Development of a Sunscreen Formulation Enriched with *Camellia sinensis* Extract in the Treatment of Melasma

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This study evaluated the antioxidant potential of *Camellia sinensis* by quantifying its bioactive compounds, which contribute to the treatment of melasma. Consequently, developing a sunscreen formulation enriched with *Camellia sinensis* extract was proposed. The findings were derived from physicochemical and microbiological analyses supported by bibliographic references. By determining the phenolic compound content in four different concentrations of *Camellia sinensis* extract, the highest percentages of gallic acid were identified in two concentrations. These results highlight the extract's antioxidant and photoprotective properties against free radicals and its promising potential to inhibit the activity of the tyrosinase enzyme.
Keywords: Melasma. *Camellia sinensis*. Phytotherapy. Antioxidant. Photoprotection.

Following the increasing incidence of skin diseases, such as melasma, caused by prolonged exposure to the sun, this study explored the possibility of developing a sustainable herbal sunscreen enriched with *Camellia sinensis* (green tea) extract to aid in the prevention and treatment of these conditions.

In recent years, research on the use of phytotherapy, particularly in dermatological cosmetics, has grown significantly. This expansion reflects the increasing exploration of the active compounds in plants. According to the World Health Organization (WHO), medicinal plants are defined as those that exert therapeutic effects, promoting balance within the body. Accordingly, natural properties with functions equal to or superior to existing dermatological products are being sought to minimize the long-term use of synthetic chemicals on the skin.

As sustainability becomes a crucial factor in corporate strategies, innovation is no longer limited to new technologies but also includes aligning economic, social, and environmental values. Companies recognized as innovative prioritize these values, creating products that resonate with their audience. In this context, the cosmetics market has embraced using raw materials derived from plants, fruits, and seeds. These "bio-cosmetics" are gaining popularity for combining environmental sustainability with human health benefits (Gallina, 2021).

The rise of phytocosmetics in the global market is driven by increasing demand for natural products, reflecting a shift towards conscious consumption and sustainable practices. The demographic attracted to these products, often called "green consumers," opt for natural and organic alternatives over synthetic formulations. These choices are justified by their perceived safety and minimal environmental impact (Lyrio et al., 2011). Moreover, such products adhere to environmental conservation and sustainability (Borges et al., 2013).

This study analyzed the photoprotective potential of *Camellia sinensis* when used in sunscreens to assist in treating melasma. Research shows that the antioxidant properties of flavonoids and polyphenols in *Camellia sinensis* extract are effective in treating dark spots and combating aging, cardiovascular diseases, and cancer. The extract's ability to inhibit leukocyte infiltration into the skin minimizes damage caused by solar radiation. By significantly reducing the activity of the enzyme tyrosinase—a key factor in melanin production—

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Camellia sinensis offers a promising solution for mitigating dark spots caused by sun exposure. The medicinal plant and phytotherapeutic industry represents a valuable economic and health innovation avenue. Products derived from phytotherapeutic compounds have demonstrated significant market potential compared to those based on synthetic chemicals.

Additional aspects considered during this research include the extract's anti-inflammatory properties. As stated by the Eucerin website (2024), the protective layer of the skin is slightly acidic, with an optimal pH range between 4.7 and 5.75.

The study also assessed the extract's organoleptic and antimicrobial properties, ensuring compliance with Anvisa's standards for stability and formulation acceptance. For instance, increased particle mobility during stability testing revealed potential formulation instabilities, necessitating adjustments in its organoleptic composition.

Key questions addressed in this study include:

- How can green tea be utilized as a skin-whitening agent?
- How can the antioxidant potential of *Camellia sinensis* extract be quantified through its bioactive compounds?
- What are the physicochemical properties of the formulation?
- What are the benefits of a sunscreen enriched with phytocosmetics?

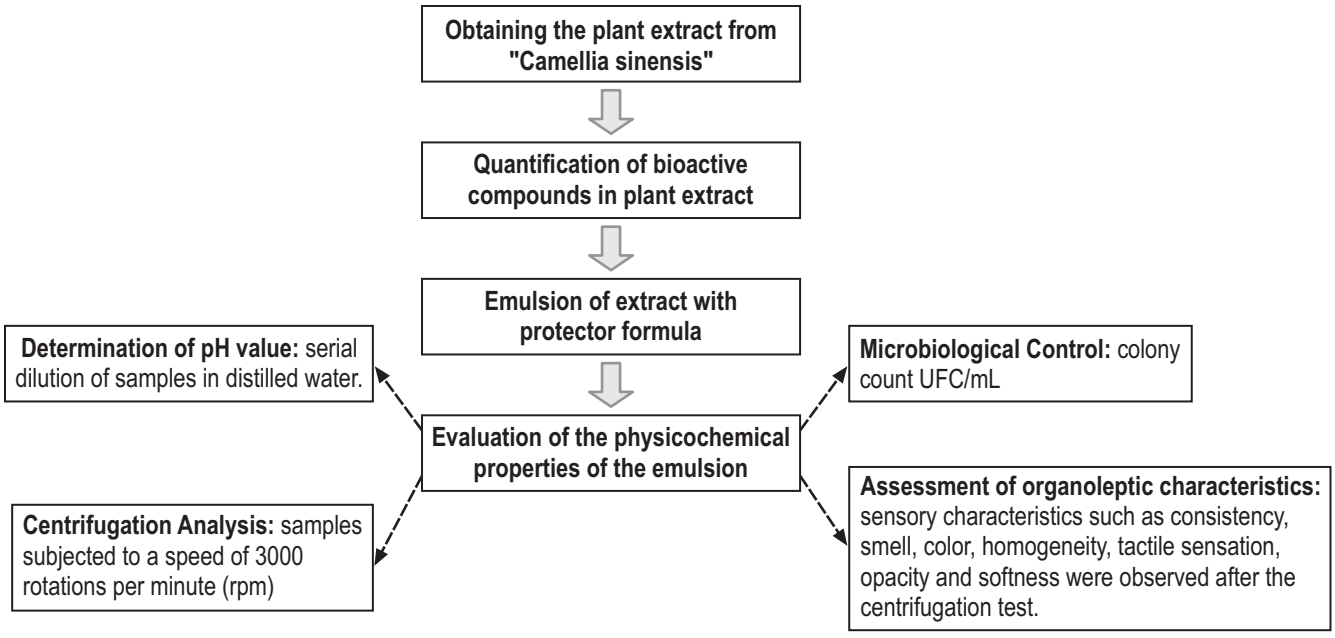
This article aims to evaluate the antioxidant potential of *Camellia sinensis* extract, focusing on its flavonoid and polyphenol content and their ability to mitigate UV-induced skin damage. Additionally, the study explores its potential for reducing skin inflammation and lightening hyperpigmentation.

The development of this product emphasizes sustainability by replacing environmentally harmful compounds with plant-based alternatives, aligning with the growing demand for eco-friendly and herbal solutions in the cosmetics market.

Materials and Methods

This study adopted an exploratory approach, integrating both qualitative and quantitative methods. The research encompassed bibliographic, documentary, and experimental procedures. A detailed experimental plan was developed to meet the proposed objectives (Figure 1).

Figure 1. Flowchart describing the experimental steps to be performed.



Conditioning and Preparation of *Camellia sinensis* Leaf Samples

The *Camellia sinensis* leaves were received and stored in the Biotechnology Laboratory at SENAI Cimatec (Salvador-BA). The leaves were washed in a 1% hypochlorite solution and then dried in an oven at 40°C for 72 hours. After drying, the leaves were crushed in a blender and macerated for 48 hours using PA ethanol (absolute ethyl alcohol, C_2H_6O) to obtain the extract.

Obtaining the Plant Extract

The extract was filtered and processed using a rotary evaporator and a magnetic stirrer to evaporate the ethanol. Subsequently, the final yield of the extract was analyzed to assess the economic potential of *Camellia sinensis*.

Quantification of Bioactive

Compounds in the Plant Extract

The bioactive compounds in the extract were quantified in duplicate using the spectrophotometric method with the Folin-Ciocalteu reagent, a mixture of phosphomolybdate and phosphotungstate, which is used to determine phenolic and polyphenolic antioxidants. Following the quantification, two emulsions were prepared by weighing the sunscreen base into two Falcon tubes and adding *Camellia sinensis* extract at 2% and 10% concentrations.

Evaluation of Physicochemical Properties of the Plant Extract and Emulsion (Sunscreen Base + Plant Extract)

The emulsions and the pure sunscreen base underwent centrifugation analysis to evaluate the formulations' stability, following the methodology described by Matias and Intiane in their study on "Evaluation of the Physicochemical Stability of Compounded Sunscreens."

An organoleptic evaluation was conducted, assessing sensory attributes such as consistency, odor, color, homogeneity, tactile sensation, opacity, and softness (ANVISA, 2004). The pH value of the 2% emulsion was measured to verify compatibility between the formulation's pH and the skin's natural pH. Finally, microbiological control tests were performed to assess colony-forming unit (CFU/mL) counts, ensuring compliance with Good Manufacturing Practices (GMP) as outlined by Anvisa's regulations.

Results and Discussion

Obtaining the Plant Extract and Calculating the Yield

The yield calculation for the extract was performed by dividing the final volume of the extract (10 mL) by the initial mass of *Camellia sinensis* leaves (300 g) and multiplying the result by 100. This resulted in a yield of approximately 3.33% after three days, considered satisfactory.

$$\frac{10}{300} x\ 100 = 0.333... \times 100 = \mathbf{3.33\%}$$

Quantification of Bioactive Compounds in the Extract

Schmitz and colleagues, in their study "Green tea and its actions as a chemoprotector," highlighted flavonoids and catechins as the primary therapeutic chemical components in *Camellia sinensis*. These compounds are potent antioxidants that inhibit skin tumor formation caused by chemical carcinogens or UVB radiation.

Using the Folin-Ciocalteu spectrophotometric method, the bioactive compounds in the extract were quantified, confirming the presence of gallic acid, a phenolic acid. When evaluating concentrations of 100 µL, 10 µL, 1 µL, and 0.1 µL of the extract, the highest gallic acid percentages were observed in the 100 µL and 10 µL concentrations (13.17% and 11.02%, respectively) (Table 1).

These findings indicate a high concentration of phenolic compounds, even at minimal volumes.

Table 1. Concentrations of gallic acid equivalent (GAE) in *Camellia sinensis* extract.

Concentration (µL)	% GA
0.1	7.57
1	9.12
10	11.02
100	13.17

These results underscore the antioxidant activity of the *Camellia sinensis* extract, demonstrating its photoprotective potential against free radicals and its ability to inhibit tyrosinase, an enzyme linked to melanin production.

Evaluation of the Emulsion's Organoleptic Characteristics

According to Matias, Bianchetti, and Rigo (2016), quality control of compounded formulations is essential for verifying stability, safety, and efficacy. The organoleptic characteristics of the emulsions were analyzed after centrifugation, focusing on attributes such as color, softness, homogeneity, tactile sensation, opacity, consistency, and odor.

Three samples were evaluated:

- Sample 1: Sunscreen base without extract.
- Sample 2: 10% emulsion containing *Camellia sinensis* extract.
- Sample 3: 2% emulsion containing *Camellia sinensis* extract.

Under artificial white light, the emulsions displayed uniform color, ideal consistency, and high homogeneity. Their tactile sensation, opacity, and overall sensory attributes were deemed excellent, confirming the formulations' suitability for use and stability.

Centrifugation Analysis

The centrifugation analysis further validated the stability of the formulations. The results confirmed the emulsions' uniformity, optimal consistency, and superior homogeneity, ensuring high-quality formulations that meet the desired standards for topical application.

Determination of pH Value

Matias (2016) emphasized that skin pH, typically between 5.5 and 6.5, contributes to bactericidal and fungicidal protection. The pH values of the 2% emulsion were within this range, maintaining compatibility with skin alkalinity. The 10^{-1} dilution of the more concentrated 10% emulsion also demonstrated suitability for topical application. All formulations exhibited average pH values of 5.3, confirming their compatibility with the epidermis.

Microbiological Control Test

João Artur Grandim, in his "Microbiology Guide," emphasized the importance of controlling microbiological contamination in cosmetic production. Uncontrolled microbial growth can render products unsellable. Cosmetic formulations, especially those containing organic substances, water, and mineral salts, are prone to microbial growth.

Microbiological testing showed growth on all plates, but colony counts were within acceptable limits. The 10^{-3} dilution plate showed only one colony, and the highest observed growth across dilutions (10^{-1}, 10^{-2}, and 10^{-3}) was below Anvisa's threshold of 10^2 CFU/mL for Type 1 products and 5×10^{-3} CFU/mL for Type 2 products.

The results confirmed that the formulations complied with Anvisa's microbiological quality standards, ensuring safety and suitability for consumer use.

Conclusion

The rising incidence of melasma and the demand for novel photoprotective active ingredients that are safe for the skin highlights the importance of introducing innovative herbal products to the market. These

products provide consumers with practical options for mitigating the harmful effects of solar radiation. Developing a sunscreen formulation enriched with *Camellia sinensis* extract offers a promising approach to addressing this need, as plant-based inputs with photoprotective properties are more accessible, cost-effective, and environmentally sustainable to produce. The findings of this study confirm the photoprotective potential of *Camellia sinensis* extract in sunscreen formulation. With a concentration of 13.17% gallic acid—a polyphenol known for its potent antioxidant properties—in just 100 microliters of extract, the results underscore the significant efficacy of this natural ingredient. These results suggest that larger volume measurements could yield even more favorable outcomes, enhancing its applicability in sunscreen products.

In conclusion, the investigation into the photoprotective properties of *Camellia sinensis* extract opens a promising pathway for developing sunscreen formulations that also aid in melasma treatment. The antioxidant-rich properties of this plant extract contribute to its whitening and photoprotective capabilities, expanding the range of cosmetics available to consumers. Moreover, its plant-based and sustainable nature aligns with global efforts to promote environmentally friendly products, enhancing its appeal in the cosmetics industry.

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