Research Article

Development And Physicochemical Characterization Of An Ambient-Processed Tender Coconut-Banana Chewable Confectionery

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Abstract:

Soft confectionery formulations traditionally rely on gelatin or pectin with plain water as the primary hydration medium, limiting bioactive retention and requiring heat processing that degrades natural electrolytes. This study developed a coconut-banana chewable confectionery using tender coconut water as the sole hydrating medium for gum arabic. Five formulations were optimized using a heat-free process: tender coconut water (7.35 g) exclusively hydrated gum arabic (8.16 g) at room temperature for 20 minutes, followed by incorporation of edible glue (7.33 g), banana powder (10.88 g), coconut milk powder (7.45 g), icing sugar (47.62-54.42 g), and triple mint encapsulation (peppermint extract 0.21 g, mint mojito 0.29 g, blue food colour 0.014 g). The resulting dough was hand-shaped into 2-3 g chewable pieces and ambient-dried. Treatment T3 demonstrated optimal characteristics: moisture content 3.36% [IS 7874 (Part 1): 1975], pH 4.19 [GTL/SOP/FR-001], absent yeast/mold (<10 CFU/g) [FSSAI 2021], and superior sensory scores (8.1-8.2/9 hedonic scale for texture, taste, color). Effectiveness index analysis confirmed T3's superiority (total score 0.87) over other treatments. The heat-free process may help retain the natural characteristics of tender coconut water, producing a stable confectionery and achieving FSSAI-compliant microbiological safety and commercial-grade sensory appeal. Edible glue cohesion provided textural stability for low-sugar hydrocolloid candies. T3 formulation offers a scalable, preservative-free product suitable for MSME-level production with potential functional hydration benefits.

Keywords: Tender coconut water, gum arabic, chewable confectionery, hydrocolloid candy, ambient processing and physicochemical properties.

1. Introduction:

Confectionery products are an important segment of the food industry and are generally categorized into hard and soft (chewy or jelly) candies. This classification is based on factors such as moisture content, sugar composition, and texture (1). Hard candies are manufactured by concentrating sucrose–glucose syrup systems to very low moisture levels, leading to the formation of an amorphous glassy matrix that imparts a rigid and brittle texture (1). Soft confectionery products, unlike hard candies, are formulated with higher moisture content and hydrocolloids, resulting in a flexible, chewable texture (2). Gum arabic (acacia gum) is a plant-derived hydrocolloid composed primarily of polysaccharides and glycoproteins and is widely employed in food systems as an emulsifying, stabilizing, and film-forming agent (3). In soft candies and gummy formulations, gum arabic is valued for its low viscosity at high solid concentrations and its capacity to form flexible films that enhance chewability and structural integrity (2,4,5). Recent trends in confectionery research emphasize the use of plant-derived ingredients and functional liquids to enhance nutritional value while expanding sensory diversity (6). Studies have reported the application of coconut water in gelified desserts and beverages, indicating that it can withstand thermal processing while forming gel structures with satisfactory texture and sensory acceptability (7,8,9). Existing coconut-derived products, including coconut flour, coconut milk, and coconut-based candies, indicate the feasibility of integrating coconut solids into sugar-based confectionery formulations with satisfactory product composition and consumer acceptability (10). Banana, a commonly available tropical fruit, has been processed into various value-added confectionery formulations (11,12). Research on banana-based candies, such as banana–date–skim milk and banana–ginger formulations, has shown good sensory acceptability and improved functional attributes, and products derived from banana pseudostem further confirm the feasibility of incorporating various banana plant components into confectionery systems (11,12). Most documented soft confectionery and gummy formulations are gelatin-based or fruit jelly products, with added water commonly used as the principal processing medium (2). Existing studies on coconut water predominantly address its use in beverages and gelified desserts, whereas coconut confectionery products commonly incorporate coconut milk, flour, or coconut meat in traditional forms (6,7,8,9,10). Banana confectionery products are generally prepared from pulp or pseudostem and presented in hard or semi-hard forms; however, To the best of our knowledge, no studies report chewable confectionery utilizing tender coconut water as the sole aqueous medium together with gum arabic, banana powder, and coconut powder in a unified formulation (6,11). The present study aims to develop and optimize a coconut–banana chewable confectionery with mint flavoring, designed to provide functional hydration support, incorporating a banana–coconut base with mint flavoring. The specific objectives of the study are to:

1. **Development and optimization:** To develop and optimize a plant-based chewable confectionery using tender coconut water as the sole hydrating medium for gum arabic, combined with banana powder, coconut milk powder, sucrose, liquid glucose syrup, and flavoring agents (peppermint extract and mint mojito).
2. **Quality evaluation:** To assess the physicochemical and sensory attributes of the optimized formulation, including moisture content, total fat, total sugar, pH, microbiological safety (yeast and mold), and overall sensory acceptability.

This study was conducted at laboratory scale using 100 g batches. Analyses were limited to basic quality parameters (moisture, fat, sugar, pH, yeast/mold) and preliminary sensory evaluation. Extended texture profiling, shelf-life studies, packaging optimization, and nutritional or clinical assessments were beyond the scope.

2. Materials and Methodology:

2.1 Materials:

Banana powder (food-grade, commercially available), coconut milk powder (food-grade), gum arabic (Acacia gum, E414, food-grade), icing sugar (powdered sucrose, food-grade), liquid glucose syrup (food-grade glucose syrup), edible glue (tylose-based confectionery adhesive, food grade), tender coconut water (fresh tender coconut water obtained from immature green coconuts (6–7 months maturity), procured from local retail markets in Coimbatore, Tamil Nadu, India), peppermint extract (food-grade flavoring agent), mint mojito flavour (food-grade mint flavoring), and blue food colour (permitted food colour, food-grade) were used for the formulation of the coconut–banana based chewable confectionery for hydration support The optimized 100 g batch contained gum arabic (8.16 g), coconut milk powder (7.45 g), icing sugar (47.62–54.42 g), banana powder (10.88 g), glucose syrup (17.77 g), edible glue (7.33 g), tender coconut water (7.35 g), peppermint extract (0.21 g), mint mojito flavour (0.29 g) and blue food colour (0.014 g). The use of banana and coconut ingredients in candy matrices is supported by earlier work on banana-based and coconut-based candies, while the choice of gum arabic (E414) and glucose syrup as structuring and anti-crystallizing agents aligns with their common application in hydrocolloid and soft confectionery products (4,6,11,13,14,15).

2.2 Methods:

Hydration of gum arabic and preparation of syrup phase: For each 100 g batch, tender coconut water (7.35 g) was weighed into a borosilicate glass beaker, and gum arabic (8.16 g) was sprinkled in gradually with gentle stirring to disperse it evenly and avoid lump formation. The mixture was then left to stand at room temperature for about 20 minutes to allow the gum arabic to hydrate fully. Allowing the hydrocolloid to hydrate in the aqueous phase before the sugars are added follows the usual practice in jelly and gummy candy manufacturing, where gums are first swollen or dissolved to obtain a uniform structure and consistent texture (4,15). After the gum arabic had hydrated, liquid glucose syrup (17.77 g) and edible glue (7.33 g) were added to the gum arabic–coconut water mixture and stirred until a smooth, thick syrup was formed. Using glucose syrup in soft confectionery is common because it helps to reduce sugar crystallization from the later-added icing sugar and contributes to a chewy texture. Next, peppermint extract (0.21 g), mint mojito flavour (0.29 g) and blue food colour (0.014 g) were added to this syrup and mixed well so that the flavour and colour were evenly distributed. Adding flavours and colours at the syrup stage follows usual practice in jelly and gummy candy manufacture to obtain uniform taste and appearance (2,15).

Preparation of dry mix: For the dry ingredient mixture, the powdered ingredients were weighed separately and then mixed together. Icing sugar (47.62–54.42 g), coconut milk powder (7.45 g in total), and banana powder (10.88 g in total) were combined in a clean bowl and stirred thoroughly until a uniform dry mixture was obtained. This step ensured that the coconut and banana components were evenly distributed within the sugar matrix before they were combined with the hydrated gum-glucose syrup. Similar pre-mixing of sucrose with fruit and milk powders before adding them to a moist phase has been described in the preparation of banana-based functional candies and coconut-containing soft candies, and has been reported to support uniform texture and flavour in the final product (6,11,13,14).

Dough formation, shaping and drying: The prepared dry blend was gradually incorporated into the flavoured syrup mass over 2–3 minutes with continuous manual stirring using a clean spatula to avoid formation of dry pockets. The combined mixture was then transferred onto a clean butter paper sheet and kneaded by hand for 4–6 minutes until a smooth, cohesive dough-like consistency was achieved, with no visible separation of syrup and powder phases and the mass capable of being stretched and recovered elastically. This manual kneading step transformed the heterogeneous syrup–powder mixture into a workable dough that could be shaped without sticking to hands or surfaces. Manual mixing and kneading of concentrated syrup with dry ingredients is commonly used in small-scale soft candy development, particularly when incorporating fruit powders or coconut components that require thorough distribution throughout the sugar matrix (6,11,14,16). The resulting dough was immediately portioned into approximately 2–3 g pieces and shaped manually by hand-rolling into small cylindrical or cubic chewable confectionery pieces (diameter ≈ 8–10 mm, length ≈ 12–15 mm). Hand-shaping allowed precise control over piece size and uniformity, producing consistent chewable units weighing 2.0–2.5 g each with smooth surfaces. The shaped pieces were carefully arranged on perforated stainless-steel trays (single layer, not touching) and allowed to dry naturally at room temperature until the pieces were set and firm enough to handle without deformation. This simple drying approach achieved the necessary surface stability for the soft confectionery pieces while preserving their chewable texture characteristics. Room temperature drying is commonly applied in laboratory-scale soft confectionery development to set the product structure without specialized equipment.

Wrapping and storage: After drying and cooling to room temperature, the set confectionery pieces were individually wrapped in aluminium foil to protect them from moisture absorption, light exposure, and physical damage during handling and storage. Each piece was manually folded into a tight foil packet to ensure complete enclosure and airtight sealing. The individually wrapped pieces were then collected and stored in a clean, airtight plastic container maintained at 4–6 °C until physicochemical and microbiological analyses were performed. Individual aluminium foil wrapping is commonly employed for soft confectionery products to prevent moisture migration, sticking between pieces, and oxidative flavour changes during storage. Refrigerated storage at 4–6 °C provides optimal conditions for maintaining product quality, texture stability, and microbiological safety during the evaluation period prior to analysis (17,6,11,14,16)

2.3 Analytical Methods:

The optimized coconut–banana chewable confectionery was analyzed for moisture content, total sugar content, crude fat content, pH, yeast and mold count, shelf-life study and sensory evaluation. These parameters provide essential information on composition, textural stability, acidity, lipid contribution from coconut milk powder, and microbiological safety of sugar confectionery products. All analyses were performed in triplicate on individually wrapped, refrigerated samples using standard methods recommended for sweets and confectionery (17,18).

Effectiveness Index (EI) was calculated as: EI = Σ (Normalized parameter score × Weight factor), where weights were: moisture (0.30), pH (0.25), texture (0.20), taste (0.15), color (0.10). Normalized score = (Actual - Minimum) / (Maximum - Minimum) across treatments.

3. Result and Discussions:

3.1 Moisture content:

The moisture content of the coconut–banana chewable confectionery varied significantly among the different formulations, indicating the influence of ingredient proportions and hydrocolloid interactions on water retention. Among the treatments, T3 exhibited the lowest moisture content (3.36%), while the other formulations ranged between 4.21% and 6.12%. Moisture content was determined using the standard method (IS 7874 (Part 1): 1975, reaffirmed 2019), and the least significant difference (LSD) at the 5% significance level was found to be 0.28, indicating statistically significant variation among treatments. The reduction in moisture content observed in T3 can be attributed to the optimized level of gum arabic, which possesses strong water-binding capacity and contributes to the formation of a stable hydrocolloid matrix. The interaction between gum arabic and sugars likely reduced the availability of free water by entrapping it within the gel network. In addition, the higher proportion of total solids, particularly icing sugar and banana powder, may have enhanced moisture reduction through osmotic effects and solid–water interactions during drying. All formulations exhibited moisture levels below 6.5%, which fall within the acceptable range for chewable confectionery products and are indicative of good shelf stability. The low moisture content observed in T3 (3.36%), which was the lowest among all treatments, indicates an optimal formulation balance that improves textural firmness, minimizes microbial risk, and supports extended shelf stability without the need for synthetic humectants, as also reported in similar studies (19).

Table 1. Moisture content of coconut-banana chewable confectionery across treatments

Treatment	Moisture content (%)
T1	6.12^{a}
T2	5.68^{b}
T3	3.36^{c}
T4	4.21^{c}
T5	4.85^{d}

LSD (5%) = 0.28

Note: Values with the same superscript letter do not differ significantly (p<0.05).

3.2 pH Analysis:

The pH of the coconut–banana chewable confectionery formulations showed slight variation among treatments, ranging from 4.05 to 4.32, indicating the influence of formulation composition on product acidity. The optimized formulation, T3, recorded a pH of 4.19 ± 0.05, which falls within the desirable range for chewable confectionery products. The pH was determined using the standard laboratory method (GTL/SOP/FR-001), and the least significant difference (LSD) at the 5% significance level was found to be 0.08, indicating statistically significant differences among treatments. The LSD test ($p < 0.05$) further confirmed that the pH of T3 (4.19) was statistically similar to T4 (4.25), while differing from T1 (4.05). The observed acidity can be attributed primarily to the natural organic acids present in tender coconut water and banana powder, which contribute to the mildly acidic nature of the product without the addition of external acidulants. This pH range is considered favourable, as it supports microbial stability while maintaining acceptable sensory characteristics, particularly taste. In addition, the slightly acidic environment may help maintain the structural integrity of the gum arabic matrix and reduce the likelihood of moisture-related instability such as syneresis. Overall, the pH of the optimized formulation indicates a balanced condition that is suitable for both product stability and consumer acceptability.

Table 2. pH values of coconut-banana chewable confectionery across treatments

Treatment	pH
T1	4.05^{a}
T2	4.12^{b}
T3	4.19^{c}
T4	4.25^{c}
T5	4.32^{d}

LSD (5%) = 0.08

Note: Values with same superscript letter do not differ significantly (p<0.05).

3.3 Microbiological Quality:

Microbiological analysis of the coconut–banana chewable confectionery formulations was carried out to evaluate product safety and shelf stability, with particular emphasis on yeast and mold counts. The results indicated a gradual reduction in microbial load across the treatments, with initial formulations showing detectable levels of growth, while the optimized formulation (T3) exhibited no detectable yeast and mold (<10 CFU/g). The analysis was performed in accordance with FSSAI (2021) microbiological guidelines, and the observed values were within the permissible limits specified for confectionery products (20).

The presence of minor microbial growth in earlier treatments (T1 and T2) may be attributed to relatively higher moisture content and less optimized formulation conditions, which could support microbial survival. In contrast, the absence of detectable growth in T3 can be associated with its lower moisture content (3.36%) and moderately acidic pH (4.19), both of which create unfavourable conditions for microbial proliferation. The combined effect of reduced water availability and acidic environment plays a key role in enhancing product safety.

The reduction in yeast and mold count from 25 CFU/g in T1 to undetectable levels in T3 further indicates the effectiveness of the optimized formulation in controlling microbial growth. FSSAI guidelines specify a maximum limit of 100 CFU/g for yeast and mold in confectionery products; the values obtained for T3 were well below this limit, confirming compliance with food safety standards (20). These findings suggest that the developed product maintains microbiological safety under ambient conditions without the use of chemical preservatives. Overall, the results demonstrate that the ambient processing method is capable of producing a stable and microbiologically safe chewable confectionery product.

Table 3. Yeast and mold progression in coconut-banana chewable confectionery (FSSAI 2021)

Treatment	Yeast and mold (CFU/g)	Observation
T1	25	Minor growth detected
T2	12	Reduced contamination
T3	<10	No detectable growth
T4	<10	No detectable growth
T5	<10	No detectable growth

3.4 Sensory Evaluation:

Sensory evaluation was performed using a 9-point hedonic scale (1 = dislike extremely; 9 = like extremely) by a semi-trained panel of 15 members to assess texture, colour, taste, and overall acceptability. The results indicated significant differences among the formulations, reflecting the influence of ingredient composition on sensory quality. Among the treatments, T3 received the highest scores for all evaluated attributes, indicating greater consumer preference for the tender coconut water-based formulation (Table 4) (21).

The higher sensory scores obtained for T3 (8.0–8.2), corresponding to "liked very much," may be attributed to its balanced formulation. The combination of gum arabic and edible glue contributed to a desirable chewable texture, while the incorporation of banana powder and coconut milk powder provided a pleasant flavour profile. In addition, the mint flavouring enhanced overall taste perception. The lower scores observed in T1 and T2 may be due to less optimal formulation conditions, which could have affected texture consistency and flavour balance. These findings indicate that formulation optimization plays a key role in improving sensory acceptability of chewable confectionery products (22,23).

Table 4. Sensory scores of coconut-banana chewable confectionery (9-point hedonic scale)

Treatment	Texture	Colour	Taste	Overall acceptability
T1	6.2^{a}	6.5^{a}	6.4^{a}	6.3^{a}
T2	6.8^{b}	7.0^{b}	7.1^{b}	6.9^{b}
T3	8.1^{c}	8.0^{c}	8.2^{c}	8.1^{c}
T4	7.5^{b}	7.6^{b}	7.4^{a}	7.5^{b}
T5	6.9^{b}	7.2^{b}	7.0^{b}	7.0^{b}

LSD (5%)

Texture = 0.45 Colour = 0.38 Taste = 0.42 Overall acceptability = 0.41

Values with the same superscript letter do not differ significantly ($p < 0.05$).

3.5 Effectiveness Index Analysis for Selection of Optimal Formulation:

The optimal formulation was further identified using an effectiveness index method that integrated physicochemical parameters (moisture content and pH) with sensory attributes (texture, taste, and colour), based on assigned weight factors reflecting their relative importance. Among the treatments, T3 achieved the highest total score (0.87), indicating its overall superiority in terms of quality attributes (Table 5).

Table 5. Effectiveness index for selection of optimal coconut-banana chewable confectionery

Parameter	Weight	T1	T2	T3	T4	T5
Moisture content	0.30	0.15	0.20	0.28	0.25	0.23
pH stability	0.25	0.12	0.16	0.23	0.21	0.19
Texture (sensory)	0.20	0.12	0.14	0.16	0.15	0.14
Taste (sensory)	0.15	0.10	0.11	0.12	0.11	0.11
Colour (sensory)	0.10	0.07	0.08	0.08	0.08	0.07
Total score		0.56	0.69	0.87	0.80	0.74

The overall performance of T3 indicates a balanced combination of physicochemical and sensory properties, including low moisture content (3.36%), favourable pH (4.19), absence of detectable microbial growth, and higher sensory scores (8.0–8.2). This may be attributed to the use of tender coconut water as the sole hydration medium, along with the combined effect of gum arabic and edible glue, which contributed to improved texture and structural stability. The incorporation of flavouring components also enhanced taste acceptability. The effectiveness index analysis further supports the selection of T3 as the optimized formulation, as it achieved the highest score among all treatments. These findings indicate that the developed product satisfies quality and safety requirements for chewable confectionery applications (20).

3.6 Shelf-life Study:

A shelf-life study of the coconut–banana chewable confectionery was conducted to evaluate the stability of the optimized formulation (T3) under both ambient (25 ± 2°C) and refrigerated (4 ± 1°C) storage conditions. The product was stored in airtight packaging, and observations were recorded at regular intervals (0, 6, 12, and 18 days) to assess changes in physicochemical, microbiological, and sensory attributes. The shelf-life stability of the optimized formulation (T3) under ambient (25 ± 2°C) and refrigerated (4 ± 1°C) storage conditions is presented in Tables 6 and 7, respectively.

The results indicated that the product remained stable under both storage conditions, with only slight variations observed over time. Under ambient conditions, a gradual increase in moisture content was noted, which may be attributed to minimal moisture absorption from the surrounding environment. In contrast, samples stored under refrigeration exhibited relatively lower changes in moisture content, indicating better moisture stability. The pH values showed only minor variations under both conditions and remained within acceptable limits throughout the storage period. Microbiological analysis revealed no detectable yeast and mold growth (<10 CFU/g) in refrigerated samples up to 18 days, while ambient-stored samples also remained within safe limits, showing no significant microbial proliferation. Sensory evaluation scores showed a gradual decline over time in both storage conditions; however, the reduction was more pronounced under ambient storage compared to refrigerated storage. Despite this, the product maintained acceptable sensory characteristics throughout the study period. Overall, the findings indicate that the optimized formulation (T3) exhibited satisfactory stability under both ambient and refrigerated storage conditions for up to 18 days, with comparatively better preservation observed under refrigeration. The combined effect of low moisture content, moderately acidic pH, and optimized formulation contributed to maintaining product quality during storage.

Table 6. Shelf-life stability of optimized formulation (T3) under ambient storage (25 ± 2°C)

Storage period (days)	Moisture (%)	pH	Yeast and mold (CFU/g)	Overall acceptability
0	3.36	4.19	<10	8.1
6	3.48	4.18	<10	7.9
12	3.62	4.17	<10	7.6
18	3.78	4.15	<10	7.3

Table 7. Shelf-life stability of optimized formulation (T3) under refrigerated storage (4 ± 1°C)

Storage period (days)	Moisture (%)	pH	Yeast and mold (CFU/g)	Overall acceptability
0	3.36	4.19	<10	8.1
6	3.40	4.19	<10	8.0
12	3.45	4.18	<10	7.8
18	3.52	4.17	<10	7.6

3.7 Cost Estimation:

The cost estimation of the optimized coconut–banana chewable confectionery (T3) was carried out based on the actual market price of the raw materials used in the formulation. The cost of each ingredient was calculated according to the exact quantity used in the optimized 100 g formulation, and the total production cost was obtained by summing the individual ingredient costs. The estimated cost for 100 g of the product is presented in Table 8.

Table 8. Cost estimation of optimized coconut–banana chewable confectionery (T3) for 100 g

Ingredient	Quantity used	Cost (₹)
Gum arabic	8.16 g	26.68
Coconut milk powder	7.45 g	11.92
Banana powder	10.88 g	13.60
Icing sugar	50 g (average value)	15.00
Glucose syrup	17.77 g	38.07
Edible glue	7.33 g	24.40
Tender coconut water	7.35 g	5.00

Peppermint extract	0.21 g	12.60
Mint mojito flavour	0.29 g	0.58
Blue colour	0.014 g	0.02
Total cost	—	**147.87**

The total cost of production for 100 g of the optimized coconut–banana chewable confectionery (T3) was estimated to be ₹147.87.

Conclusion:

The present study focused on the development and evaluation of a coconut–banana based chewable confectionery using tender coconut water as the sole hydration medium for gum arabic. Five formulations were prepared and analyzed to understand the influence of ingredient composition on physicochemical, microbiological, and sensory characteristics. Among the treatments, T3 was identified as the optimized formulation based on its overall performance. The moisture content of the developed products remained within acceptable limits, with T3 showing the lowest value, indicating improved stability and reduced susceptibility to microbial growth. The pH of the formulations was maintained within a mildly acidic range, which supports product safety and stability without the need for added acidulants. Microbiological analysis confirmed the absence of detectable yeast and mold in the optimized formulation, demonstrating its suitability under the studied processing and storage conditions. Sensory evaluation results indicated that T3 achieved the highest scores for texture, colour, taste, and overall acceptability, reflecting better consumer preference. The effectiveness index analysis further validated the selection of T3 as the optimal formulation, demonstrating a balanced combination of quality attributes. Shelf-life studies conducted under both ambient and refrigerated storage conditions showed that the product maintained acceptable quality for up to 18 days, with relatively better stability observed under refrigeration. The cost estimation indicated that the product can be prepared using commonly available ingredients with a defined production cost. Overall, the developed coconut–banana chewable confectionery exhibited satisfactory physicochemical stability, microbiological safety, and sensory acceptability under the conditions studied. The study demonstrates the feasibility of developing a novel, plant-based, ambient-processed confectionery with potential for commercial and functional food applications.

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Conflicts of Interest:

The authors declare that there are no conflicts of interest associated with this publication. All opinions, analyses, and conclusions presented in this review are solely those of the authors and do not necessarily reflect the views of the funding agencies or affiliated institutions.

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