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RESEARCH ARTICLE

Formulation and Evaluation of Herbal Lipstick Using *Hibiscus sabdariffa*

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Abstract: Widespread safety concerns regarding synthetic colorants, heavy metal contamination, and chemical preservatives in modern cosmetics have resulted in transition toward plant-derived alternatives. This work presents the systematic compounding, standardization, and physicochemical characterization of an organic lipstick formulation using bioactive colorants extracted from the dried calyces of *Hibiscus sabdariffa*. Anthocyanin pigments were stabilized within a structural lipid matrix consisting of *Apis mellifera* purified wax, hexadecan-1-ol, and cold-pressed *Ricinus communis* seed oil. To prevent lipid peroxidation and ensure organoleptic acceptability, natural tocopherols and volatile distillates of *Rosa damascena* were incorporated. The compounded formulation was subjected to rigorous analytical evaluation, including thermal stability, mechanical breaking point, rheological spreadability, surface micro-uniformity, hydrogen ion concentration, and skin compatibility. The resulting product displayed an aesthetically appealing, deep pinkish-red hue with a homogeneous, non-gritty texture and a melting point stabilized at 58°C to 62°C. Mechanical testing demonstrated a robust breaking point of 150 g, indicating structural integrity suitable for practical application without fracture. A physiological pH value of 6.2 ± 0.1 ensured complete compatibility with mucosal tissue, which was further validated by the complete absence of erythema, edema, or dermal irritation during *in-vivo* acute dermal safety trials on New Zealand White rabbits over a 72-hour monitoring period under Institutional Animal Ethics Committee (IAEC) approval. These results validate the therapeutic and cosmetic viability of *Hibiscus sabdariffa* as a sustainable, non-toxic chromophore for high-performance personal care formulations.

Keywords: *Hibiscus sabdariffa*; Physicochemical properties; Lipstick; Anthocyanins; Skin irritation.

1. Introduction

The pursuit of personal aesthetics and dermal embellishment is a fundamental aspect of human cultural evolution, dating back to ancient civilizations. Historical records indicate that the systematic application of pigments and topical preparations was well-established as early as 4000 to 5000 BC, derived from the classical Greek term *Kosmetikos*, denoting the specialized skill of ordering, arranging, or decorating [1]. Early Roman cultures adapted this term to *Cosmetae*, describing dedicated individuals tasked with prepending aromatic distillates and therapeutic baths [2]. In the modern world, the nomenclature transitioned during the early twentieth century to encompass make-up and decorative cosmetics as commercial entities, precipitating the establishment of a multi-billion-dollar global industry catering to different demographic cohorts [3].

Legislative guidelines were established globally to regulate this rapidly expanding commercial sector and protect consumer health. In the Indian subcontinent, the Central Drugs Standard Control Organization regulates these commodities under the statutory provisions of the Drugs and Cosmetics Act of 1940 and the subsequent Rules of 1945 [4]. This legislation defines a cosmetic as any substance or mixture intended to be placed in contact with the external parts of the human body, including the epidermis, hair system, nails, lips, and external genital organs, or with the teeth and the mucous membranes of the oral cavity, solely or mainly to clean them, perfume them, change their appearance, protect them, keep them in good condition, or correct body odors [5].

Cosmetic preparations are scientifically categorized based on their site of application and functional role. Dermal cosmetics comprise protective and decorative formulations such as foundations, compact powders, and barrier creams [6]. Hair preparations focus on the cleansing and conditioning of the hair shaft and scalp, including surfactants and styling gels [7]. Ocular and unguent cosmetics include mascaras, eyeliners, and specialized nail lacquers designed to alter regional pigmentation [8]. Dental and oral hygiene products, such as dentifrices and rinses, are formulated to maintain oral cleanliness and control microflora [9].

Among these different categories, lip cosmetics, particularly lipsticks and protective balms, represent the most widely utilized decorative formulations globally [10]. The human labial epithelium lacks a keratinized stratum corneum and sweat glands, rendering

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it highly susceptible to environmental stressors, solar radiation, thermal fluctuations, and atmospheric particulate matter, which induce dehydration, chapping, and barrier degradation [11]. An ideal lipstick formulation must function bi-directionally: providing an aesthetically pleasing coloration while serving as an occlusive barrier to prevent trans-epidermal water loss and environmental damage [12].

Despite the ubiquity of commercially available lipsticks, the reliance on synthetic pigments, coal tar-derived dyes, artificial plasticizers, and halogenated preservatives poses reported dermatological and systemic hazards. Synthetic colorants, such as eosin derivatives, halogenated fluoresceins, and azo dyes, are associated with contact dermatitis, cheilitis, localized photosensitivity, and cumulative heavy metal toxicity arising from trace contaminants like lead, cadmium, and aluminum [13]. The inadvertent ingestion of these chemical agents during daily activities, including eating and speaking, presents long-term toxicological risks [14]. These adverse effects have driven a consumer shift back toward organic, plant-derived alternative. Traditional Ayurvedic treatises, specifically the *Charaka Samhita*, document a vast pharmacopoeia of botanical agents possessing natural pigments, high antioxidant capacities, anti-inflammatory properties, and tissue-regenerative properties [15].

An optimal lipstick formulation must maintain strict physicochemical parameters, including physical stability across varying thermal ranges, uniform spreadability without dragging, resistance to fracture under shear stress, absence of grittiness, and prolonged retention on the mucosal surface [16]. This study focuses on the systematic development, optimization, and pharmacognostic standardization of a natural, non-toxic lipstick utilizing the natural pigments of *Hibiscus sabdariffa* flowers, stabilized within an organic wax-oil eutectic mixture to deliver a safe, functional, and aesthetically viable cosmetic alternative.

2. Materials and Methods

2.1. Raw Materials

2.1.1. Collection and Authentication of Plant Materials

The fresh floral specimens of *Hibiscus sabdariffa* (Family: Malvaceae) were obtained from localized botanical reserves in Shivamogga, Karnataka, India. The botanical identity of the plant material was verified and authenticated at the Department of Pharmacognosy, National College of Pharmacy, Shivamogga, where a voucher specimen was deposited for future reference. The calyces were manually separated from the inner receptacle, washed thoroughly under running distilled water to eliminate superficial soil, dust, and particulate contaminants, and subjected to controlled shade drying at a temperature of 30 ± 2°C for a period of ten days until a constant weight was achieved.

2.1.2. Lipid and Wax Bases

Natural structural lipids utilized in compounding included yellow beeswax, obtained by physical rendering of the honeycombs of *Apis mellifera*, and pharmaceutical-grade hexadecan-1-ol (cetyl alcohol). Cold-pressed, unrefined castor oil extracted from the seeds of *Ricinus communis* was acquired to serve as the liquid hydrophobic vehicle and pigment-dispersing medium.

2.1.3. Antioxidants, Fragrances, and Auxiliary Agents

Naturally derived d-α-tocopheryl acetate (Vitamin E) was procured to function as a lipophilic antioxidant to inhibit lipid peroxidation within the unsaturated fatty acid phases of the formulation. Steam-distilled essential oil of *Rosa damascena* was sourced to serve as the natural organoleptic modifier, imparting scent while providing mild antimicrobial preservation.

2.2. Physicochemical Functions of Ingredients

The logical incorporation of each raw material within the formulation is dictated by its physical, chemical, and dermatological attributes, as summarized in Table 1.

2.2.1. Apis mellifera Secretions (Beeswax)

Purified beeswax consists predominantly of alkyl esters of fatty acids (primarily myricyl palmitate, $C_{15}H_{31}COOC_{30}H_{61}$), free wax acids, and hydrocarbon chains. Its incorporation at a critical concentration provides the necessary mechanical strength and rigidity to the stick formulation. Beeswax facilitates the formation of a cohesive crystalline network upon cooling, which prevents the separation of the liquid oil phase, a phenomenon known as syneresis. Additionally, it exhibits excellent plasticizing properties, allowing the lipstick to resist thermal deformation at elevated environmental temperatures while maintaining a smooth gloss upon application.

Table 1. Physicochemical Role of Ingredients Used in Herbal Lipstick

Sl. No.	Ingredient Name	Scientific/IUPAC Name	Physicochemical Role
1	Beeswax	*Apis mellifera* Cera	Primary structural matrix and hardening agent
2	Cetyl Alcohol	Hexadecan-1-ol	Co-emulsifier, texture builder, and opacifier
3	Castor Oil	*Ricinus communis* Seed Oil	Hydrophobic dispersing vehicle and gloss enhancer
4	Hibiscus Powder	*Hibiscus sabdariffa* Calyx Powder	Natural hydrophilic colorant and antioxidant
5	Vitamin E Oil	d-α-Tocopheryl acetate	Lipophilic antioxidant and lipid stabilizer
6	Rose Essential Oil	*Rosa damascena* Flower Oil	Organoleptic modulator and antimicrobial agent

2.2.2. Hexadecan-1-ol (Cetyl Alcohol)

Cetyl alcohol ($CH_3(CH_2)_{15}OH$) is a long-chain fatty alcohol that functions as an auxiliary structuring agent and co-emulsifier. It intercalates within the larger beeswax-oil crystalline lattice, refining the crystal size and preventing the formation of large, brittle crystal domains that cause cracking. By acting as an emollient and opacifying agent, cetyl alcohol enhances the velvety texture of the lipstick, reducing the greasy sensation of heavy oils and ensuring a matte-to-satin finish on the lips.

2.2.3. Ricinus communis Seed Oil (Castor Oil)

Castor oil is characterized by an extremely high concentration of ricinoleic acid (12-hydroxy-octadec-9-enoic acid, $C_{18}H_{34}O_3$), an unsaturated fatty acid containing a polar hydroxyl group. This unique molecular architecture imparts high viscosity, excellent thermal stability, and superior wetting capabilities. It serves as an optimal dispersing medium for the hydrophilic *Hibiscus sabdariffa* pigment particles, preventing agglomeration and sedimentation. Upon topical application, castor oil forms a cohesive, light-refracting film that provides a highly aesthetic gloss, while its humectant properties draw moisture to the lips.

2.2.4. Hibiscus sabdariffa L. Calyces

The intense coloration of the calyces of *Hibiscus sabdariffa* is attributed to a high concentration of water-soluble anthocyanins, primarily delphinidin-3-sambubioside and cyanidin-3-sambubioside. These polyphenolic compounds undergo structural transitions depending on the localized pH, displaying a vibrant red-to-pink hue under mildly acidic conditions (pH = 3.0 to 6.5). Beyond pigmentation, these molecules possess high radical scavenging activities, neutralizing reactive oxygen species on the lips and reducing oxidative stress induced by ultraviolet radiation.

2.2.5. Tocopherol (Vitamin E)

The inclusion of unsaturated fatty acids, such as the ricinoleic acid present in castor oil, renders the formulation highly susceptible to atmospheric oxidation at room temperature. This oxidative degradation results in the formation of short-chain aldehydes and ketones, clinically recognized as rancidity, which compromises the odor, taste, and safety of the cosmetic. d-α-Tocopherol acts as a chain-breaking antioxidant by donating hydrogen atoms to free radicals, terminating the lipid peroxidation cascade and extending the product's shelf-life without the need for synthetic parabens or butylated hydroxytoluene.

$$LOO^{\cdot} + \text{Tocopherol-OH} \longrightarrow LOOH + \text{Tocopherol-O}^{\cdot}$$

2.2.6. Rosa damascena Essential Oil

The volatile oil of *Rosa damascena*, obtained via hydrodistillation, is composed of geraniol, citronellol, and nerol. It functions as a natural scenting agent, masking the earthy odors of the raw wax-oil matrix. The terpene constituents of rose oil possess mild antiseptic and broad-spectrum antimicrobial properties, which inhibit the growth of opportunistic bacterial and fungal pathogens within the formulation during storage and usage.

2.2.7. Metallic Lipstick Moulds

To achieve a uniform cylindrical morphology, a professional, split-type, multi-cavity brass lipstick mould was utilized. The high thermal conductivity of the metallic brass ensures rapid and uniform heat dissipation during the cooling phase, preventing thermal stress fractures, hollow core formation, or surface pitting. This results in a smooth, high-gloss external surface on the finished sticks.

2.3. Preparation of the Natural Colorant Extract

The standardized preparation of the fine botanical pigment powder was conducted according to the following protocol:

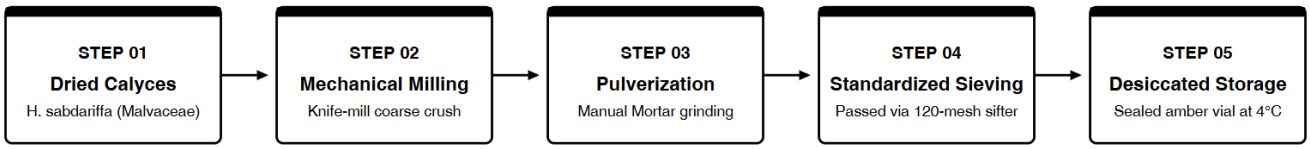

Figure 1. Process for the preparation of raw pigments from the calyces of *Hibiscus sabdariffa*.

1. The shade-dried calyces of *Hibiscus sabdariffa* were crushed into a coarse powder using an analytical knife mill.
2. The coarse material was transferred to an agate mortar and pestle for manual pulverization to minimize thermal damage to the heat-sensitive anthocyanin pigments.
3. The resulting powder was passed through a calibrated 120-mesh stainless steel sieve to isolate particles with a diameter $\leq$ 125 μm. A uniform, fine particle size is critical to prevent a gritty texture in the lipstick, which can lead to localized irritation and uneven pigment transfer during application.
4. The standardized powder was stored in an airtight amber glass container containing active silica gel desiccants at 4°C to prevent moisture absorption and enzymatic degradation of the chromophores.

2.4. Formulation and Preparation of the Herbal Lipstick

The herbal lipstick was compounded utilizing a controlled thermal fusion and dispersion technique [17]. The exact quantitative proportions of the ingredients required to prepare a standard 10 g batch are specified in Table 2.

Table 2. Composition for the Herbal Lipstick Formulation

Sl. No.	Ingredient Name	Weight/Volume Required	Percentage Composition (w/w)
1	Beeswax	4.0 g	40%
2	Cetyl Alcohol	1.0 g	10%
3	Castor Oil	3.0 g	30%
4	*Hibiscus sabdariffa* Powder	2.0 g	20%
5	Vitamin E Oil	5.0 drops	≈1.5%
6	Rose Essential Oil	3.0 drops	≈0.8%

The formulation process was carried through the following steps:

1. The fine *Hibiscus sabdariffa* calyx powder (2.0 g) was quantitatively transferred to a dry vessel containing cold-pressed castor oil (3.0 g). The mixture was subjected to high-shear mechanical dispersion at 500 rpm for fifteen minutes to ensure complete wetting of the hydrophilic pigment particles and the formation of a homogeneous, intensely red suspension.
2. Purified beeswax (4.0 g) was placed in a clean, dry porcelain evaporating dish and melted on a thermostatic water bath maintained at 75 ± 2°C until a clear, isotropic liquid phase was obtained.
3. In a separate vessel, cetyl alcohol (1.0 g) was melted at 55 ± 2°C and subsequently added to the molten beeswax phase under continuous, gentle agitation to form a uniform structuring base.
4. The castor oil-pigment dispersion was slowly introduced into the molten wax base in a steady stream, maintaining the temperature at 70°C to prevent premature solidification. The mixture was continuously stirred with a glass rod to ensure uniform distribution of the pigment particles within the molten lipid matrix.
5. The porcelain dish was removed from the heat source, and the mixture was allowed to cool under gentle stirring.
6. Once the temperature reached 50°C, the heat-sensitive additives including five drops of Vitamin E oil and three drops of Rose essential oil were incorporated. This specific temperature threshold is critical to prevent the thermal volatilization of the rose oil terpenes and the chemical oxidation of tocopherol.
7. The molten, uniform mass was poured in a continuous, non-interrupted stream into the cavities of a professional brass lipstick mould, which had been pre-warmed to 37°C to prevent thermal shock and resultant contraction cavities.
8. The filled mould was placed in a refrigeration chamber at 4 ± 1°C for five minutes to accelerate crystallization, and then transferred to room temperature (25 ± 2°C) for twenty minutes to achieve complete mechanical equilibrium.

9. The mould was split, and the solidified herbal lipsticks were carefully extracted and fitted into clean, functional lipstick tubes for physicochemical characterization.

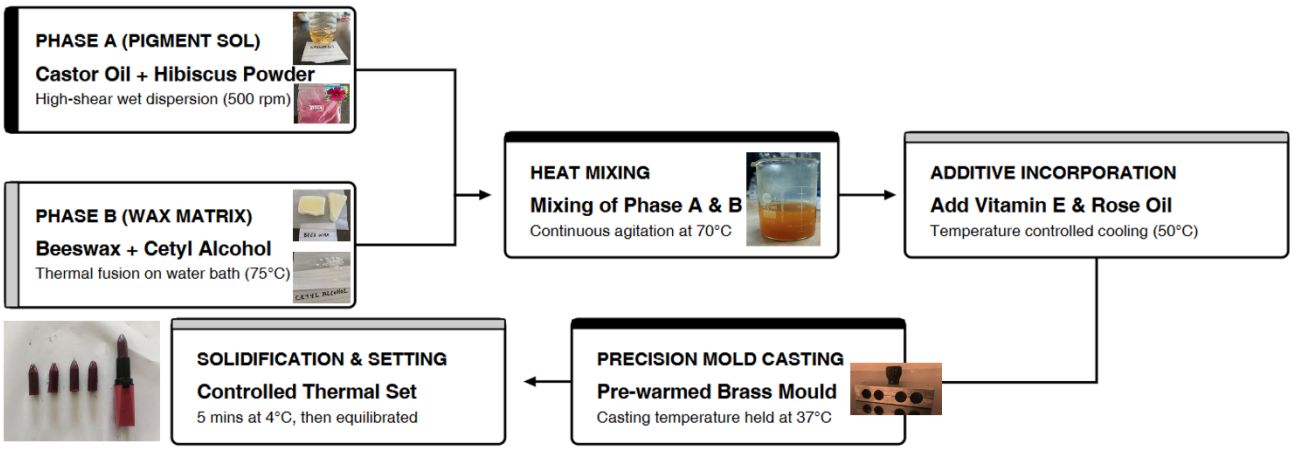

Figure 2. Compounding and Formulation Method

2.5. Physicochemical and Dermatological Evaluation Protocols

The prepared herbal lipstick formulation was subjected to systematic evaluation to determine its functional efficiency, stability, and safety profile.

2.5.1. Organoleptic Characterization

The visual parameters, including color, uniformity of pigmentation, surface texture, and presence of structural defects, were evaluated under standardized daylight conditions (D65 illuminant). The scent, uniformity, and subjective texture profiles were characterized physically by a panel of three independent cosmetic formulators under standardized laboratory conditions to evaluate aesthetic and structural acceptability, avoiding direct human oral consumption.

2.5.2. Rheological Properties

The presence of gritty particulate matter was determined by spreading a thin layer of the formulation onto a clean microscopic slide and examining it under a light microscope at 100× magnification. Surface anomalies, including physical cracking, crystalline blooming, and air entrapment, were inspected visually under a magnifying lens (5×).

2.5.3. Melting Point Determination

The slip melting point, which is the temperature at which the lipstick starts to flow within a capillary tube, was determined using a standard capillary tube apparatus. The lipstick was packed into a thin-walled glass capillary tube to a height of 10 mm and cooled at 4°C for twenty-four hours. The capillary was then attached to a precision thermometer and heated in a water bath at a rate of 0.5°C per minute. The temperature at which the column of lipstick became completely transparent and flowed upward was recorded [18].

2.5.4. Mechanical Breaking Point

The mechanical strength of the formulation was evaluated using a customized horizontal load test. The lipstick was extended to its maximum length (20 mm) and secured horizontally in a rigid clamp assembly. Weights were suspended from the tip of the stick at a distance of 15 mm from the base in increments of 10 g every ten seconds. The cumulative weight required to cause complete fracture of the stick was recorded as the mechanical breaking point [18].

2.5.5. Application Force and Pay-off

The force of application was determined qualitatively by applying the lipstick onto high-purity chromatographic paper using constant manual pressure. The uniformity of the color transfer (pay-off) and the resistance of the stick to bending, crumbling, or physical distortion during application were observed over multiple continuous strokes.

2.5.6. Measurement of Micro-Hydrogen Ion Concentration (pH)

Because the lipstick is applied to the sensitive lips, its pH must closely align with physiological limits to prevent tissue irritation. A 1% (w/v) dispersion of the herbal lipstick was prepared by melting 1.0 g of the formulation in 99.0 mL of freshly boiled and cooled deionized water at 70°C, followed by intensive agitation. The mixture was cooled to 25°C to allow the wax phase to solidify, and the aqueous filtrate containing the extracted pigment was analyzed using a calibrated digital pH meter.

2.5.7. Spreadability

Spreadability was assessed using a parallel-plate method. A standardized sample of the lipstick (0.5 g) was placed between two horizontal glass plates (10 cm × 10 cm). A weight of 100 g was gently placed on the upper plate for five minutes, and the surface area of the spread lipstick was measured. The time required for the upper slide to separate from the lower slide under lateral shear stress was also recorded to assess slip properties.

2.5.8. Adhesion and Retention

The pigment retention and mucosal adhesion properties of the formulation were evaluated *ex vivo* utilizing freshly excised goat buccal mucosa obtained from a local registered slaughterhouse. A uniform, standardized layer of the lipstick (0.1 g) was applied onto the mucosal tissue surface (2 cm × 2 cm) secured in a modified Franz-type diffusion cell apparatus. The tissue was subjected to continuous wash-off using simulated salivary fluid (pH 6.8) at a constant flow rate of 1.0 mL/min at 37 ± 0.5° C to simulate physiological salivary dynamics. The persistence of the red pigment tint on the mucosal surface was monitored visually at 30-minute intervals to determine the retention threshold.

2.5.9. Accelerated Stability Studies

The formulated sticks were subjected to accelerated stability testing in accordance with the International Council for Harmonisation (ICH) Q1A (R2) guidelines. Replicate samples were packaged in commercial cosmetic containers and stored under three distinct environmental conditions for a period of ninety days:

1. Low-temperature refrigeration chamber maintained at 4 ± 0.5°C.
2. Ambient climate chamber maintained at 25 ± 2°C and 60 ± 5% relative humidity.
3. Elevated temperature incubator maintained at 40 ± 2°C and 75 ± 5% relative humidity.

The samples were evaluated at intervals of 15, 30, 60, and 90 days for physical changes in color, scent, surface sweating, and mechanical integrity.

2.5.10. Acute Dermal Irritation Studies in Rabbits

The experimental protocol was reviewed and approved by the Institutional Animal Ethics Committee (IAEC) of the National College of Pharmacy, Shivamogga, Karnataka, India (Approval No. NCP/IAEC/2025/11-08). The study was conducted in strict compliance with the guidelines of the Committee for Control and Supervision of Experiments on Animals (CCSEA), Ministry of Fisheries, Animal Husbandry and Dairying, Government of India.

Healthy New Zealand White rabbits (male, weighing 2.0 ± 0.2 kg, n=3) were used for the *in-vivo* acute dermal irritation study, following the OECD Guideline for Testing of Chemicals No. 404 (Acute Dermal Irritation/Corrosion). The animals were housed individually in suspended stainless steel cages under controlled environmental conditions (temperature: 22 ± 3°C, relative humidity: 50 ± 10%, and a 12-hour light/dark cycle) with free access to a standard pellet diet and purified water.

Approximately 24 hours prior to the study, the hair on the dorsal thoracolumbar region of each rabbit was carefully clipped to expose an area of approximately 10 cm2, ensuring the epidermis remained intact without abrasions. A quantity of 0.5 g of the compounded herbal lipstick formulation was applied uniformly over a 6 cm2 portion of the cleared skin. The test site was covered

with a sterile, non-reactive gauze patch and secured with a non-irritating hypoallergenic adhesive tape to form a semi-occlusive dressing for a contact period of 4 hours.

After 4 hours, the patches were carefully removed, and the residual formulation was gently washed using warm deionized water. The application sites were examined and graded for skin reactions, specifically erythema and edema, at 1, 24, 48, and 72 hours post-patch removal. Dermal changes were scored quantitatively according to the standardized Draize scoring system (ranging from 0 to 4 based on severity) [19, 20].

3. Results

3.1. Organoleptic and Physical Characteristics

The prepared herbal lipstick exhibited a highly appealing, uniform pinkish-red color, derived from the natural anthocyanins of *Hibiscus sabdariffa*. The formulation possessed a smooth, continuous surface with a mild, pleasant rose scent and a neutral taste. Visual and microscopic examinations revealed a homogeneous distribution of pigment particles, with no signs of crystalline blooming, air bubbles, phase separation, or surface sweat droplets. These organoleptic properties are shown in Table 3.

Table 3. Organoleptic Properties of the Prepared *Hibiscus sabdariffa* Formulation

Parameter	Observed Characteristic	Rating
Color	Vibrant Pinkish-Red	Highly satisfactory
Odor	Pleasant, floral rose fragrance	Excellent
Taste	Neutral, non-greasy	Highly acceptable
Surface Texture	Smooth, lustrous, and homogeneous	Highly satisfactory
Grittiness	Absent under 100×magnification	Confirmed non-gritty
Homogeneity	Uniform color distribution	Highly satisfactory

3.2. Physicochemical Properties

The quantitative values obtained from the physicochemical testing of the herbal lipstick are shown in Table 4.

Table 4. Physicochemical Parameters and Rheological Properties of the Standardized Lipstick

Sl. No.	Physicochemical Parameter	Observed Experimental Value	Standard Ideal Range
1	Slip Melting Point	59.5 ± 1.2°C	55°C to 65°C
2	Mechanical Breaking Point	150 ± 5.5 g	> 120 g (Optimal)
3	pH of 1% Aqueous Extract	6.2 ± 0.12	5.5 to 6.8 (Physiological)
4	Spreadability Time	7.0 ± 0.8 seconds	5.0 to 10.0 seconds
5	Force of Application	Easy, smooth slide with no dragging	Easily applicable
6	Pay-off (Color Transfer)	High pigment transfer on single stroke	Optimal
7	Retention Time on Mucosa	2.5 ± 0.5 hours	Adequate for natural formulations

3.2.1. Melting Point

The slip melting point was recorded at 59.5 ± 1.2°C. This temperature lies within the ideal range of 55°C to 65°C required for high-quality lipsticks. This ensures that the formulation remains solid and structurally stable at body temperature and under warm climatic conditions, yet melts smoothly when subjected to the friction of application on the lips.

3.2.2. Mechanical Breaking Strength

The mechanical breaking point of the stick was determined to be 150 ± 5.5 g. A breaking point above 120 g is considered optimal for commercial cosmetics, confirming that the optimized ratio of beeswax (40%) to liquid castor oil (30%) provides sufficient mechanical resilience to withstand normal lateral force during application without fracturing.

3.2.3. Hydrogen Ion Concentration (pH)

The aqueous extract of the formulation displayed a pH of 6.2 ± 0.12, which is compatible with the natural slightly acidic-to-neutral pH of the human skin surface. This minimizes the risk of chemical irritation, dryness, or discomfort on the lips.

3.2.4. Spreadability

The formulation exhibited a spreadability time of 7.0 ± 0.8 seconds, indicating excellent glide and smooth application without excessive waxiness. The pay-off test showed a distinct, uniform color band on a single stroke, confirming that the castor oil effectively dispersed the *Hibiscus* powder across the substrate.

3.2.5. Ex-Vivo Adhesion and Retention

Under continuous simulated salivary wash-off dynamics (pH 6.8, 1.0 mL/min at 37°C), the lipstick formulation demonstrated an average mucosal retention time of 2.5 ± 0.5 hours (as shown in Table 4). The pigment remained uniformly distributed across the *ex-vivo* goat buccal mucosal tissue with high resistance to premature erosion or mechanical wash-off, validating the excellent film-forming properties of the hydrophobic beeswax-castor oil eutectic matrix.

3.3. Stability and Compatibility

3.3.1. Accelerated Stability

The physical and chemical parameters of the formulation remained stable throughout the ninety-day accelerated stability study, as shown in Table 5.

Table 5. Accelerated Stability Study Results of the Prepared Formulation Over 90 Days

Storage Temperature	Relative Humidity	Evaluation Interval	Color Stability	Odor Degradation	Syneresis/Sweating	Mechanical Integrity
4 ± 0.5°C	Controlled	Day 30	Stable	None	Absent	No change
		Day 90	Stable	None	Absent	No change
25 ± 2°C	60 ± 5%	Day 30	Stable	None	Absent	No change
		Day 90	Stable	None	Absent	No change
40 ± 2°C	75 ± 5%	Day 30	Minor Fading	Very Mild	Absent	Slight softening
		Day 90	Slight Fading	Very Mild	Absent	Softened, no flow

At 4°C and 25°C, the lipstick maintained its color, rose scent, and structural integrity without physical deformation or oil separation (syneresis). At the elevated temperature of 40°C, a slight softening of the wax matrix was observed, which is typical for lipsticks containing natural beeswax. However, no liquid oil run-off or structural collapse occurred, and only minor pigment fading was detected by day 90.

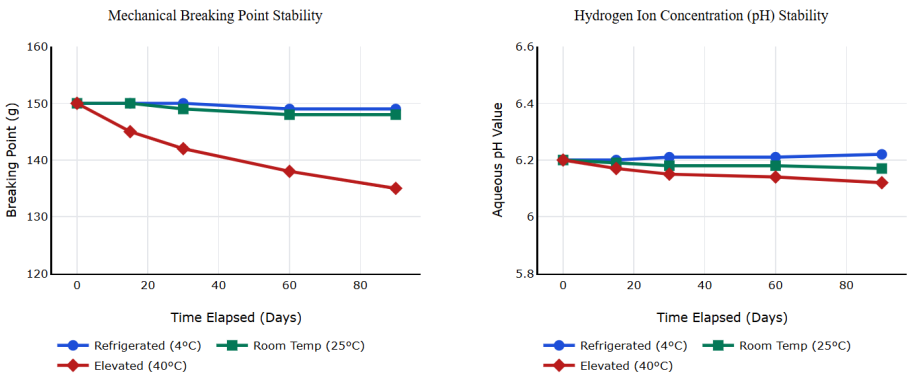

Figure 3. Results of Accelerated Stability Studies

3.3.2. Human Skin Irritation Patch Testing

In-Vivo Acute Dermal Irritation Study The acute dermal irritation potential of the optimized *Hibiscus sabdariffa* lipstick was evaluated in New Zealand White rabbits (n=3) over a 72-hour post-exposure observation period. Visual inspection of the exposure sites at 1, 24, 48, and 72 hours revealed a complete absence of any inflammatory dermal responses. No localized erythema, eschar formation, or edema was observed in any of the experimental animals. The calculated primary dermal irritation index (Draize score) was 0.0, classifying the compounded formulation as completely non-irritating and dermatologically safe for topical application. No systemic toxicological signs or behavioral abnormalities were recorded during the study, confirming the biocompatibility of both the organic wax-lipid base and the botanical anthocyanin colorant extract.

4. Discussion

The development of personal care products utilizing botanical ingredients requires careful optimization of the lipid-wax matrix to ensure physical stability, user-friendly rheology, and safety. In this formulation, *Apis mellifera* beeswax served as the primary structural agent, establishing a robust crystalline network that prevented phase separation, or syneresis, under thermal stress. To prevent the stick from becoming brittle, cetyl alcohol was incorporated as a co-emulsifier and texturizer. This long-chain fatty alcohol refines the wax crystal domains, yielding a more uniform, velvety texture that enhances spreadability on the lips. The choice of *Ricinus communis* (castor) oil as the continuous liquid phase was critical for pigment dispersion. The high content of ricinoleic acid, with its unique polar hydroxyl group, provides high viscosity and excellent wetting properties. This polar molecular structure allows castor oil to form stable complexes with the hydrophilic anthocyanin pigments of *Hibiscus sabdariffa*, preventing the particle agglomeration that causes a gritty feel.

Hibiscus sabdariffa calyces contain natural anthocyanins, primarily delphinidin-3-sambubioside and cyanidin-3-sambubioside. These pigments yield a rich, pinkish-red color under mildly acidic conditions. By stabilizing the formulation at a physiological pH of 6.2 ± 0.12, the vibrant color of the anthocyanins was preserved while maintaining compatibility with the lips. To prevent the oxidation of the unsaturated fatty acids in castor oil, natural tocopherols (Vitamin E) were added. This lipophilic antioxidant terminates the lipid radical cascade, preventing rancidity and extending the product's shelf life. The volatile oil of *Rosa damascena* not only masked the base odors of the waxes but also provided mild, natural antimicrobial preservation.

The prepared herbal lipstick exhibited a slip melting point of 59.5 ± 1.2°C and a mechanical breaking strength of 150 ± 5.5 g, indicating it can withstand the lateral forces of application without fracturing. The formulation proved to be completely non-irritating and biocompatible in rabbits under OECD 404 experimental guidelines, showing zero dermal toxicity, and remained stable under accelerated aging conditions (4°C and 25°C). These results show that *Hibiscus sabdariffa* is a highly viable, sustainable, and safe natural alternative to synthetic dyes in functional cosmetic formulations.

5. Conclusion

This work presented the successful formulation of a natural herbal lipstick utilizing plant-derived, non-toxic ingredients. The vibrant color was achieved using fine *Hibiscus sabdariffa* calyx powder, stabilized within a balanced lipid matrix of beeswax, cetyl alcohol, and castor oil. The formulation displayed highly satisfactory organoleptic properties, including a smooth, non-gritty texture, a pleasant rose aroma, and excellent color transfer. Analytical testing confirmed a melting point of 59.5°C, a mechanical breaking strength of 150 g, and a skin-compatible pH of 6.2, ensuring structural durability and physiological safety. Accelerated stability studies and *in-vivo* dermal irritation testing on rabbit models verified that the formulation is physically stable, biocompatible, and non-irritating. The results show the potential of *Hibiscus sabdariffa* as a sustainable, bioactive colorant for high-performance, eco-friendly personal care products.

Compliance with ethical standards

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Conflict of interest statement

The authors declare that they have no known competing financial interests, personal relationships, or professional affiliations that could have influenced the work reported in this manuscript. There are no conflicts of interest associated with any of the proprietary

raw materials, botanical sources, or commercial cosmetic products mentioned in this study, and the research was conducted independently of any external commercial influence.

Statement of ethical approval

The experimental protocol for the *in-vivo* acute dermal safety trials was formally reviewed and approved by the Institutional Animal Ethics Committee (IAEC) of the National College of Pharmacy, Shivamogga, Karnataka, India (Approval No. NCP/IAEC/2025/11-08). All animal housing, handling, and experimental procedures were performed in strict compliance with the guidelines of the Committee for Control and Supervision of Experiments on Animals (CCSEA), Ministry of Fisheries, Animal Husbandry and Dairying, Government of India.

Statement of informed consent

Not applicable. This investigation does not contain any clinical trials, diagnostic surveys, case reports, or personal data involving human participants, and therefore, statement of informed consent is not applicable to this research.

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