Optimization and Evaluation of the Physical Properties of a Functional Tooth Cream Formulation Containing Cocos Nucifera Extracts for Remineralization of White Spot Lesions

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KEYWORDS
Cocos nucifera, Dental demineralization,Green synthesis, Remineralization, and sustainable resources

ABSTRACT

Background: Modern toothpaste formulations incorporate various active ingredients designed to preserve enamel integrity and provide an effective cleaning experience. However, their effectiveness in preventing and managing white spot lesions in orthodontic patients is still under debate. A detailed examination of these active ingredients' functional properties is essential to maximize their benefits. This study aimed to optimize a functional toothpaste formulation containing Cocos nucifera extracts for the remineralization of white spot lesions and to assess its physical properties in comparison to commercially available ACP-CCP toothpaste formulations.

Materials and Methods: Freshly extracted coconut was sourced from the local farm. Pulp was grated and equally split into two halves. One part of the prepared pulp extract was ground in a motor, and milk was extracted. This was then stored at -4 degrees. The other part was lyophilized and free dried at -80 degrees. This was then ground into a paste. Both of these extracts were separately used in the preparation of two tooth cream formulations of *Cocos nucifera.* The two tooth cream formulations, along with a commercial formulation of ACP- CCP paste, were taken separately, and the physical properties of these materials were then evaluated. These included color, odor, taste, smoothness, relative density, tube inertness, homogeneity, determination of spreadability, sharp and edge abrasive particle determination, foamability, moisture, and volatile matter determination.

Results: The formulated toothpastes, bright white with aromatic odor and satisfactory taste, demonstrated good consistency, smooth texture, stability, and appropriate pH levels (control: 10, C. Milk: 8.7, L. Coconut: 9). Abrasiveness tests revealed 5% abrasive particles in C. Milk and less than 20% in L. Coconut, with equal foamability across samples. Spreadability was highest in the control, moderate in C. Milk, and lowest with visible abrasives in L. Coconut.

Conclusion: The study successfully formulated novel tooth creams from Cocos nucifera pulp extracts, with the coconut milk paste demonstrating comparatively better results in consistency, stability, and spreadability than the lyophilized coconut paste and showing similar properties to commercial ACP-CCP tooth cream.

1. Introduction

Orthodontic treatment aims to correct a malocclusion involving teeth and jaws (1).Unfortunately, dental enamel loss resulting in white spot lesions is noted in about 75% of the orthodontic cases (2,3). When the bioavailable Ca/P ratio drops and remineralization is impeded, the resultant uninterrupted demineralization will lead to the development of white spot lesions. When compared to their sound counterparts, the WSL and surrounding dentin showed decreased mechanical qualities and mineral densities, while the enamel WSL showed increased creep. Disparities in surface microstructure (including the imprints left by the indenter) and molecular composition that cause a significant alteration in the condition of the dentin and surrounding visually intact enamel in addition to the visually afflicted enamel(4) Clinically in orthodontic patients, an early caries lesion in the enamel is first observed surrounding the bracket surfaces. These WSL usually occur due to high plaque retention around the bracket surfaces, which increases the acid production from the plaque bacteria (4). Diagnostic testing methodologies are also available to determine the exactness of the lesion (5–7).

At present, there are a lot of available medicaments in the form of mouth wash, varnish, tooth cream, etc., that are useful for the prevention and management of WSL, but still effectiveness in complete reversal is still unknown (8).Certain techniques, such as laser and resin infiltration, have been found

to be effective in the management of white spot lesions(9). Before offering a patient treatment choices, the aetiology, extent, and depth of the white spot lesions must be determined since the accessible enamel substructure will affect the therapy's outcome (10). Yet to prevent the occurrence of these WSL, there is no single product that can be standardized for usage as well as be economical in usage(11).

Modern toothpaste formulas include a variety of active chemicals that work together to maintain the enamel surface while offering a thorough cleansing experience. In general, they are hydrocolloid suspended in an abrasive or a combination of them along with surfactants, flavourings, sweeteners, colorings and preservatives substances (12). It serves multiple purposes, including regular usage for anti-malodor, anit plaque, anti microbial(13), anti tartar fluoride delivery agents(14), whitening agents, erosion prevention agents, and hypersensitivity prevention agents (15). It is important to thoroughly examine the chemical makeup of toothpaste to ensure that the ingredients do not damage dental enamel and that they can best fulfil their potential.

Intrinsic qualities of plant extracts, such as their biocompatibility and medicinal potential, have garnered significant attention since they act as renewable natural reservoirs(17). Notable characteristics like bioactivity, adaptability, and biodegradability are displayed by these plant-derived extracts(17–19). Contrary to synthetic materials, biomaterials made from plant extracts have some drawbacks, such as possible allergenicity and restricted mechanical qualities. (21–23). Like other herbal products, coconut is one of the most commonly used raw materials for food preparation in almost all households. Within a coconut, there are about six layers: the exocarp, endocarp, mesocarp, testa, kernel (coconut flesh), and water. All these individually have medicinal properties affecting various functions in the human body(25,27). Few studies have suggested that these can promote remineralization of enamel (25,26).

Previously, we found that the pulp extracts from the freshly ground coconut could effectively improve the surface availability of calcium and phosphate, obtaining a Ca/P ratio close to ideal 1.6. Keeping in mind the advantages and surplus availability of this herbal raw material, the current study aimed at formulating novel tooth cream preparations made from the pulp extracts of Cocos nucifera and comparing their physical properties with commercial formulations of ACP-CCP tooth cream.

2. Materials and Methods:

Formulation of extract of Cocos nucifera

For the investigation, cocos nucifera was obtained from the nearby coconut farm in Tamil Nadu's Tiruppur district. By grating, the pulp extract of the same was produced. After that, the sample was divided evenly into two groups. Using a muslin cloth, the extracted materials from one group were blended and extracted without the addition of any water. The resulting coconut milk extract was kept in storage at -4 degrees. The extract from the second half was lyophilized after it had been freeze-dried for a full day. After that, the extract was kept refrigerated.

Tooth paste preparation- Coconut milk: Toothpaste was prepared using the dry gum method to ensure a consistent and high-quality product. Initially, carboxymethyl cellulose (CMC) and calcium carbonate were mixed in a mortar to ensure even distribution. Next, glycerin was gradually added to the mixture while continuously stirring to prevent lumps. This mixture was then transferred to a mixing vessel. Subsequently, of coconut milk was added to the vessel, stirring with a mechanical stirrer until homogeneous.

Additional ingredients were then incorporated, including peppermint oil, sucrose, methyl paraben, titanium dioxide, and sodium lauryl sulfate. These ingredients were accurately measured and mixed thoroughly. The consistency was adjusted as needed by adding more coconut milk, glycerin, calcium carbonate, or CMC. The mixture was then homogenized at high speed to ensure even distribution of all components. Once the desired consistency and pH were achieved, the toothpaste was transferred to

airtight containers. (Table 1).

Table 1: Ingredients in the experimental Toothpaste Formulation containing Coconut milk obtained from *Cocos nucifera*

Ingredients	**Purpose**
Coconut milk	Active ingredient (Remineralizing agent)
Calcium carbonate	Abrasive
Glycerin	Humectant
carboxymethyl cellulose	Binder
peppermint oil	Flavouring agent
sucrose	Sweetener
methyl paraben	Preservative
Titanium dioxide	Colorant
Sodium Lauryl sulfate	Surfactant

Tooth paste preparation- Lyophilised Coconut: A modified toothpaste was developed by substituting the main ingredient with a lyophilized coconut mixture. The process began by mixing carboxymethyl cellulose (CMC) with calcium carbonate, after which glycerin and the coconut mixture were added and blended until uniform. This was followed by the addition of peppermint oil, sucrose, methyl paraben, titanium dioxide, and sodium lauryl sulfate. The final mixture was homogenized and then stored in suitable containers. (Table 2)

Table 2: Ingredients in the experimental Toothpaste Formulation containing Lyophilised coconut extracts obtained from *Cocos nucifera*

Ingredients	**Purpose**
Lyophilized coconut mixture	Active ingredient (Remineralizing agent)
Calcium carbonate	Abrasive
Glycerin	Humectant
Carboxymethyl cellulose	Binder
Peppermint oil	Flavouring agent
Sucrose	Sweetener
Methyl paraben	Preservative
Titanium dioxide	Colorant
Sodium Lauryl sulfate	Surfactant

Assessment of Physical properties:

1. Color, Odor, Taste, Smoothness, and Relative Density:

The color of the toothpaste formulation was assessed visually. The stuff had a fragrance, which revealed an odor. The formulation was carefully tasted to check for flavor. By rubbing the paste formulation between the fingertips, the smoothness was evaluated.

2. Tube inertness:

Under typical storage conditions, including a heating temperature of 45°C for ten days, the container used for herbal toothpaste did not generate any corrosion or deterioration. By slicing the inside surface

of the tube, opening it, and looking for any indications of deterioration or chemical reactions within the container, the inertness of the material was determined.

3. Homogeneity:

When applying normal force at 27–20°C, the toothpaste must extrude a homogenous mass from the collapsible tube or any other suitable container. Additionally, the bulk of the contents must protrude from the container's crimp before being gradually rolled.

4. Determination of Spreadability:

Slip and drag characteristics of paste are used to determine spreadability. Weighed and placed between two glass slides (10 x 10 cm) one over the other (sliding is not allowed), the 1-2g of herbal toothpaste was then dragged in the opposite direction by the slides. After three minutes, measure the toothpaste's spreading (in cm).

5. Sharp and edge abrasive particle determination:

The contents were applied to the finger and scratched on the butter paper for 6 inches to check for the presence of any sharp or abrasive particles. on repeating the same process ten times. The sharp or edge abrasive particles could find.

6. Foamability:

The foaming power (foamability) of herbal toothpaste was determined by combining 1 gram of toothpaste with 10 ml of water in a measuring cylinder, noting the initial volume, and shaking 10 times. The total volume of foam was calculated.

7. Moisture and volatile matter determination:

Moisture and volatile matter were determined by placing 5gm of herbal toothpaste in a porcelain dish 6-8cm in diameter and 2-4cm in depth. Dried in a 105°C oven.

Calculations:

% by mass = 100 ml / M Ml -Mass loss (g) during drying

- The mass (g) of the material used in the test

3. Results

Assessment of physical properties:

The formulated toothpastes were evaluated for various properties. Visually, they exhibited a bright white color, and their odor was aromatic and characteristic. The taste was manually tested and found satisfactory. Both toothpastes demonstrated good consistency and a smooth texture, showing no signs of deterioration such as phase separation, gassing, or fermentation when stored at 34 ± 3°C for one week, confirming their stability. Smoothness was assessed by rubbing the paste between fingers. The pH of the control toothpaste was 10, while the formulated C. Milk and L. coconut toothpastes had pH values of 8.7 and 9, respectively.

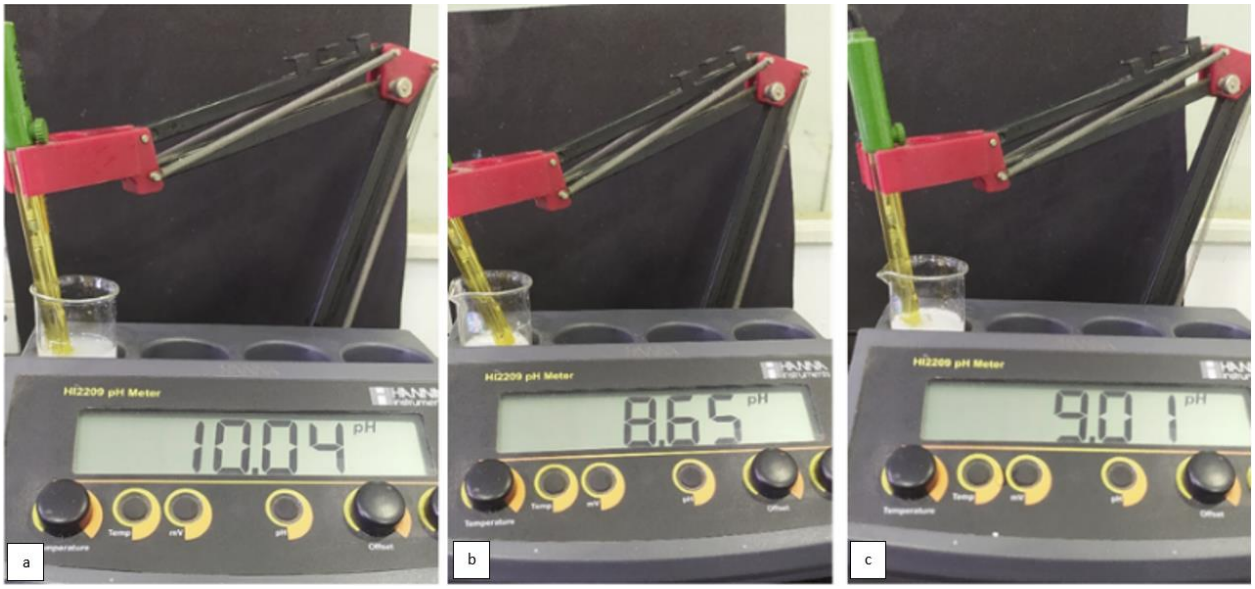

Figure 1: Depicts the pH testing of the a) CCP- ACP tooth cream, b) Cononut milk, c) Lyophilized coconut.

Abrasiveness: The toothpaste was applied to a finger and scraped across a 15-20 cm length of butter paper, at least 10 times, to confirm the absence of any sharp or abrasive particles. As shown in the images below (Figure 2a - control, b - Coconut. Milk tooth paste, C - Lyophilized. Coconut toothpaste), no particles with edges or sharp points were found in the control sample. In the C. Milk formulated toothpaste, 5% abrasive particles were detected, while the L. Coconut formulated toothpaste showed less than 20% abrasive particles.

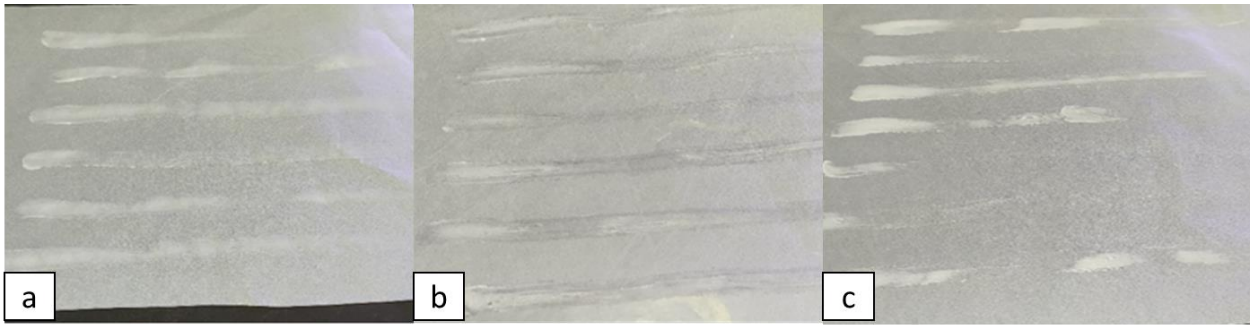

Figure 2: Abrasiveness testing: a - control, b - Coconut milk tooth paste, C - Lyophilized coconut toothpaste

Formability: The foamability test was conducted by taking the required amount of the formulated toothpaste and adding 10 ml of water. The solution was shaken vigorously 10 times, and the increase in the solution's level indicated the presence of foam due to the foaming agent. The pictures below show the foamability of the three different toothpaste formulations, each demonstrating an equal amount of foam formation(Figure 3).

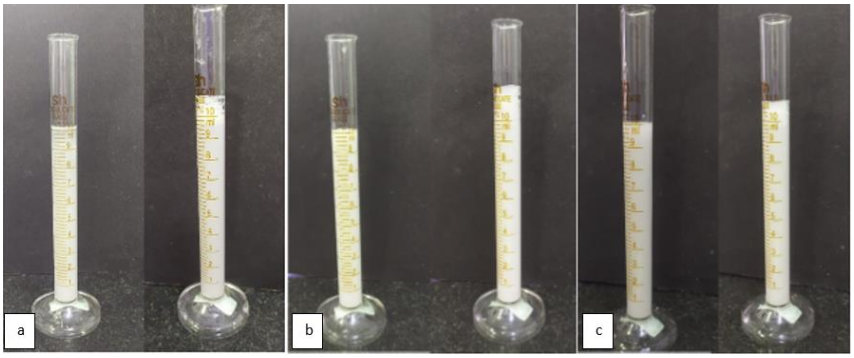

Figure 3: Foamability testing: a - control, b - Coconut milk tooth paste, and C - Lyophilized coconut toothpaste

Spreadability: The capacity of paste to slide and drag must be taken into account in order to assess spreadability. The 1-2g of toothpaste was weighed, placed between two glass slides (10 x 10 cm), one over the other (sliding is not permitted), and then the slides pulled the toothpaste in the other way. Measure the spreading of the toothpaste in centimetres after three minutes. The average value obtained from three measurements was recorded when the experiment was repeated. The control sample has high spreadability while sliding with the glass slides. While the formulated toothpaste with L.Coconut toothpaste had no proper sliding and not equally spread in the two sides of the glass slides. And also, the abrasive particles are found visibly. The formulation with Coconut milk toothpaste had better spreadability compared to L.Coconut formulated toothpaste as shown in the Figure 4.

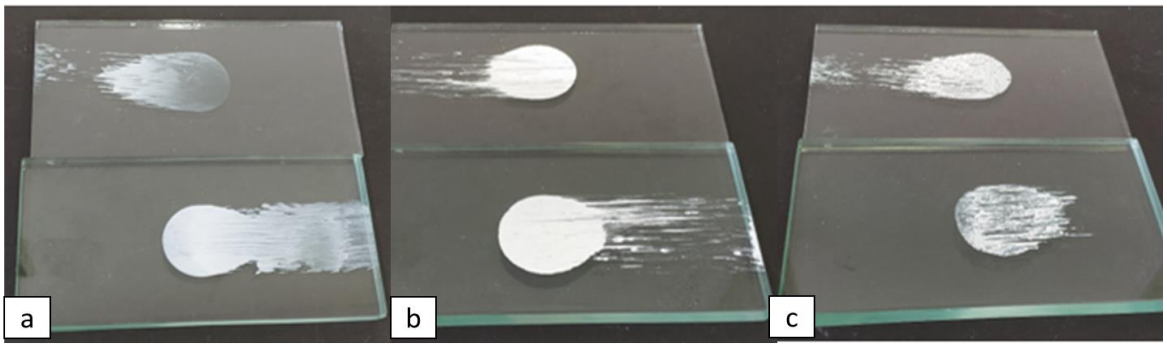

Figure 4: Spreadability testing: a - control, b - Coconut milk tooth paste, and C - Lyophilized coconut toothpaste

4. Discussion

Two tooth paste were prepared from the pulp extracts of *Cocos nucifera* and were compared with a commercially available ACP- CCP toothpaste for its physical assessment. The assessment of the formulated toothpastes revealed promising results.

Significant inhibitory efficacy against common oral infections has been established by *Cocos nucifera*, suggesting the existence of extremely potent antimicrobial substances. This suggests that incorporating Cocos nucifera into modern oral care systems can substantially contribute to oral health. Identifying these active compounds opens the door to developing innovative oral care products to control oral diseases.*(27)* In our previous study, toothpaste derived from coconut milk extracts showed antimicrobial efficacy against S. mutans, S. aureus, and C. albicans at various dilutions. Furthermore, toothpaste with varying dilutions of lyophilized coconut extracts shown antibacterial activity against P. aeruginosa. With human gingival fibroblasts, these innovative tooth creams made from coconuts also demonstrated low cytotoxicity and high cell vitality, which was equivalent to commercial formulations' biocompatibility. These results demonstrate the potential of Cocos nucifera extracts as useful components in toothpaste formulations, providing strong antibacterial activity and superior biocompatibility to preserve dental health.(28,30)

In our previous study, both C. Milk and L. Coconut toothpastes had a bright white color, aromatic odor, satisfactory taste, and smooth texture. They remained stable without phase separation, gassing, or fermentation at 34 ± 3°C for one week. The pH values were 8.7 for C. Milk and 9 for L. Coconut, compared to the control's pH of 10.

Abrasiveness tests showed no sharp particles in the control toothpaste. The C. Milk toothpaste contained 5% abrasive particles, while L. Coconut had less than 20%. Foamability tests indicated equal foam production across all formulations. Spreadability tests showed the control toothpaste had the highest spreadability. The L. Coconut formulation had poor sliding and visible abrasive particles, while C. Milk demonstrated better spreadability but faced challenges in uniform application.

Overall, C. Milk toothpaste offers a more balanced profile, combining effective cleaning with better spreadability and less abrasiveness compared to L. Coconut.

5. Conclusion

The study successfully formulated novel tooth creams from Cocos nucifera pulp extracts, with the coconut milk paste demonstrating comparatively better results in consistency, stability, and spreadability than the lyophilized coconut pastes and showing similar properties to commercial ACP-CCP tooth cream.

Additional Information

Disclosures

Human subjects: All authors have confirmed that this study did not involve human participants or tissue.

Animal subjects: All authors have confirmed that this study did not involve animal subjects or tissue.

Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info**: All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships**: All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Intellectual property info**: The Novel Tooth cream formulation with *Cocos nucifera* extracts that has been mentioned in the study has been filed for a patent and the procedure is in progress. **Application number is as follows: 202441045651.**

Other relationships: All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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