# *Development and stability evaluation of an exfoliating phytocosmetic based on Moringa oleifera, Orbignya phalerata, Psidium guajava and Apis mellifera*

*Desenvolvimento e avaliação da estabilidade de um fitocosmético esfoliante à base de Moringa oleifera, Orbignya phalerata, Psidium guajava e Apis mellifera*

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## RESUMO

Este estudo teve como objetivo formular e avaliar a estabilidade de um fitocosmético esfoliante sustentável utilizando óleo de moringa (*Moringa oleifera*), óleo de coco babaçu (*Orbignya phalerata*), pó de semente de goiaba (*Psidium guajava*) e mel de abelha (*Apis mellifera*). A pesquisa focou no desenvolvimento de um produto ecologicamente correto que valoriza matérias-primas naturais e minimiza o impacto ambiental. A metodologia incluiu a obtenção de componentes por meio de processos que simulam técnicas artesanais, como extração de óleo e produção de pós esfoliantes. Foram desenvolvidas quatro formulações: duas à base de mel, adequadas para produção artesanal, e duas à base de Natrosol, destinadas à indústria cosmética. Os testes de estabilidade foram realizados ao longo de 30 dias sob três condições de armazenamento: temperatura ambiente (25 ± 2 °C), refrigeração (5 ± 2 °C) e incubadora (40 ± 2 °C). As análises incluíram pH, densidade, características organolépticas, teor de umidade e centrifugação. Os resultados indicaram que as formulações à base de mel apresentaram maior estabilidade em todos os parâmetros, enquanto as formulações à base de Natrosol mostraram instabilidade – particularmente em altas temperaturas – com separação de fases e alterações organolépticas. O pH de todas as formulações permaneceu dentro da faixa aceitável para a pele humana, o que corrobora sua viabilidade como produtos cosméticos. Em conclusão, o objetivo foi parcialmente alcançado, resultando em um esfoliante sustentável e replicável artesanalmente, que valoriza os recursos naturais regionais. No entanto, melhorias são necessárias para viabilizar a produção em escala industrial das formulações à base de Natrosol.

**Palavras-chave:** Medicamento Fitoterápico; Fármacos Dermatológicos; Gorduras Vegetais; Mel.

## ABSTRACT

This study aimed to formulate and evaluate the stability of a sustainable exfoliating phytocosmetic using moringa oil (*Moringa oleifera*), babassu coconut oil (*Orbignya phalerata*), guava seed powder (*Psidium guajava*), and bee honey (Apis mellifera). The research focused on developing an environmentally friendly product that values natural raw materials while minimizing environmental impact. The methodology included obtaining raw materials through procedures simulating artisanal extraction techniques, such as oil extraction and the production of exfoliating powders. Four formulations were developed: two honey-based formulations suitable for artisanal production and two Natrosol-based formulations intended for the cosmetics industry. Stability tests were performed over 30 days under three storage conditions: room temperature (25 ± 2 °C), refrigeration (5 ± 2 °C), and incubator (40 ± 2 °C). Analyses included pH, density, organoleptic characteristics, moisture content, and centrifugation. Results indicated that the honey-based formulations exhibited greater stability across all parameters, while the Natrosol-based formulations showed instability – particularly at high temperatures – with phase separation and organoleptic alterations. The pH of all formulations remained within the acceptable range for human skin, supporting their suitability for dermatological application. In conclusion, the objective was partially achieved, resulting in a sustainable and artisanally replicable exfoliant that values regional natural resources. However, improvements are required to enable industrial-scale production of the Natrosol-based formulations.

**Keywords:** Phytotherapeutic Drugs; Dermatologic Agents; Vegetable Fats; Honey.

## INTRODUCTION

The field of cosmetology represents a rapidly expanding area for pharmaceutical professionals. Brazil currently ranks as the 4th largest cosmetics consumer market worldwide and the 2nd in annual product launches (Abihpec; Abdidhppec, 2015).

Despite the sector's growth, the extensive use of cosmetics may trigger adverse effects, since many conventional products contain potentially harmful substances such as allergens, carcinogens, and endocrine disruptors. The prolonged bioaccumulation of these compounds has been associated with contact dermatitis, allergies, skin diseases, hair loss, reproductive and developmental disorders, and even carcinogenesis (Gamage et al., 2022).

Mechanical exfoliants traditionally employ plastic microbeads made from polymers such as polyethylene, polypropylene, polyethylene terephthalate, polymethyl methacrylate, and nylon. These materials are non-biodegradable and, when improperly discarded, reach rivers and oceans, posing risks to aquatic life that may ingest microplastics, ultimately contaminating the food chain and impacting human health (Almeida, 2021; Marcos et al., 2020).

With increasing environmental awareness and a rising preference for natural ingredients, consumer demand for phytocosmetics has become an important driver for the cosmetics industry to adopt more sustainable practices across the entire product life cycle – from sourcing to post-consumption disposal. Sustainable cosmetics aim to minimize environmental impact through the use of plant-derived materials, eco-friendly manufacturing processes, and responsible waste management (Gamage et al., 2022; Almeida, 2021; Saretta, Brandão, 2021).

According to the 2024 Panorama of Solid Waste in Brazil (ABREMA), the country generated approximately 81 million tons of municipal solid waste in 2023, reinforcing the urgent need for solutions that reduce waste generation and promote circular economy principles (Abrema, 2020).

Agro-industrial residues represent an important opportunity in this regard. Around 30 – 40% of fruit-processing waste – including seed, peel, and pulp residues – contains valuable compounds such as fibers, vitamins, minerals, antioxidants, and bioactive phytochemicals. Properly valorizing these by-products through scientific and technological research can reduce waste while generating new sustainable raw materials (Nascimento Filho; Franco, 2015).

*Moringa oleifera* seeds contain 35–40% oil, rich in oleic acid and various phytochemicals such as alkaloids, carotenoids, tannins, anthraquinones, and flavonoids, which contribute to antioxidant and anti-inflammatory activity (Zhong et al, 2018; Bhoomika et al., 2007). Honey from Apis mellifera demonstrates moisturizing, antimicrobial, healing, and antioxidant properties that make it highly valuable for dermatological and cosmetic applications (Alves, 2019; Al-Kafaween et al., 2023).

The almond of babassu coconut (*Orbignya phalerata*) may contain up to 72% oil, composed mainly of lauric and myristic acids, which provide notable emollient and moisturizing properties, widely explored in cosmetic, soap, and personal-care industries (Soler, Vitali, Muto, 2007; Queiroga et al., 2015).

*Psidium guajava* (guava), widely used in traditional medicine, possesses antimicrobial, antioxidant, anti-inflammatory, and healing properties due to its high content of phenolic compounds, carotenoids, and essential minerals. Guava seeds, often discarded as waste, are rich in lipids, fatty acids, fibers, and bioactive molecules of interest for cosmetology (Gutiérrez, Mitchell, Solis, 2008; Garcês et al., 2024).

In addition to the direct benefits for the skin, the bioactive compounds present in plant oils and extracts can modulate inflammatory processes and protect against oxidative stress. Studies indicate that flavonoids, carotenoids, and polyphenols found in moringa, babassu, and guava seeds have the ability to neutralize free radicals and reduce lipid peroxidation, mechanisms frequently associated with skin aging and dermatological disorders (Santos, 2011; Anvisa, 2004; Viana, 2025). Thus, the incorporation of these extracts into cosmetic formulations not only promotes aesthetic effects but also contributes to maintaining skin health at the molecular level.

Furthermore, the use of agro-industrial residues in cosmetology aligns with the principles of the circular bioeconomy, promoting resource-use efficiency and reducing environmental impact. Recent research has shown that the application of green extraction technologies, such as extraction with natural solvents, ultrasound, or microwaves, allows for obtaining high-quality bioactive compounds from agro-industrial by-products, ensuring microbiological safety and functional stability of the ingredients (Viana, 2025; Sgobbe, 2024). This technological approach not only adds economic value to the residues but also strengthens the sustainability of the cosmetic sector, encouraging responsible practices and continuous scientific innovation.

Considering the need to develop an environmentally safe product that could be reproduced both at artisanal and industrial scales while minimizing waste and promoting sustainable innovation in cosmetology, the present study aimed to formulate an exfoliating phytocosmetic based on moringa oil, babassu oil, guava seed powder, and honey, using plant-based raw materials from the Cariri region.

## MATERIALS AND METHODS

### MATERIALS

Honey (Apis mellifera), moringa oil (*Moringa oleifera*), babassu coconut oil (*Orbignya phalerata*), babassu coconut almond (*Orbignya phalerata*), guava seeds (*Psidium guajava*), Natrosol® (hydroxyethylcellulose), vitamin A, vitamin E, and BHT were used in the formulations. The honey and babassu almonds were purchased at a local market in Juazeiro do Norte, Ceará, Brazil. Babassu oil and babassu almond powder were partly extracted following artisanal procedures, and an additional quantity of babassu oil was purchased in the local market to complete the amounts needed.

Moringa oil, Natrosol®, vitamin A, vitamin E, and BHT were provided by Centro Universitário Paraíso (UniFAP). Guava fruits were obtained from a local market, manually processed, and seeds were separated for later drying and grinding.

All equipment used was properly identified as requested:

– Domestic grinder: Philco PH900, Brazil.

– Drying oven (40 °C): DeLeo DL-200, Brazil.

– Conventional domestic oven (200 °C): Electrolux 50L, Brazil.

– Analytical balance: Shimadzu AY220, Japan.

– Centrifuge: Científica Mod. 80-2B, China.

– pH meter: Quimis Q400A, Brazil.

– Refrigerator (5 ± 2 °C): Consul CRM36, Brazil.

– Climatic chamber (40 ± 2 °C): Nova Ética 402/6D, Brazil.

## DELINEATION

All procedures were adapted from the stability evaluation principles recommended in the Brazilian Pharmacopeia (ANVISA, 2024) and current cosmetic stability literature, since the ANVISA (2004) guide describes mainly the centrifugation test and does not determine complete methodologies for stability protocols.

### Preparation of guava seed powder

Fourteen fresh guavas were processed in a domestic grinder using 500 mL of distilled water for every 7 fruits. Seeds were separated using a sieve and weighed. Half of the seeds were dried in an oven at 40 °C for 24 hours, and the remaining portion was dried in a domestic oven at 200 °C for approximately 1 hour, with manual stirring every 15 minutes to simulate an artisanal community procedure. After drying, seeds were ground again in the domestic grinder until obtaining a fine powder.

### Obtaining babassu coconut oil and powder

Babassu oil was extracted by decoction. Babassu almonds (200 g) were crushed in a domestic grinder with 500 mL of water. The mixture was heated in a pan over medium heat and boiled for 15 minutes. After cooling, it was manually filtered using a cotton cloth. The extraction procedure was repeated three times, each with the addition of 500 mL of distilled water. The combined extracts were refrigerated until the oil solidified and was manually separated.

The crushed almond residue was dried in an oven at 40 °C for 48 hours, then ground to reduce particle size.

### Exfoliant formulation

Four formulations were prepared:

– A1 and B1: honey-based formulations intended for community/artisanal reproduction.

– A2 and B2: Natrosol®-based formulations intended for potential industrial use.

• The use of BHT at 1% is not supported by literature and contradicts the sustainable proposal. Therefore, such concentration must be reconsidered in future formulations.

• Natrosol® formulations did not include a surfactant, making the incorporation of oils technically incompatible.

• No preservative system was included, which is inadequate for aqueous gel systems, especially those containing Natrosol®.

• Water source for Natrosol® hydration must be specified in future experiments (purified, distilled, or deionized).

**Table 1:** Exfoliant formulations

| RAW MATERI | CONCENTRATION (%) | | | | QUANTITY (g) | | | |
|---|---|---|---|---|---|---|---|---|
| | A1 | A2 | B1 | B2 | A1 | A2 | B1 | B2 |
| Babassu Oil | 2.5 | 2.5 | 2.5 | 2.5 | 6 | 6 | 6 | 6 |
| Moringa Oil | 2.5 | 2.5 | 2.5 | 2.5 | 6 | 6 | 6 | 6 |
| Guava Seed Powder | 2.5 | 2.5 | 2.5 | 2.5 | 6 | 6 | 6 | 6 |
| Babassu Coconut Almond Powder | 2.5 | 2.5 | 2.5 | 2.5 | 6 | 6 | 6 | 6 |
| Vitamin A | 1 | 1 | --- | --- | 2.4 | 2.4 | --- | --- |
| Vitamin E | 1 | 1 | --- | --- | 2.4 | 2.4 | --- | --- |
| BTH | --- | --- | 1 | 1 | --- | --- | 2.4 | 2.4 |
| Honey | 240g | --- | 240g | --- | 211.2 | --- | 213.6 | --- |
| Natol | --- | 240g | --- | 240g | --- | 211.2 | | 213.6 |

A1: Formulation based on Polawax® + babassu oil + moringa extract + guava seed powder;

A2: Formulation based on Polawax® + babassu oil + moringa extract + guava seed powder + honey; B1: Formulation based on Natrosol® + babassu oil + moringa extract + guava seed powder; B2: Formulation based on Natrosol® + babassu oil + moringa extract + guava seed powder + honey.

### pH determination

The pH was measured using a Quimis Q400A pH meter. Measurements were performed five times throughout the 28-day stability study, at days 0, 7, 14, 21, and 28.

### Organoleptic characteristics

Odor, color, and appearance were evaluated visually every 7 days during the 28-day monitoring period and compared with the initial characteristics.

### Density Determination

For honey-based formulations (A1 and B1), samples were collected with a pipette to reach 1 mL in a graduated cylinder and weighed.

For Natrosol® formulations (A2 and B2), samples were pipetted up to 5 mL and weighed.

Density (g/mL) was calculated as mass/volume.

### Moisture Determination

Aliquots of 5 g were weighed in triplicate in beakers and placed in a greenhouse oven at 65 °C for 24 hours. The samples were weighed again to determine moisture loss.

### Centrifugation test

Following the Brazilian Pharmacopeia (ANVISA, 2024), triplicate samples of each formulation were centrifuged at 3000 rpm for 30 minutes, using a Científica 80-2B centrifuge. Samples were then inspected for phase separation or instability.

**Stability study conditions**

Formulations were stored for 28 days under the following controlled conditions:

Refrigeration: 5 ± 2 °C

Room temperature: 25 ± 2 °C

Incubator: 40 ± 2 °C

Analyses were conducted at 7-day intervals, totaling 28 days.

## RESULTS AND DISCUSSIONS

### OBTAINING GUAVA SEED POWDER

Seven fresh guavas were processed with 500 mL of distilled water in a domestic grinder and then sieved, yielding 19.218 g of guava seeds in the first extraction. The procedure was repeated, totaling approximately 38.5 g of seeds.

Half of the material was dried in an oven at 40 °C for 24 h, while the remaining half was dried in a domestic oven at 200 °C for 1 h. After drying, both batches were ground to reduce particle size, producing 25.594 g of guava seed powder, with a mass loss of 33.52% during drying.

In addition, it was observed that the different drying conditions directly influenced the texture and behavior of the material during grinding. Seeds dried at 40 °C retained a lighter coloration and resulted in more homogeneous grinding, whereas those exposed to 200 °C darkened noticeably and exhibited greater hardness, requiring longer processing time. These observations suggest that drying temperature may affect not only the final yield but also physical and chemical characteristics relevant to subsequent processing and analytical steps.

Previous studies corroborate that drying temperature can significantly affect the physical and technological properties of seeds. According to Oliveira et al. (2017), higher drying temperatures alter parameters such as apparent density, hardness, and structural integrity in legume seeds, directly influencing subsequent milling performance. This observation is in agreement with support the differences observed in guava seeds dried at 40 °C and 200 °C, indicating that the thermal treatment applied may be a determining factor in the physical behavior of the resulting powder.

**Figure 1:** Obtaining guava seed powder. (a) fresh fruit (b) sieving to obtain the seeds (c) half of the seeds before drying (d) powder obtained from guava seeds.

## OBTAINING BABASSU COCONUT OIL

The extraction method yielded 10.231 g of babassu coconut oil (Figure 2). As the formulations required 24 g, an additional quantity of commercial babassu oil was purchased locally.Babassu almond powder was obtained from the residue of the oil extraction. From 40.405 g of crushed almonds, 32.3 g remained after drying, corresponding to a 20.06% mass reduction. Studies on babassu oil extraction corroborate these findings, indicating that the process typically generates a substantial amount of residual biomass, commonly referred to as "cake," which retains valuable physical and chemical properties. According to Ferreira, Freitas and Almeida (2023), even though the kernel represents only a small fraction of the fruit, the post-extraction residue forms a significant proportion of the processed material and presents potential for reuse in technological applications. These observations support the results obtained in the present study, in which a considerable mass of dry almond residue was retained after oil extraction, consistent with reports in the literature on babassu coproduct utilization.


**Figure 2:** Oil obtained by the 3rd extraction method.

The babassu coconut powder was obtained from the crushed almond generated in the oil extraction process as described in the methodology. From the crushed almond, 20.281 g plus 20.124 g were weighed, totaling 40.405 g. After the drying process, 32.3 g were weighed, totaling a loss of 20.06% of mass.

## EXFOLIANT FORMULATION

The stabilization of components in phytocosmetic formulations remains a challenge, and the use of natural inputs is of industrial relevance due to their physicochemical and sensory properties.

The ingredients were organized into phases as follows:

**Phase A:** Exfoliants (guava seed powder and babassu almond powder)

**Phase B:** Emollients (babassu coconut oil and moringa oil)

**Phase C:** Antioxidants (vitamin A, vitamin E and butylated hydroxytoluene-BHT) — correction applied: vitamins A and E are antioxidants, not preservatives; BHT is also an antioxidant

**Phase D:** Bases (honey or Natrosol®)

All raw materials were weighed, and the phases were gradually incorporated into Phase D under manual stirring. Samples containing 20 g of each formulation were stored under refrigeration (5±2 °C), room temperature (25±2°C), and incubator conditions (40 °C). Figures 3 and 4 indicate the raw materials and storage methods.

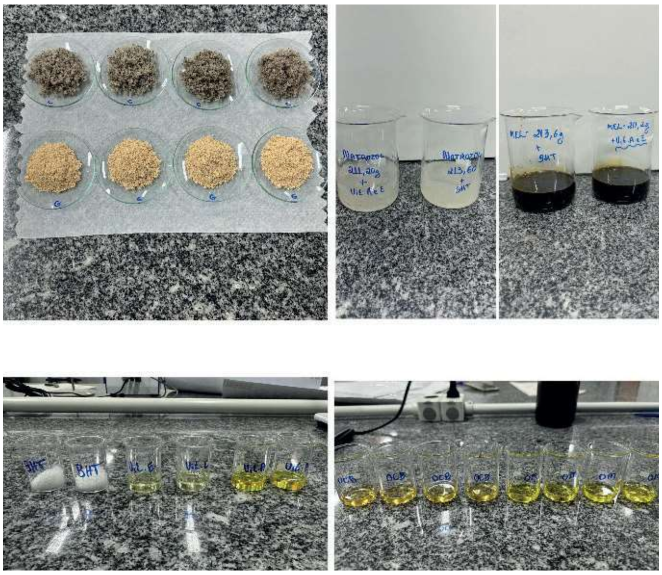

**Figure 3:** Raw materials. (a) Phase A: crystalline structure observed at 25°C (b and c) Phase D: transition region; (d) Phace C: partial degradation; (e) Phase B: complete transformation

**Figure 4:** Storage of exfoliant samples. (a) incubator (b) refrigerator (c) room temperature.

Recent studies corroborate the feasibility of incorporating natural exfoliating particles derived from plant residues into cosmetic formulations. Di Bella et al. (2025) demonstrated that powders obtained from fruit seeds and agro-industrial by-products present suitable granulometry, stability, and sensory acceptance when used as natural exfoliants, offering an environmentally sustainable alternative to synthetic microbeads. These findings support the inclusion of guava seed powder and babassu almond powder in Phase A of the present study, reinforcing their relevance in modern phytocosmetic development.

**pH DETERMINATION**

pH was measured immediately after preparation (Day 1) and then every 7 days up to Day 28.

Table 2 presents the unified pH results for all formulations under all storage conditions, including initial values and standard deviations (two decimal places), as recommended.

**Table 2** – pH variation of formulations submitted to different storage conditions for 28 days.

| | REFRIGERATOR | ROOM TEMPERATURE | INCUBATOR |
|---|---|---|---|
| **A1 (initial pH): 4.56** | | | |
| Week 1 | 3.50 | 3.99 | 3.68 |
| Week 2 | 3.51 | 3.46 | 3.57 |
| Week 3 | 3.52 | 3.54 | 3.60 |
| Week 4 | 3.46 | 3.47 | 3.57 |
| **SD*** | 0.0260 | 0.2530 | 0.0550 |
| **B1 (initial pH): 4.57** | | | |
| Week 1 | 3.45 | 3.56 | 3.52 |
| Week 2 | 3.40 | 3.65 | 3.60 |
| Week 3 | 3.50 | 3.45 | 3.45 |
| Week 4 | 3.52 | 3.52 | 3.54 |
| **SD*** | 0.0537 | 0.0835 | 0.0619 |
| **A2 (initial pH): 4.55** | | | |
| Week 1 | 5.30 | 5.30 | 5.22 |
| Week 2 | 5.14 | 4.93 | 4.53 |
| Week 3 | 5.19 | 4.82 | 4.50 |
| Week 4 | 5.12 | 4.32 | 4.52 |
| **SD*** | 0.0807 | 0.4040 | 0.3520 |
| **B2 (initional pH): 4.55** | | | |
| Week 1 | 5.29 | 4.76 | 5.01 |
| Week 2 | 5.21 | 4.51 | 4.52 |
| Week 3 | 5.21 | 4.48 | 4.56 |
| Week 4 | 5.23 | 4.44 | 4.44 |
| **SD*** | 0.0378 | 0.1447 | 0.2570 |

SD*= Standard desviation; A1: Formulation based on Polawax® + babassu oil + moringa extract + guava seed powder; A2: Formulation based on Polawax® + babassu oil + moringa extract + guava seed powder + honey; B1: Formulation based on Natrosol® + babassu oil + moringa extract + guava seed powder; B2: Formulation based on Natrosol® + babassu oil + moringa extract + guava seed powder + honey.

Formulations A1 and B2 exhibited the smallest standard deviations under refrigeration, indicating higher stability at low temperature. At room temperature, formulation B1 showed the best pH stability, and under high temperature (40 °C), A1 and B1 remained the most stable.

Formulation A2, however, demonstrated the greatest variability under all storage conditions. These results reinforce that lower temperatures favor the physicochemical stability of natural formulations, which is consistent with findings from Ibanez et al. (2024), who observed that natural products are highly sensitive to thermal stress, leading to pH shifts and loss of functional properties.

Additional evidence supporting these observations is provided by the work of Leão and Klafke (2022) and Pavlačková et al. (2018) who demonstrated that phytocosmetic emulsions containing plant-derived powders and oils undergo significant pH fluctuations when stored above 30 °C, primarily due to the thermal degradation of bioactive constituents and the acceleration of hydrolysis reactions. The authors reported that refrigerated samples maintained pH values with minimal deviation, while those subjected to elevated temperatures showed progressive acidification, mirroring the instability patterns identified in formulations A2 and, to a lesser extent, in A1 and B1 under incubator conditions. These findings reinforce that temperature control is a determining factor for maintaining the physicochemical integrity of formulations enriched with natural inputs.

## ORGANOLEPTIC CHARACTERISTICS

The organoleptic characteristics observed over the course of the 4 weeks were odor, color and appearance; the results were organized in the following tables.

Tables 2 and 3 summarize odor and appearance changes during 28 days. The reader is instructed to consult these tables as soon as the characteristics are mentioned in the text.

**Key findings:**

- Honey-based formulations (A1 and B1) showed *no changes* in odor, color, or appearance under any condition.
- Natrosol-based formulations (A2 and B2) presented:
- Rancidity at high temperature beginning on Week 3 (Table 2)
- Phase separation, especially at 40 °C and room temperature (Table 3)
- No formulation exhibited changes in color.

**Table 3:** Aspect variation of formulations submitted to different storage conditions for 4 weeks

| FORMULATION | WEEK | REFRIGERATOR | ROOM TEMPERATURE | INCUBATOR |
|---|---|---|---|---|
| ***A1*** | 1 | unchanged | unchanged | unchanged |
| ***A1*** | 2 | unchanged | unchanged | unchanged |
| ***A1*** | 3 | unchanged | unchanged | unchanged |
| ***A1*** | 4 | unchanged | unchanged | unchanged |
| ***B1*** | 1 | unchanged | unchanged | unchanged |
| ***B1*** | 2 | unchanged | unchanged | unchanged |
| ***B1*** | 3 | unchanged | unchanged | unchanged |
| ***B1*** | 4 | unchanged | unchanged | unchanged |
| ***A2*** | 1 | unchanged | + fluid | + fluid |
| ***A2*** | 2 | unchanged | phase separation | phase separation |
| ***A2*** | 3 | unchanged | phase separation | phase separation |
| ***A2*** | 4 | unchanged | phase separation | phase separation |
| ***B2*** | 1 | unchanged | + fluid | + fluid |
| ***B2*** | 2 | unchanged | + fluid | phase separation |
| ***B2*** | 3 | unchanged | phase separation | phase separation |
| **B2** | 4 | unchanged | phase separation | phase separation |

These results corroborate studies indicating that natural gelling agents may have reduced thermal resistance compared with natural viscous matrices such as honey, which contains sugars and proteins capable of contributing to structural stability.

These observations are consistent with the findings of Pavlačková et al. (2018) and Rosário et al. (2021), who reported that natural gelling agents such as xanthan gum, carrageenan, and plant-based polysaccharides often exhibit lower thermal resistance compared to viscous matrices like honey, which contain sugars and proteins that enhance structural stability. In their study, formulations containing honey maintained consistent organoleptic properties (odor, color, and appearance) under various storage conditions, whereas formulations with polymer-based gels showed phase separation and signs of rancidity when exposed to elevated temperatures. These results support the current findings that honey-based formulations (A1 and B1) preserved their organoleptic integrity, while Natrosol®-based formulations (A2 and B2) were more susceptible to thermal-induced changes. In the odor analyses, there were no variations between the formulations evaluated.

**DETERMINATION OF DENSITY**

Honey-based formulations displayed higher density, consistent with the known viscous nature of honey. Natrosol-based formulations exhibited lower density and greater sensitivity to physicochemical changes, confirming previous stability observations. The density of the samples can be verified below:

A1: 1.07 g/mL

B1: 1.20 g/mL

A2: 0.88 g/mL

B2: 0.99 g/mL

Additionally, the study *Hydration and Barrier Potential of Cosmetic Matrices with Bee Products* (Pavlačková et al., 2020) confirms that cosmetic matrices containing honey exhibit distinct physical characteristics compared to polymer- or gel-based systems: honey confers higher viscosity and promotes the formation of dense matrices, enhancing phase cohesion and structural stability. This behavior favors the increase in apparent density of honey-based formulations, as observed in A1 and B1, and helps explain why these samples exhibited higher density compared to Natrosol®-based formulations, which displayed lower density and greater susceptibility to physicochemical changes (Pavlačková et al., 2020).

**DETERMINATION OF MOISTURE**

Moisture loss results are presented in Table 4.

**Table 4:** Moisture variation of formulations

| FORMULATION | MEAN INITIAL MASS | MEAN FINAL MASS | % REDUCTION |
|---|---|---|---|
| A1 | 5 g | 4.559 g | 8.82% |
| B1 | 5 g | 4.835 g | 3.30% |
| A2 | 5 g | 2.586 g | 48.28% |
| B2 | 5 g | 1.785 g | 64.30% |

Natrosol formulations lost significantly more water during drying, confirming lower moisture retention capability, which correlates with their instability (phase separation and rancidity).

These findings are consistent with the study by Salehi et al. (2022), which demonstrated that cosmetic creams with lower water retention capacity undergo greater moisture loss, leading to physical and chemical instability, including phase separation and reduced efficacy. This supports the current results, where Natrosol®-based formulations (A2 and B2) lost approximately 48–64% of their mass, indicating a higher susceptibility to drying and consequent destabilization, whereas honey-based formulations (A1 and B1) retained moisture more effectively, maintaining their structural integrity (Salehi, Mortazavi, Moghimi, 2022).

**CENTRIFUGE TEST**

The centrifugation test intensified particle movement and allowed the observation of potential instabilities. Honey-based formulations remained homogeneous, while Natrosol-based formulations presented phase separation (Figure 5).


**Figure 5:** Centrifuged samples

These findings are aligned with previous studies demonstrating that natural formulations with weaker polymeric structures are more prone to structural collapse under mechanical stress. Furthermore, the study of Tafuro et al. (2022) demonstrated that surfactant-free cosmetic emulsions subjected to centrifugation (3000 rpm, 30 min) exhibited phase separation in all samples containing aqueous or low-polysaccharide phases, evidencing the structural fragility of these systems under mechanical stress. These results corroborate the current findings, in which Natrosol®-based formulations (A2 and B2) – likely with weaker or less dense polymeric structure – showed phase separation after centrifugation, whereas honey-based formulations (A1 and B1) maintained homogeneity, indicating greater structural resistance and cohesion under stress (Tafuro et al., 2022).

The study also reinforces the feasibility of utilizing agro-industrial residues and regional raw materials in sustainable cosmetics, promoting responsible innovation, environmental impact reduction, and circular bioeconomy practices. The use of plant-derived particles as natural exfoliants can provid efficient and environmentally appropriate, offering a viable alternative to conventional microplastics and meeting the growing demand for cosmetic products with reduced environmental footprint and enhanced dermatological safety.

In summary, this work contributes to the advancement of sustainable phytocosmetic development while highlighting the technical limitations and challenges involved in scaling artisanal formulations to industrial production. Future strategies should prioritize the optimization of polymeric formulations, rigorous control of extraction and stabilization processes, and validation of functional efficacy, ensuring product quality, safety, and sustainability within the cosmetic sector.

## CONCLUSION

The present study enabled the development and stability evaluation of a sustainable exfoliating phytocosmetic, employing high-value natural raw materials from the Cariri region, namely *Moringa oleifera* oil, babassu oil (*Orbignya phalerata*), guava seed powder (*Psidium guajava*), and Apis mellifera honey. The results demonstrate that honey-based formulations (A1 and B1) exhibited superior physicochemical and organoleptic stability compared to Natrosol®-based formulations (A2 and B2), showing greater resistance to pH changes, moisture loss, density variations, and phase separation, even under adverse storage conditions.

The analyses confirm that the viscous matrix conferred by honey promotes structural cohesion and water retention, preserving sensory characteristics and product integrity, whereas aqueous polymer-based systems displayed structural fragility and susceptibility to thermally and mechanically induced changes, as evidenced by centrifugation tests. Although Natrosol®-based formulations may hold potential for industrial production, technical adjustments are required to ensure stability and homogeneity. Special attention should be given to oil incorporation and the selection of preservatives compatible with aqueous systems.

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## CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding this research.

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