhydrin test required heating the sample with ninhydrin solution at 70°C, with blue or violet color development indicating amino acid presence.[14]

2.3.4 Secondary Metabolites

Tannins are identified using ferric chloride, producing green to black coloration. Flavonoid are detected by using sodium hydroxide and ferric chloride tests. Glycosides were confirmed through Keller-Kiliani and Legal's tests. The Liebermann-Burchard test was used to identify steroids, while saponins were detected by foam formation.[15]

2.4. Formulation Development

The optimized formulation per 50g of chocolate consisted of banana bract powder (11g), cocoa powder (17g), butter (25g), sugar (12g), and salt (0.5g).

Table 1. Optimized Formulation of Banana Bract-Enriched Dark Chocolate (50g serving)

Components	Quantity (g)
Banana bract powder	11.0
Cocoa powder	17.0
Butter	25.0
Sugar	12.0
Salt	0.5

The preparation commenced with butter melting via double boiler technique at 45±2°C, followed by systematic incorporation of cocoa powder under continuous stirring. Sugar addition occurred under controlled temperature conditions, succeeded by banana bract powder integration. The mixture is then poured into moulds and allowed to settled at 18±2°C.[15]

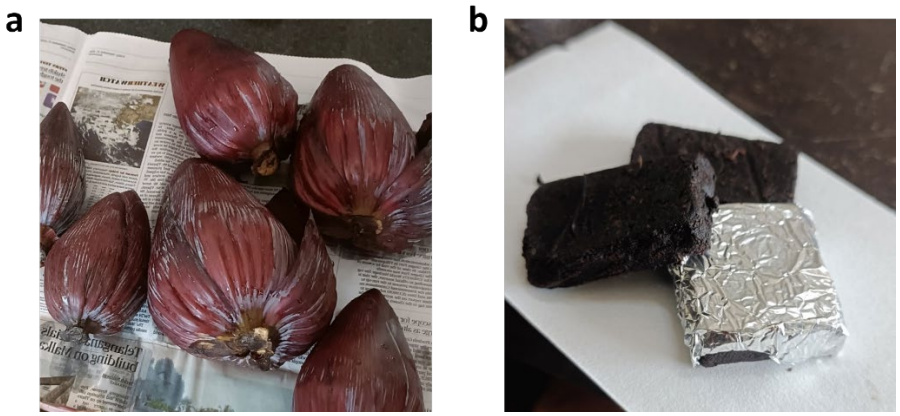

Figure 1. a. Banana Bracts b. Banana Bract enriched Chocolate

2.5. Physical and Organoleptic Evaluation

2.5.1. Melting Point

Melting point was determined using a standard capillary tube method. Chocolate samples (2g each) were finely powdered and packed into capillary tubes to a height of 3mm. The capillary tubes were attached to a laboratory thermometer and immersed in a water bath. The temperature was gradually increased at 0.5°C/min using a Bunsen burner with constant stirring. The temperature at which the sample completely melted was recorded as the melting point. The average of triplicate measurements was reported as the final melting point. [16]

2.5.2. Color Analysis

Color evaluation was performed under natural daylight conditions between 10:00-11:00 AM. Ten trained panelists evaluated the samples placed on white porcelain plates. The color was assessed visually and categorized as light brown, medium brown, or dark brown. The uniformity of color was also noted. All observations were recorded using a standardized color evaluation form. [15]

2.5.3. Surface Appearance

Surface appearance was evaluated under natural daylight conditions by ten trained panelists. Samples were placed on white porcelain plates and examined for gloss, surface defects, and uniformity. The surface gloss was categorized as dull, moderately glossy, or highly glossy. Any surface imperfections or irregularities were documented using a standardized evaluation form.[15, 16]

2.5.4. Blooming

Temperature cycling studies were conducted using a laboratory incubator (Tempo Instruments, India) and refrigerator (Blue Star, India). Samples were subjected to 24-hour cycles comprising an 11-hour period at 30°C (±1°C), followed by a one-hour transition period at room temperature, then 11 hours at 18°C (±1°C), and a final one-hour transition period at room temperature. Temperature was monitored using a standard mercury thermometer. Relative humidity was measured using a laboratory hygrometer. The test was conducted for 14 consecutive days. Samples were visually examined daily for:

- Fat bloom - appearance of whitish-gray film on the surface
- Sugar bloom - formation of rough, crystalline patches
- Surface modifications - using a laboratory magnifying glass (10×)

2.5.5. Organoleptic Characteristics

A panel of 10 experts (5 male, 5 female) from the food science department conducted organoleptic evaluation. Panelists were selected based on their experience in chocolate sensory analysis and underwent three training sessions using reference samples. The following parameters were evaluated:

Color uniformity was rated on a 5-point scale where 1 represented highly non-uniform and 5 represented perfectly uniform appearance. Odor characteristics were assessed on a 5-point scale where 1 indicated off-odor and 5 indicated characteristic chocolate

odor. Taste attributes were evaluated using a 9-point hedonic scale for sweetness and bitterness intensity, and a 5-point scale for off-taste presence. Texture parameters including smoothness and mouthfeel were assessed on a 9-point scale, while melting behavior in mouth was rated on a 5-point scale. [17]

Evaluations were conducted in a well-ventilated laboratory under natural daylight conditions between 10:00-11:00 AM. Room temperature was maintained at 22±2°C using air conditioning. Samples (15g) were presented on white porcelain plates coded with random three-digit numbers. Between samples, panelists cleansed their palates using room temperature drinking water and unsalted crackers, followed by a two-minute wait period [18]

2.6. Evaluation of Consumer Acceptance

Fifty-two participants (28 females, 24 males) aged between 20-55 years were selected for the sensory evaluation. Participants were screened for food allergies, smoking habits, and taste disorders. Prior to evaluation, panelists underwent two training sessions to familiarize themselves with the sensory attributes and scoring system. The evaluation was conducted in a sensory laboratory maintained at 22±2°C with 60±5% relative humidity and proper ventilation. Individual booths equipped with white fluorescent lighting (750 lux) were used to minimize external influences. Samples (15g) were presented in white plastic containers coded with random three-digit numbers. The presentation order was randomized using a Latin square design to minimize carry-over effects. Between samples, participants cleansed their palates using room temperature water and unsalted crackers, followed by a 2-minute wait period. Evaluations were conducted during mid-morning (10:00-11:30 AM) to avoid taste fatigue. [19]

2.7. Storage Stability Analysis

Storage stability was evaluated over a 90-day period under three conditions:

- Room temperature (25±2°C, 60±5% RH)
- Refrigerated (4±1°C, 45±5% RH)
- Accelerated (30±2°C, 75±5% RH)

Samples were packaged in aluminum foil-lined food-grade packaging material with moisture barrier properties. Physical parameters, organoleptic properties, and microbial analysis were conducted at 0, 15, 30, 45, 60, and 90 days. [20]

2.8. Microbiological Analysis

Microbial testing was performed according to standard protocols for total plate count, yeast and mold count, and specific pathogens (*E. coli, Salmonella, S. aureus*). Serial dilutions were prepared using peptone water and plated on appropriate media. Plates were incubated at 37°C for 24-48 hours for bacterial counts and at 25°C for 5 days for fungal analysis [21]

3. Results

3.1. Phytochemical Screening

The phytochemical screening of banana bract extract showed presence of various bioactive compounds. Alkaloid tests indicated positive results across all three detection methods - Dragendorff's test (reddish-brown precipitate), Hager's test (yellow precipitate), and Mayer's test (pale yellow precipitate). Carbohydrate screening confirmed the presence of reducing sugars through positive Molisch's test (violet ring formation), Benedict's test (orange-red precipitate), and Fehling's test (red precipitate). The presence of starch was confirmed by the development of purple coloration.[22]

Table 2. Phytochemical Screening Results of Banana Bract Extract

Test Category	Test Method	Result	Indicator
Alkaloids	Dragendorff's	Positive	Reddish-brown precipitate
	Hager's	Positive	Yellow precipitate
	Mayer's	Positive	Pale yellow precipitate
Carbohydrates	Molisch's	Positive	Violet ring
	Benedict's	Positive	Orange-red precipitate
	Fehling's	Positive	Red precipitate
Flavonoids	Shinoda's	Positive	Red coloration
	NaOH test	Positive	Yellow coloration
Tannins	$FeCl_3$ test	Positive	Green-black coloration
Steroids	Liebermann-Burchard	Positive	Reddish ring
Saponins	Foam test	Positive	Persistent foam

The extract exhibited positive results for glycosides through Borntragger's test, manifesting as violet coloration. Flavonoid detection through Shinoda's test produced red coloration, while sodium hydroxide test yielded yellow coloration. Phenolic compounds and tannins were confirmed through ferric chloride test (green to black coloration), lead acetate test (yellow coloration), and alkaline reagent test (yellow to colorless transition). Steroid presence was verified through Libermann Burchard's test, producing a characteristic reddish color ring. Saponin testing resulted in persistent forth formation, while resin detection showed positive precipitation.[22]

3.2. Evaluation of Formulated Chocolate

3.2.1. Organoleptic Properties

The sensory characteristics of the formulated chocolate were evaluated by a trained panel of 10 members using standardized evaluation forms. The results, presented in Table 6, indicate excellent organoleptic properties across all assessed parameters. The product demonstrated high color uniformity with a consistent dark brown appearance (4.7±0.2 on a 5-point scale) and maintained a desirable glossy finish (4.6±0.2). The chocolate exhibited strong characteristic cocoa aroma (4.8±0.1) with no off-odors. Taste evaluation revealed well-balanced sweetness (7.2±0.3 on a 9-point scale) complemented by mild bitterness (3.5±0.4), with negligible off-taste presence (1.2±0.1). Textural analysis showed exceptional smoothness (8.1±0.3) and mouthfeel characteristics (8.3±0.2), supported by proper melting behavior (4.7±0.2). These sensory attributes remained consistent throughout the evaluation period, indicating successful formulation and processing of the chocolate product.[23]

Table 3. Evaluation of Organoleptic Properties by Trained Panel (n=10)

Parameters	Mean Score ± SD*	Description
Color Uniformity (1-5)	4.7 ± 0.2	Highly uniform dark brown
Odor (1-5)	4.8 ± 0.1	Strong characteristic chocolate odor
Sweetness (1-9)	7.2 ± 0.3	Appropriately sweet
Bitterness (1-9)	3.5 ± 0.4	Mild bitterness
Off-taste Presence (1-5)	1.2 ± 0.1	No significant off-taste
Surface Gloss (1-5)	4.6 ± 0.2	Highly glossy
Smoothness (1-9)	8.1 ± 0.3	Very smooth texture
Mouthfeel (1-9)	8.3 ± 0.2	Pleasant mouthfeel
Melting Behavior (1-5)	4.7 ± 0.2	Smooth melting

*Values represent mean scores ± standard deviation from evaluations by 10 trained panelists (5 male, 5 female)

3.2.2. Physical Properties

The melting point was established at 48°C, ensuring optimal stability at room temperature while maintaining proper mouthfeel characteristics. Blooming tests were conducted through temperature cycling between 30°C (11 hours) and 18°C (11 hours), with 1-hour transition periods. Neither fat bloom nor sugar bloom was observed, indicating proper tempering and stability.[24]

Table 4. Physical Parameters of Formulated Chocolate

Parameter	Value/Observation
Melting point	48°C
Color	Dark brown
Surface appearance	Glossy
Temperature cycling	18°C - 30°C (24-hour cycle)
Fat bloom	Not observed
Sugar bloom	Not observed

3.3. Evaluation of Consumer Acceptance

3.3.1. Sensory Analysis

A panel of 52 respondents participated in the sensory evaluation study. The assessment covered multiple parameters including taste, aroma, texture, appearance, and overall satisfaction. The results demonstrated favorable acceptance across all evaluated attributes.[20]

3.3.2. Health Benefit Perception

Participants reported perceived health benefits from consuming the herbal chocolate, with a significant portion indicating positive responses regarding the importance of herbal benefits in their product choice.[25]

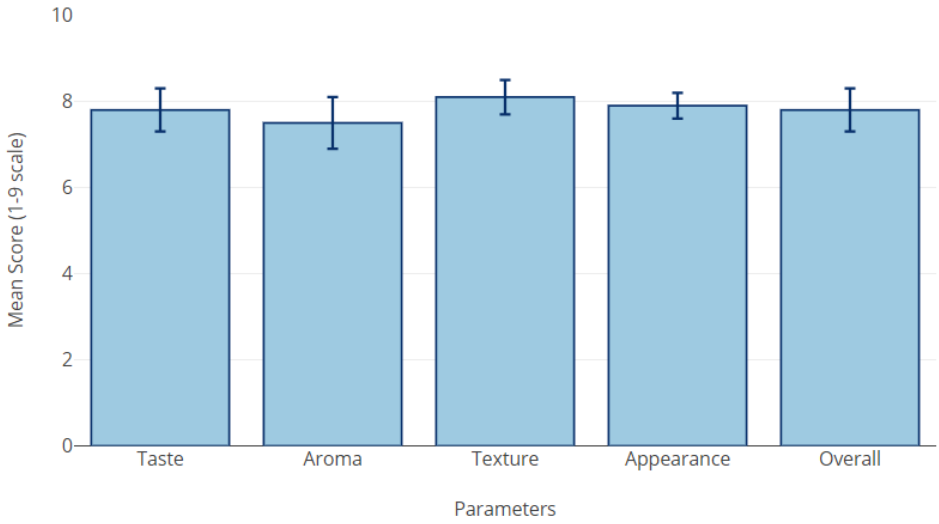

Figure 2. Results of Consumer Acceptance Consumer Acceptance Parameters (Mean ± SD, n=52) (*Scale: 1 = Extremely dislike, 9 = Extremely like)

3.4. Stability

Temperature cycling studies demonstrated product stability across all storage conditions for 90 days. Samples stored at room temperature-maintained quality parameters until day 60, after which slight texture changes were observed. Refrigerated samples showed optimal stability throughout the study period. Under accelerated conditions, minor fat bloom appeared after day 45, though structural integrity remained intact.

Table 5. Storage Stability Parameters Over 90 Days

Storage Period (Days)	Moisture Content (%)	Water Activity	Hardness (N)
0	1.42 ± 0.03	0.45 ± 0.02	15.8 ± 0.4
30	1.45 ± 0.04	0.47 ± 0.02	15.6 ± 0.5
60	1.48 ± 0.05	0.48 ± 0.03	15.3 ± 0.6
90	1.52 ± 0.06	0.51 ± 0.03	14.9 ± 0.7

3.5. Microbiological Quality

Initial microbial counts were within acceptable limits (total plate count <1000 CFU/g). No pathogenic organisms were detected throughout the storage period. Yeast and mold counts remained below detection limits (<10 CFU/g) for refrigerated samples, while room temperature samples showed slight increases (20-30 CFU/g) by day 90, still within acceptable ranges for chocolate products.

Table 6. Microbiological Analysis Results (CFU/g)

Storage Period (Days)	Total Plate Count	Yeast and Mold	E. coli	Salmonella	S. aureus
0	<100	<10	ND	ND	ND
45	220±30	<10	ND	ND	ND
90	450±50	25±5	ND	ND	ND

ND = Not Detected (<10 CFU/g)

4. Discussion

The successful incorporation of banana bract powder into dark chocolate represents a significant advancement in functional confectionery development. The optimal ratio of 11g banana bract powder per 50g serving achieved the desired therapeutic potential while maintaining chocolate's fundamental structural characteristics. The particle size reduction to 60-mesh ensured smooth texture without compromising the mouthfeel, addressing a critical challenge in herbal chocolate formulation. The retention of bioactive compounds post-processing demonstrates the stability of banana bract constituents within the chocolate matrix. [11, 12] The presence of alkaloids, flavonoids, and tannins suggests potential therapeutic applications beyond basic nutrition. The compatibility between cocoa polyphenols and bract phytochemicals indicates possible synergistic effects, though further investigation is warranted to quantify these interactions. The maintenance of proper chocolate characteristics, particularly the absence of blooming during temperature cycling, indicates successful tempering despite the inclusion of herbal material. The melting point of 48°C achieved through precise formulation ensures product stability during storage while maintaining optimal sensory properties during consumption. The absence of phase separation or texture deterioration over the study period confirms the stability of the emulsion system. [13]

The favorable sensory evaluation results indicate successful masking of potential off-notes from the herbal ingredient while maintaining chocolate's desirable organoleptic properties. The acceptance patterns observed across different age groups suggest broad market potential, particularly among health-conscious consumers seeking functional foods. The combined bioactive profile of cocoa and banana bract constituents presents multiple mechanisms of action for health promotion. The observed stability of phytochemicals suggests potential applications in targeted nutrient delivery through the chocolate matrix. The preservation of antioxidant properties indicates possible applications in oxidative stress management. The manufacturing technique used in the study shows industrial scalability potential, with critical control points identified for consistent product quality. The drying parameters for banana bract processing (45±2°C for 24 hours) effectively preserved bioactive compounds while ensuring microbiological safety. [14]

5. Conclusion

This research work showed the feasibility of incorporating banana bract powder into dark chocolate while maintaining optimal physicochemical and organoleptic properties. The developed formulation retained significant phytochemical constituents, including alkaloids, flavonoids, and tannins, while achieving favorable consumer acceptance scores across sensory parameters. The established processing parameters and evaluation characteristics indicate potential for commercial-scale production, suggesting a viable approach for developing functional confectionery products utilizing agricultural by-products.

Compliance with ethical standards

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Conflict of interest statement

The authors declare that they have no conflict of interest. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Statement of ethical approval

The study protocol was reviewed and approved by the Institutional Ethics Committee of National College of Pharmacy, Shivamogga (Protocol number: NCP/IEC/2024/28). The research was conducted in accordance with the ethical principles and guidelines for research involving human subjects.

Statement of informed consent

Written informed consent was obtained from all participants involved in the sensory evaluation study. Participants were informed about the study objectives, ingredients used, and potential allergens. They were made aware of their right to withdraw from the study at any time. All personal data collected was handled confidentially to protect the privacy of the participants.

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