Innovative Approaches to Enhance the Stability and Bioavailability of Herbal Actives in Haircare Formulations

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***Abstract*— With the growing interest in herbal-based haircare products, there is a strong need for formulations that enhance the stability and bioavailability of herbal actives. In this context, the present study developed guava butter gel formulated with guava seed oil encapsulated in a niosomal vesicular delivery system.**
The formulations were evaluated through physical analysis, pH evaluation, microscopic examination, temperature variation test, cyclic temperature test, accelerated stability study and direct sunlight exposure test. The niosomal guava butter gel maintained a uniform appearance, consistent texture, stable pH, and showed no signs of phase separation under all stress conditions. Microscopy evaluation confirmed the presence of spherical vesicles dispersed uniformly within the gel, indicating successful encapsulation and protection of guava seed oil.
Although bioavailability testing was not performed, the enhanced stability of the niosomal formulation-supported by previous studies on niosome based delivery systems-suggests a potential improvement in active delivery. Overall, the findings indicate that improved stability and bioavailability of herbal actives in hair care formulations resulting from niosome encapsulation of herbal components.

***Index Terms*— Herbal actives, Niosomes, Guava butter gel, Stability study, Bioavailability, Haircare formulation.**

I. INTRODUCTION

Herbal actives have been used in both traditional and modern haircare practices due to their multifunctional benefits for hair health. They are incorporated in wide range of herbal hair product because they can strengthen, nourish, and repair hair for naturally smoother, shinier, and more manageable hair. But in formulations, herbal actives have significant issues with bioavailability and stability. Many phytoconstituents are unstable, sensitive to deterioration when subjected to UV radiation, temperature, and oxygen. Herbal-based preparations effectiveness and shelf life are lowered by these limits.
A rinse-off hair butter gel is a semi-solid formulation created with active ingredient guava seed oil, which is rich in antioxidants, phenolic compounds and essential fatty acids like linoleic acid.
It helps nourish and strengthen the hair shaft, lock in moisture, minimize frizz, and improve shine, smoothness, and manageability during short contact time. But guava seed oil is heat sensitive and unstable when exposed to light, and oxygen during formulation or storage.
Innovative techniques such as Niosomal delivery systems can be employed to get rid of problems related to herbal haircare product's stability and bioavailability. Niosomes are vesicular nanocarriers formed by the self-assembly of non-ionic surfactants such as Tween 80 or Span 60, often stabilized with lipids such as cholesterol or stearic acid. Their bilayer structure encloses an aqueous core. Niosomes are capable of encapsulating hydrophilic, lipophilic, or amphiphilic molecules and shield them against degradation caused by heat, light, oxidation or changes in pH. Previous research studies on niosomal formulations revealed in herbal haircare products better stability, delivery and general performance. These findings support the present work, indicating

that adding niosomes to guava butter gels can enhance the stability and bioavailability of active compounds in haircare formulations.

II. MATERIALS AND METHODOLOGY

2.1 Materials

2.1.1. Active ingredient:

Guava Seed oil

Botanical name: Psidium guajava L.

Family: Myrtaceae

Plant part used: Seeds of the guava fruit

Chemical constituents: Rich in antioxidants, phenolic compounds and essential fatty acids like linoleic acid

Uses: Nourishes, strengthen, reduce frizz, enhance shine, smoothness and manageability of hair shaft.

2.1.2 Base materials

Sr.No.	Material	Role of material
1	Carbopol 934	Gelling agent
2	Cocoa butter	Emollient
3	Glycerine	Humectant
4	Distilled water	Solvent
5	Glycerol monostearate	Emulsifier
6	Cetyl alcohol	Co-emulsifier
7	Triethanolamine	pH adjuster
8	Rose essential oil	Fragrance
9	Phenoxyethanol	Preservative
10	Methyl paraben	Preservative
11	Propyl paraben	Preservative

Table no: 1

2.1.3 Materials used in niosome formation

1. Tween 80-Non-ionic surfactant
2. Stearic acid-Lipid component
3. Ethanol-organic solvent
4. Distilled water-Hydrating the lipid-surfactant film to form vesicles.

2.2 Methodology

2.2.1 Formulation of Niosomal Guava Butter Gel

2.2.1(A) Formulation table of Niosomes (Thin layer hydration method)

Sr. no.	Ingredients	Quantity %
1	Tween 80	8.76
2	Stearic acid	2.00
3	Guava seed oil	3.24
4	Ethanol	1.00
5	Distilled water	6.60

Table no:2

Procedure

1 In a beaker, mix Tween 80, stearic acid, ethanol, and guava seed oil.
2 Place the mixture on a magnetic stirrer and stir with alternative heating until the ethanol evaporates completely (this forms a thin film).
3 Slowly add warm distilled water to hydrate the thin film and continue stirring until a thick dispersion forms.
4 Sonicate the mixture for about 10 minutes to reduce particle size and improve uniformity.
5 Check the niosome formation under a microscope.
6 If niosomes are visible the prepared niosomal dispersion can now be used to make the guava butter gel.

2.2.1(B) Formulation table of niosomal guava butter gel preparation

Sr. no.	Ingredients	Quantity 50%
1	Distilled Water	34.95
2	Glycerin	2.00
3	Carbopol 934	0.75
4	Cocoa butter	3.15
5	Glycerol monostearate	1.92
6	Cetyl alcohol	1.28
7	Phenoxyethanol	0.29
8	Methyl paraben	0.046
9	Propyl paraben	0.005
10	Triethanolamine	Q. s
11	Rose essential oil	Q. s
12	Niosomes	5

Table no:3

Procedure

1. Weigh and take distilled water in a beaker.
2. Sprinkle Carpobol 934 slowly into the water while stirring. Keep it for 1-2 hours to fully swell.
3. Add methyl and propyl paraben (dissolved in a small quantity of warm water) and glycerin to the above mixture.
4. Then heat the water phase to about 70 -75°C.
5. In another beaker, add cocoa butter, cetyl alcohol, and glycerol monostearate.
6. Heat this mixture to 70–75°C until completely melted and uniform.
7. Slowly add the hot oil phase into the hot water phase with continuous stirring.
8. Mix until a smooth and uniform emulsion is obtained.

9. After forming the emulsion, cool the mixture to below 45°C and then add Phenoxyethanol (to prevent evaporation loss).
10. Once the gel base cools to 30-35°C, slowly add the prepared niosomal dispersion.
11. Mix gently until a uniform and homogenous niosomal guava butter gel is formed.
12. Adjust pH if needed and store in clean and dry container.
13. Add Triethanolamine dropwise while stirring gently and adjusts the pH.
14. Add fragrance and mix until the gel becomes smooth.
15. Transfer the guava butter gel into clean and dry container.

Fig no:1 Guava butter gel prepared using niosomes

Fig no:2 Formulated niosomal guava butter in a well-labelled container.

III. EVALUATION PARAMETERS

1.Physical analysis

Gel prepared was tested both organoleptically (appearance, odor, color) and physically (consistency, homogeneity and phase separation) through the naked eye.

2. pH test

1g of prepared gels was dispersed in 100 mL of distilled water. pH was measured using a calibrated digital pH meter.

3.Microscopic analysis

Microscopic analysis was conducted to evaluate particle morphology, uniformity, and distribution within the niosomal gel. A portion of the formulation was sonicated for 10 minutes to reduce particle size and enhance homogeneity, after which a small sample was placed on a clean glass slide, covered with a coverslip, and observed under an optical microscope at appropriate magnification. This assessment was performed to identify any aggregation or coalescence and to verify the uniform dispersion of guava seed oil–loaded niosomes throughout the butter gel matrix.

4.Direct sunlight exposure test

Formulations were exposed to sunlight for 8 h daily for 7 days. Photostable formulations are less prone to oxidative degradation, discoloration, and odor development caused by light exposure.

5.Temperature Variation test

For four weeks samples were kept at 4° C, 25° C and 45° C. Samples were evaluated for changes in color, consistency, odor, and phase separation. This test helps to identify any temperature-induced instability such as emulsion breakdown, crystallization, or degradation of actives.

6.Cyclic temperature test

Three cycles were carried out, each consisting of 24° hrs at 4° C followed by 24hrs at 40° C. This test stimulates the temperature stress a cosmetic product may face during transport or seasonal storage.

7.Accelerated stability study

The guava butter gels were kept at different temperatures such as 8 ± 0.1°C (refrigerator), 25 ± 0.1°C (room temperature), and 40 ± 0.1 °C (oven) with 75% relative humidity over four weeks. The gels were regularly checked for pH, color, texture, odor and consistency.

IV. RESULT AND DISCUSSION

4.1Initial observation

Parameter	Observation
Appearance	Smooth, creamy gel
color	Off-white
odor	Fragrance of rose oil
Consistency	Soft buttery texture
Homogeneity	Uniform & stable
pH	5.0

Table no:4

4.2 Microscopic evaluation

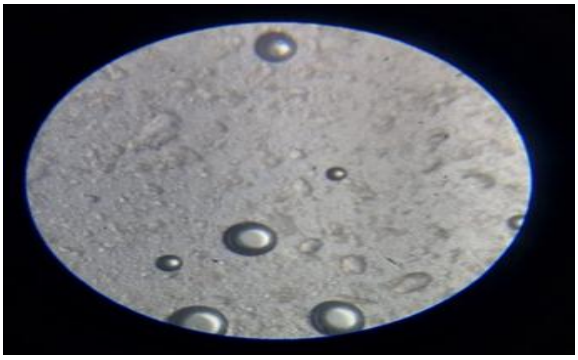

Fig no:3 Microscopic visual of Niosome encapsulated guava seed oil after incorporating in butter gel

Microscopic investigation confirmed the successful formation of spherical niosomal vesicles of different sizes. The variation in droplet sizes points to heterogeneity in the vesicle population, typical in thin-film hydration method. The vesicles appear distinct and non-aggregated, indicating no immediate phase separation. Although guava seed oil cannot be visualized directly under optical microscopy, its encapsulation is inferred from the successful formulation of stable vesicular structures typical of niosome systems

4.3 Observation after stability studies

1. Direct Sunlight Exposure Test

Following seven days of daily eight hours of direct sunlight, the niosomal guava butter gel showed no apparent color change, scent change, or indications of oxidation. The consistency and texture remained constant; no phase separation was noted. These findings suggest the good photostability of the formulation.

2. Temperature Variation Test (4°C, 25°C, 45°C for 4 weeks)

The gel maintained its smooth and consistent appearance during the temperature variation test. There was no oil separation, no odor change, no change in viscosity at any temperature. The formula showed no physical instability and the fragrance stayed constant, hence supporting excellent thermal resistance.

3. Cyclic Temperature Test (4°C ↔ 40°C for 3 cycles)

The gel kept its homogeneity and structural integrity after several cycles of temperature. There was on separation, no change in color, smell, and viscosity. The niosomal gel seemed to resist changing environmental conditions without destabilization.

4. Accelerated Stability Study (8°C, 25°C, 40°C with 75% RH for 4 weeks)

The gel showed no alteration in texture, smell, or appearance throughout the faster storage investigation. Degradation, phase separation, or microbial development showed none of their indicators. This confirms that the formulation under extended storage stress is physically and chemically stable.

4.4 Correlation with bioavailability

Although direct bioavailability testing was not done in the current study, the increased stability of the niosomal composition supported by earlier research on niosome-based delivery systems points to a possible advancement in active delivery. For instance, Zarkesh et al. (2017) showed how niosomal minoxidil gels dramatically raised follicular drug accumulation and dermal permeability over those seen with conventional forms. Similarly, Teeranachaideekul (2022) found that niosomes containing pumpkin seed oil showed better anti-hair-loss activity and more overall follicular penetration. Furthermore, Ghadge & Shete (2024) proving that nanocarriers including niosomes shield sensitive herbal compounds from disintegration and greatly enhance scalp delivery and bioavailability are broad investigations on herbal nanocosmetics. Taken together, these investigations seem to confirm the hypothesis that including niosomes into guava butter gel improves bioavailability, enhances stability, and boosts the general performance of herbal ingredients in hair products.

V. CONCLUSION

The niosomal guava butter gel showed better physical, chemical, thermal, and photostability in all stability tests. It exhibited consistent appearance, good texture, no phase separation, and a steady pH over storage and stress scenarios. Microscopic study verified the existence of well-formed vesicles, therefore showing good protection and encapsulation of guava seed oil inside the gel matrix. The increased stability consistent with results from prior niosome studies suggests the possibility for better bioavailability and regulated release of herbal components. Overall, the niosomal

guava butter gel offers effective, sustainable solution for the formulation of herbal hair care products.

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