



FORMULATION AND CHARACTERIZATION OF BUTTERFLY PEA FLOWER-BASED HERBAL LIPSTICK

Taru Jagdar¹, Girish Kumar Vyas^{1*}

¹Career Point School of Pharmacy, Career Point University, Kota, Rajasthan, India.

Corresponding Author*: Girish Kumar Vyas, Career Point School of Pharmacy, Career Point University, Kota, Rajasthan, India.

Email ID: jagdartaupharmacy@gmail.com

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ABSTRACT

Background: Growing consumer and regulatory concern over synthetic azo and coal-tar dyes in lip cosmetics has renewed interest in botanical colorants with intrinsic bioactivity. *Clitoria ternatea* (butterfly pea) flowers accumulate an unusually pH-stable family of polyacylated delphinidin glycosides, ternatins, that combine vivid colour with documented antioxidant activity, yet their deliberate use as a primary colourant in lipstick has received little systematic investigation.

Methods: Three fusion-cast lipstick formulations (F1–F3) containing 5%, 10%, and 15% w/w *C. ternatea* flower extract in a conventional wax–oil base were developed, with 0.5% w/w citric acid incorporated to lower the microenvironmental pH and shift the ternatin pigments from their native blue-violet hue toward a lipstick-appropriate pink-rose through stabilisation of the flavylium cation. Formulations were characterised for colour behaviour, pH, hardness, melting range, spreadability, DPPH radical-scavenging activity, and 90-day accelerated stability ($40\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ / $75\% \text{ RH} \pm 5\%$) of the optimised batch.

Results: All formulations displayed pharmacopoeially acceptable hardness (280–395 g), melting behaviour (58–68 °C), and spreadability, with citric acid reproducibly shifting pH from 5.8–6.3 to 3.8–4.2 and colour from blue-violet to pink-rose without loss of structural integrity. One-way ANOVA confirmed that extract concentration had a statistically significant effect on every physicochemical and antioxidant parameter examined ($p < 0.01$ in all cases), and Tukey's HSD post-hoc test showed that the majority of pairwise formulation differences were individually significant. F2 (10% extract) offered the best overall balance of texture, hardness, and spreadability, and exhibited concentration-dependent DPPH scavenging ($\text{IC}_{50} = 48.7\text{ }\mu\text{g/mL}$). Accelerated stability testing of F2 showed less than 9% anthocyanin loss and only minor pH and hardness drift over 90 days.

Conclusion: *C. ternatea* anthocyanins, deployed with a citric-acid pH-shifting strategy, constitute a viable and statistically validated natural colorant for lip cosmetics that additionally confers antioxidant benefit, supporting their development as a clean-label alternative to synthetic lip pigments, pending confirmatory chromatographic standardisation and dedicated dermal safety evaluation as outlined in Sections 4 and 6.

KEYWORDS: *Clitoria Ternatea*, Butterfly Pea Flower, Ternatin Anthocyanins, Natural Cosmetic Colorant, Herbal Lipstick, DPPH Antioxidant Activity, One-way ANOVA.

Introduction

Lipstick remains one of the most universally used cosmetic products, its formulation having evolved from ancient

mineral- and berry-derived pigments to the engineered wax–oil–colourant systems of contemporary cosmetic science. Industry analyses place the global lipstick market

in the range of USD 9-18 billion for 2023, with most forecasts converging on a compound annual growth rate of approximately 5% through the early 2030s, a trajectory driven in part by consumer demand for products that combine colour, gloss, and additional functional benefits[1,2]. A substantial share of commercial lipsticks nevertheless still relies on synthetic and coal-tar-derived colourants — including certified dyes such as Red 6, Red 7, FD&C Red 40, and D&C Orange 17. Because lip skin is thin, mucosal, and subject to repeated ingestion-adjacent exposure, it readily absorbs applied compounds, and chronic exposure to some synthetic colourants has been associated with contact sensitisation, allergic dermatitis, and, in a minority of cases, concerning degradation products[3]. This safety and sustainability concern has driven sustained interest in natural alternatives, among which anthocyanins — the flavonoid pigments responsible for the red, purple, and blue colouration of many fruits and flowers — are particularly attractive, combining tinctorial strength with antioxidant activity and a generally favourable dermal safety profile[4].

Clitoria ternatea (butterfly pea) is an especially promising anthocyanin source in this context. Its flowers accumulate a distinctive family of polyacylated delphinidin glycosides known as ternatins, which are markedly more stable across a wide pH and temperature range than the unacylated anthocyanins typical of common berries[5-7]. A defining feature of these pigments is their reversible, pH-dependent chromatic behaviour: strongly acidic conditions favour the red flavylium cation, near-neutral pH favours violet-blue hemiketal and quinonoid forms, and alkaline conditions push the colour toward blue-green[8,9]. Around pH 3.5–4.5 the flavylium cation dominates, imparting a pink-rose hue — the rationale for using a mild, food-grade acid such as citric acid to deliberately shift *C. ternatea* pigments from their native blue-violet toward a warmer, cosmetically appropriate pink. This pH-responsive behaviour has, in fact, been exploited well beyond cosmetics: recent work has incorporated butterfly pea anthocyanins into polymer films as visual pH-indicators for intelligent food-freshness packaging, underscoring both the robustness of the colour-shift mechanism and the pigment's versatility across application domains[10].

Beyond colour, *C. ternatea* extracts carry a well-documented bioactivity profile. Comprehensive reviews and recent primary studies report antioxidant, anti-inflammatory, antidiabetic, hepatoprotective, and photoprotective activities for the flower extract and its anthocyanin-rich fractions, alongside an expanding footprint in nutraceutical, functional-food, and cosmetic applications[11-13]. Green, high-resolution extraction and characterisation methods — including UHPLC-MSn profiling — have further refined understanding of the ternatin complement and its biological activity in recent extraction-optimisation studies[14]. Collectively, this places *C. ternatea* in a distinctive position among natural colorants: few plant pigments combine

comparable pH-tunable hue, thermal and chemical stability, and intrinsic antioxidant benefit within a single, food-grade, and traditionally consumed botanical source[15].

Despite this favourable profile, the great majority of prior *C. ternatea* research has addressed food and beverage colouring, intelligent packaging, or pharmacological screening rather than lip cosmetics specifically. Natural-colorant cosmetic science more broadly has established methodological templates for evaluating herbal lipsticks: Bharat, Bhimte, and Grover[16], and Pal, Verma, and Bhatt[17] formulated lipsticks using carotenoids from *Rosa* and *Tagetes* species, Saraf and Kaur[18] reviewed annatto- and henna-based systems, and Desai and Yadav[19], and Jain, Pawar, and Jain[20] incorporated hibiscus, pomegranate, and rose-petal anthocyanins into conventional wax-oil bases without compromising hardness or spreadability. None of these anthocyanin-based lipstick studies, however, examined a deliberate pH-shifting strategy to broaden the achievable colour range, and none used *C. ternatea* specifically. Work that has used *C. ternatea* in topical formulations, such as Butkinaree et al.'s (2022) 12-week stability study of a butterfly-pea cream, has not extended to lip products, and Kumar and Mishra's (2020) review of Ayurveda-informed cosmetic formulation explicitly identified systematic, analytically validated studies of *C. ternatea* in lip-care products as an open research need. Dweck's (2002) foundational review of botanical colourants had, in fact, flagged pH buffering and light-protective packaging as the principal technical hurdles for anthocyanin-based cosmetic products two decades earlier, a challenge this study addresses directly through the citric-acid pH-shift strategy.

The present study addresses this gap by developing, optimising, and comprehensively evaluating lipstick formulations coloured entirely with *C. ternatea* extract. Specifically, the objectives were to (i) formulate three lipsticks at increasing extract concentration and characterise the effect of a citric-acid pH-shift on colour and dispersion pH; (ii) benchmark the formulations against standard pharmacopoeial expectations for hardness, melting behaviour, and spreadability; (iii) quantify antioxidant activity by DPPH radical scavenging and confirm the statistical robustness of formulation differences by one-way ANOVA with Tukey's post-hoc test; and (iv) evaluate the accelerated (90-day) physical and chemical stability of the optimised formulation, so as to establish *C. ternatea* anthocyanins as an analytically validated, dye-free colorant platform for lip cosmetics.

Materials and Methods

Plant Material, and Extraction

Fresh *C. ternatea* flowers were collected from a home terrace garden in Kota, Rajasthan, during the early morning to capture peak anthocyanin content, and supplemented with dried flowers procured commercially. Flowers were shade-dried at 25–30 °C for 5–7 days, pulverised, and

passed through a 40-mesh sieve. The powdered material was macerated in 60% aqueous ethanol (1:10 w/v drug-to-solvent ratio) for 24 hours at room temperature with intermittent stirring, filtered successively through muslin cloth and Whatman No. 1 filter paper, and concentrated by rotary evaporation at 40 °C under reduced pressure. The resulting concentrate was stored at 4 °C under nitrogen in amber glass to minimise oxidative and photolytic degradation prior to use[21-23]. Total anthocyanin content of the extract was determined by the pH-differential spectrophotometric method, reading absorbance at 520 nm and 700 nm at pH 1.0 and 4.5 and expressing results as cyanidin-3-glucoside equivalents[24]. Total anthocyanin content by this method was used as the primary chemical standardisation metric for the extract in the present formulation-development study; chromatographic and colorimetric profiling of individual phytoconstituents were not performed and are identified as priority follow-up analyses in Section 6.

Lipstick Formulation

Three formulations (F1, F2, F3), containing 5%, 10%, and 15% w/w *C. ternatea* extract respectively, were prepared by conventional fusion-casting in a base of beeswax, carnauba wax, castor oil, lanolin, titanium dioxide, and standard preservatives/antioxidants (propylparaben, butylated hydroxytoluene, and vitamin E). Citric acid (0.5% w/w) was dissolved in a minimal volume of water and blended into the pigmented molten base to lower its microenvironmental pH to approximately 3.5–4.0, thereby favouring the flavylum cation form of the ternatin pigments. The molten mass was cast into stainless-steel moulds, cooled, refrigerated to complete solidification, de-moulded, and packaged in light-protective containers. The complete composition of the three formulations is summarised in Table 1.

Physicochemical and Biological Evaluation

Formulations were evaluated for appearance and colour uniformity by visual inspection under standardised diffuse lighting; surface and dispersion pH using a calibrated digital pH meter; hardness by the breaking-point method (incremental weight-loading of a horizontally supported

stick until fracture); melting range by the capillary method at a controlled heating rate of 2 °C/min; spreadability by the parallel-plate method under a standard 500 g load; and subjective texture on volunteer forearm skin, following physicochemical evaluation protocols comparable to those established in previous herbal lipstick formulation studies[16,17,19,20]. Antioxidant activity was assessed by the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical-scavenging assay based on the original method of Brand-Williams et al.²⁵, across a concentration range of 10–100 µg/mL, with IC₅₀ derived from the resulting dose–response curve and ascorbic acid used as the positive reference standard.

Accelerated Stability Studies

The optimised formulation (F2) was subjected to 90-day accelerated stability testing at 40 °C ± 2 °C and 75% RH ± 5%, in accordance with ICH guideline Q1A(R2)[26], with appearance, pH, hardness, and anthocyanin content assessed at days 0, 30, 60, and 90.

Statistical Analysis

All measurements were performed in triplicate (n = 3 per formulation) and are expressed as mean ± standard deviation (SD). Differences among formulations F1, F2 and F3 for each physicochemical and antioxidant parameter were evaluated by one-way analysis of variance (ANOVA), with F-statistics and p-values computed from the reported group means, standard deviations, and sample sizes using the standard one-way ANOVA between/within sum-of-squares formulation (df between = 2, df within = 6). Where the omnibus ANOVA was significant (p < 0.05), pairwise comparisons among F1, F2 and F3 were performed using Tukey's Honestly Significant Difference (HSD) post-hoc test based on the studentized range distribution[27]. A probability value of p < 0.05 was considered statistically significant throughout. Full F-statistics, degrees of freedom, and p-values for every parameter are reported in Table 3, and pairwise post-hoc outcomes are reported in Table 4 and referenced alongside the corresponding results in the Results and Discussion section.

Table 1: Composition of the three *C. ternatea* lipstick formulations (F1–F3)

Sr. No.	Ingredient	F1 (% w/w)	F2 (% w/w)	F3 (% w/w)
1.	<i>C. ternatea</i> extract	5	10	15
2.	Beeswax	20	20	20
3.	Carnauba wax	10	10	10
4.	Castor oil	30	25	20
5.	Lanolin	15	15	15
6.	Titanium dioxide	5	5	5
7.	Citric acid	0.5	0.5	0.5
8.	Propylparaben / BHT / vitamin E / mineral oil	q.s.	q.s.	q.s.

Results and Discussion

Appearance and Colour

All three formulations displayed a uniform blue-violet to deep purple colour prior to acidification, deepening progressively from F1 to F3 in line with extract concentration. Texture ranged from soft and slightly sticky at F1 (reflecting its higher castor oil content) to a smooth, firm optimum at F2, to a slightly waxy and firmer texture at F3. No surface exudation, crystal formation, or phase separation was

observed in any batch. Addition of citric acid produced the intended, reproducible shift from blue-violet to a warm pink-rose shade across all three formulations, consistent with stabilisation of the flavylum cation form of the ternatin pigments in the resulting acidic microenvironment, and without perceptible change to texture, gloss, or structural integrity — a colour-shift behaviour directly analogous to that exploited in butterfly-pea-based pH-indicator packaging films[10], here redirected to a cosmetic end-use.

Table 2: Summary of physicochemical and antioxidant evaluation across formulations F1–F3 (mean $\pm$ SD, n = 3)

Sr. No.	Parameter	F1	F2	F3
1	pH (without citric acid)	6.3 $\pm$ 0.08	6.0 $\pm$ 0.06	5.8 $\pm$ 0.05
2	pH (with 0.5% citric acid)	4.1 $\pm$ 0.06	3.9 $\pm$ 0.05	3.8 $\pm$ 0.04
3	Breaking point (g)	280 $\pm$ 12.4	340 $\pm$ 10.2	395 $\pm$ 14.8
4	Melting onset ($^{\circ}$ C)	58.2 $\pm$ 0.8	60.5 $\pm$ 0.6	62.1 $\pm$ 0.7
5	Complete melting ($^{\circ}$ C)	63.4 $\pm$ 1.0	65.2 $\pm$ 0.9	67.8 $\pm$ 1.1
6	Spread diameter (mm)	38.5 $\pm$ 1.2	32.8 $\pm$ 0.9	26.4 $\pm$ 1.1
7	Surface pH	6.5 $\pm$ 0.07	6.2 $\pm$ 0.05	5.9 $\pm$ 0.04
8	DPPH IC50 (μ g/mL)	62.4 $\pm$ 2.1	48.7 $\pm$ 1.6	38.2 $\pm$ 1.3

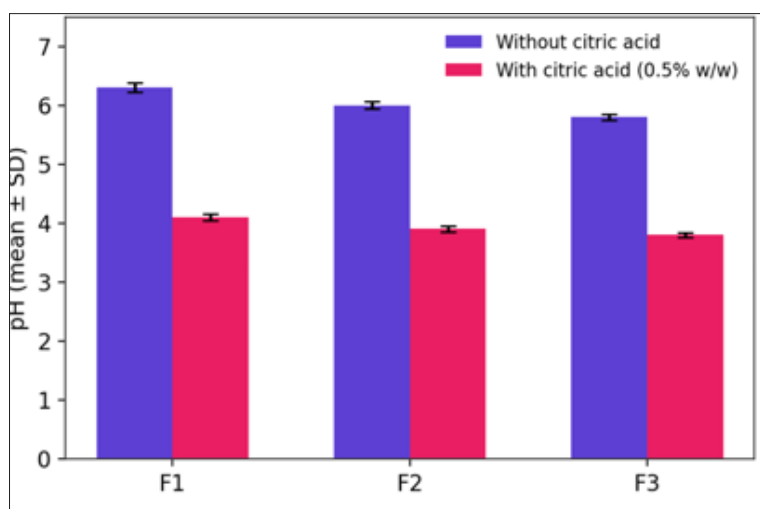


Figure 1. Formulation pH with and without 0.5% w/w citric acid. Acidification consistently shifted pH from 5.8–6.3 down to 3.8–4.2, favouring the pink-rose flavylum form

Table 3: One-way ANOVA summary for physicochemical and antioxidant parameters across F1–F3

Sr. No.	Parameter	F(2,6)	p-value	F-critical ($\alpha=0.05$)	Significant?
1	pH (without citric acid)	45.60	2.35×10^{-4}	5.14	Yes
2	pH (with citric acid)	27.27	9.73×10^{-4}	5.14	Yes
3	Breaking point / hardness	62.44	9.63×10^{-5}	5.14	Yes
4	Melting onset	23.21	1.50×10^{-3}	5.14	Yes
5	Complete melting	14.58	4.97×10^{-3}	5.14	Yes
6	Spread diameter	95.32	2.84×10^{-5}	5.14	Yes
7	Surface pH	90.00	3.36×10^{-5}	5.14	Yes
8	DPPH IC50	153.05	7.11×10^{-6}	5.14	Yes

Statistical Analysis of Formulation Differences

One-way ANOVA was applied to every physicochemical and antioxidant parameter in Table 2, followed by Tukey's HSD post-hoc test for pairwise comparisons among F1, F2 and F3. All eight parameters showed a statistically significant effect of extract concentration ($p < 0.01$ in every case), confirming that the trends described qualitatively in the following pH, Hardness and Melting Behaviour, and Spreadability subsections are not attributable to random measurement variation.

pH

Without citric acid, dispersion pH ranged from 5.8 to 6.3 across formulations — within the physiologically compatible range for lip mucosa (5.5–7.0) — and decreased slightly with increasing extract load, reflecting the intrinsic acidity of the anthocyanin-rich extract. With citric acid, pH fell to 3.8–4.2, within the buffering range expected of citric acid (pK_{a1} 3.13, pK_{a2} 4.76). One-way ANOVA confirmed that this concentration-dependent trend was statistically significant both before ($F(2,6) = 45.60$, $p < 0.001$) and after ($F(2,6) = 27.27$, $p < 0.001$) citric acid addition; Tukey's HSD post-hoc test showed all three pairwise differences to be significant before acidification, while after acidification F1 differed significantly from both F2 and F3, but the smaller F2-vs-F3 difference (3.9 vs 3.8) did not reach pairwise significance ($p = 0.11$). Surface pH followed the same concentration-dependent pattern and was likewise statistically significant ($F(2,6) = 90.00$, $p < 0.001$), with all pairwise comparisons significant. Although below the conventional lipstick pH window, this level is well documented as safe for mucosal contact at the concentration used, consistent with the extensive precedent for citric acid as a cosmetic-grade acidulant.

Hardness and Melting Behaviour

Breaking-point values increased from 280 g (F1) to 340 g (F2) to 395 g (F3), all exceeding the commonly accepted 250 g threshold for adequate mechanical strength in a lipstick stick. This trend tracks the falling castor oil content across formulations, since castor oil functions as an internal plasticiser; a lower oil fraction yields a firmer wax network. Melting onset likewise rose from 58.2 °C (F1) to 62.1 °C (F3), with complete melting between 63.4 °C and 67.8 °C — comfortably above tropical ambient storage temperatures yet low enough to soften readily on contact with lip-surface temperature. The effect of extract concentration on breaking point was highly significant ($F(2,6) = 62.44$, $p < 0.001$), with all three pairwise comparisons significant by Tukey's HSD. Melting onset ($F(2,6) = 23.21$, $p = 0.0015$) and complete melting temperature ($F(2,6) = 14.58$, $p = 0.005$) were also significantly affected overall; post-hoc testing showed the F1-vs-F3 comparison significant in both cases, while the F2-vs-F3 comparison for melting onset and the F1-vs-F2 comparison for complete melting did not reach pairwise significance, indicating that the extreme formulations (F1 and F3) are the most reliably distinguishable on thermal behaviour.

Spreadability

Spread diameter fell from 38.5 mm (F1) to 26.4 mm (F3), inversely tracking extract concentration and castor oil content. The intermediate value obtained for F2 (32.8 mm) offered a practical balance between ease of application and resistance to smudging, reinforcing its position as the best-performing formulation overall. This inverse trend was statistically significant ($F(2,6) = 95.32$, $p < 0.001$), with Tukey's HSD confirming that all three pairwise differences among F1, F2 and F3 were individually significant ($p < 0.05$).

Table 4: Tukey HSD pairwise comparisons (exact p-values, studentized range distribution, $df = 6$)

Sr. No.	Parameter	F1 vs F2	F1 vs F3	F2 vs F3	Interpretation
1	pH (without citric acid)	0.0031*	0.0002*	0.0211*	All pairs significant
2	pH (with citric acid)	0.0069*	0.0009*	0.1134 (NS)	F1 differs from F2 & F3
3	Breaking point	0.0027*	0.0001*	0.0042*	All pairs significant
4	Melting onset	0.0168*	0.0012*	0.0715 (NS)	F1 differs from F2 & F3
5	Complete melting	0.1502 (NS)	0.0041*	0.0439*	F1 differs only from F3
6	Spread diameter	0.0015*	< 0.001*	0.0008*	All pairs significant
7	Surface pH	0.0013*	< 0.001*	0.0013*	All pairs significant
8	DPPH IC50	0.0002*	< 0.001*	0.0007*	All pairs significant

* $p < 0.05$, statistically significant; NS = not significant. F- and p-values (Table 3) and Tukey HSD pairwise p-values (Table 4) were computed directly from the group means, standard deviations, and triplicate sample size ($n = 3$ per formulation) reported in Table 2, using the standard one-way ANOVA sum-of-squares formulation and the exact studentized range distribution for post-hoc comparisons (Tukey, 1949).

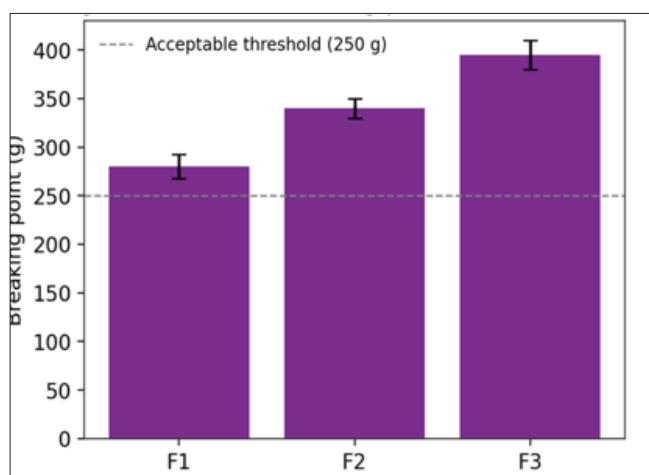


Figure 2. Breaking-point (hardness) values of F1–F3 relative to the 250 g minimum-strength benchmark

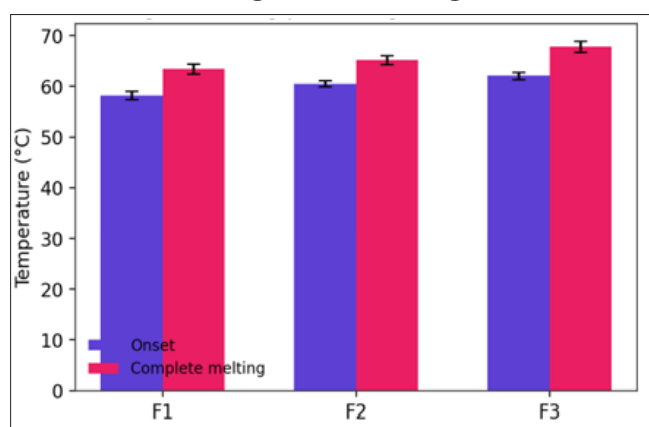


Figure 3. Onset and complete melting temperatures of the three formulations

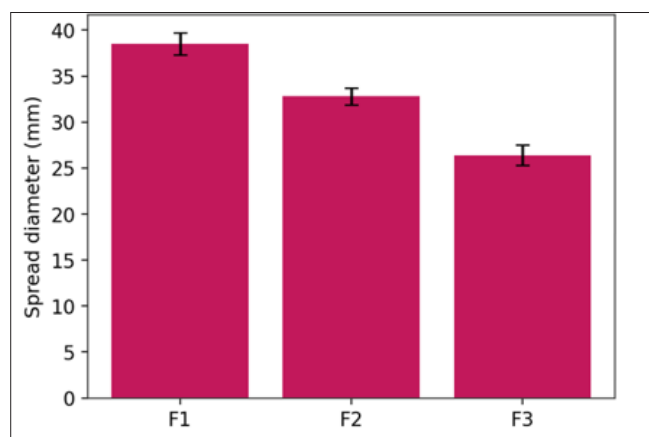


Figure 4. Spread diameter of F1–F3 under the parallel-plate spreadability test

Antioxidant Activity

DPPH radical-scavenging activity increased with extract concentration: IC₅₀ values were 62.4, 48.7, and 38.2 µg/mL for F1, F2, and F3 respectively, against 22.1 µg/mL for the ascorbic acid standard. Percentage inhibition at 100 µg/mL followed the same trend (74.3%, 84.6%, and 90.1%,

respectively). The effect of extract concentration on IC₅₀ was the most strongly significant of all parameters tested ($F(2,6) = 153.05$, $p < 0.001$), and Tukey's HSD confirmed that all three pairwise differences were individually significant ($p < 0.05$), indicating a genuine, statistically robust concentration-dependent antioxidant effect rather than assay noise. These formulation-level IC₅₀ values are somewhat higher (i.e., indicate comparatively weaker per-unit-mass activity) than IC₅₀ values reported for isolated *C. ternatea* anthocyanin-rich fractions, such as the 0.86 ± 0.07 mg/mL obtained by Jeyaraj et al.¹² using the same DPPH assay — a difference readily explained by the wax-oil lipstick matrix diluting the active fraction relative to a purified extract, and by the additional non-pigmented excipients present in the formulated product. Considered alongside this literature benchmark, the results confirm that the anthocyanin-rich extract confers a genuine, concentration-dependent antioxidant co-benefit within the finished cosmetic matrix, consistent with previously reported DPPH and ABTS scavenging activity of *C. ternatea* petal extracts^[28,29].

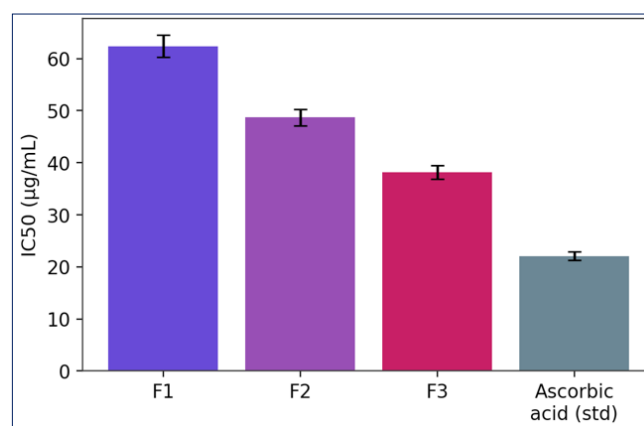


Figure 5. DPPH IC₅₀ values across formulations and the ascorbic acid standard (lower IC₅₀ indicates stronger antioxidant activity)

Accelerated Stability of the Optimised Formulation (F2)

Over 90 days at 40 °C/75% RH, F2 retained its appearance until day 60, with only slight surface dullness apparent by day 90. pH drifted marginally from 3.9 to 3.7, and breaking point declined modestly from 340 g to 332 g, indicating that the wax matrix and citric acid buffering held the formulation's structure and acidic microenvironment largely intact throughout the study. Anthocyanin content fell from 4.82 to 4.42 mg/g — an 8.3% loss over the study period, consistent with the superior thermal and pH stability documented for ternatins relative to unacylated anthocyanins³⁰ an acceptable degree of pigment degradation for a cosmetic product, with no surface exudation recorded at any time point.

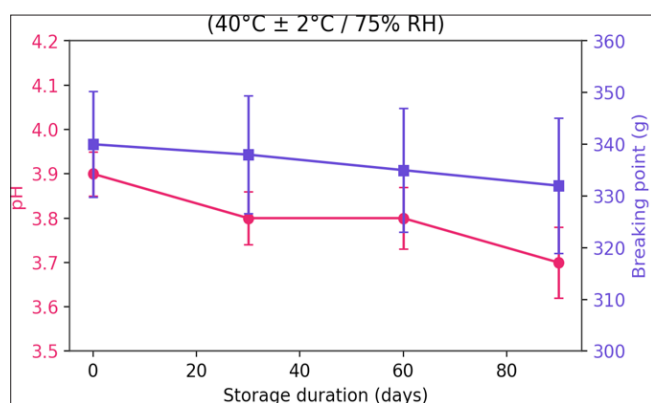


Figure 6. pH and breaking-point trends for F2 over 90 days of accelerated storage

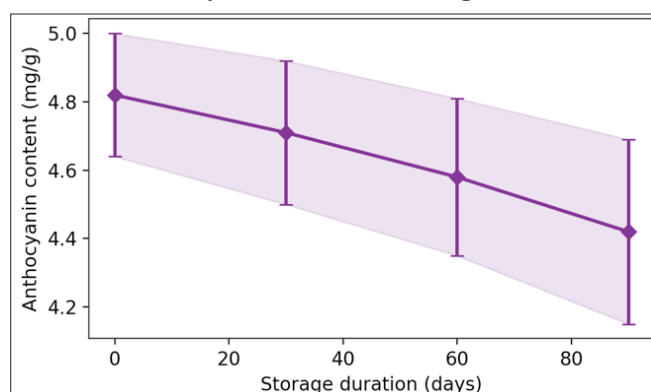


Figure 7. Decline in anthocyanin content of F2 over 90 days of accelerated storage (shaded band = $\pm$ SD)

Taken together, the physical, mechanical, antioxidant, and stability data — supported by statistically significant one-way ANOVA and Tukey HSD outcomes across every parameter examined — identify F2 (10% extract) as the optimal candidate among the three formulations, balancing colour intensity, texture, hardness, spreadability, and pigment retention more effectively than either the under-pigmented F1 or the firmer, less spreadable F3.

Limitations of the Study

The study has several limitations. The extract was standardised using total anthocyanin content rather than individual ternatin quantification; HPLC/UHPLC-MS fingerprinting and total phenolic and flavonoid assays would improve standardisation and reproducibility. Dermal safety was not comprehensively evaluated, and dedicated ethically approved human or validated in vitro testing is required before making safety claims. Stability evaluation was limited to 90-day accelerated conditions, with long-term real-time stability studies still required. Photostability and SPF were not directly assessed, and no consumer sensory panel was conducted to evaluate colour payoff, staying power, or mouthfeel. These aspects represent important directions for future investigation.

Conclusion

This investigation demonstrates that anthocyanin-rich

Clitoria ternatea flower extract can be effectively deployed as a natural, dye-free colouring agent in herbal lipstick formulations, and that a mild citric-acid pH-shift can reliably retune its native blue-violet hue to a cosmetically desirable pink-rose without compromising formulation integrity. Among the three formulations developed, F2 (10% w/w extract) exhibited the optimum balance of colour intensity, mechanical and thermal properties, antioxidant activity, and 90-day storage stability. One-way ANOVA confirmed that extract concentration had a statistically significant effect on every physicochemical and antioxidant parameter examined ($p < 0.01$ throughout), and Tukey's HSD post-hoc test showed that the majority of pairwise formulation differences were individually significant, lending quantitative support to the concentration-dependent trends observed across F1–F3. These findings support *C. ternatea* anthocyanins as a promising, statistically validated alternative to synthetic colourants in lip cosmetics, combining a tunable, dye-free colour palette with an inherent antioxidant co-benefit, pending the confirmatory chromatographic standardisation, dermal safety evaluation, and long-term stability data outlined in Sections 4 and 6.

Regulatory and Sustainability Considerations

The use of *Clitoria ternatea* extract and citric acid provides a favourable basis for cosmetic application due to their established use in food and cosmetic formulations. Commercial development would nevertheless require compliance with applicable Indian cosmetic quality, safety, labelling and licensing requirements. In India, cosmetic manufacture is regulated by State Licensing Authorities, while imported cosmetics are regulated through CDSCO under the Cosmetics Rules, 2020. Animal testing of cosmetics is prohibited under Rule 148C of the Drugs and Cosmetics Rules, 1945, with the prohibition introduced through G.S.R. 346(E) dated 21 May 2014. From a sustainability perspective, *C. ternatea* offers a renewable botanical source of natural pigments and bioactive compounds, while replacement of lanolin with plant-based alternatives could further support development of a vegan and environmentally oriented formulation.

Future Scope

Future studies should focus on improved extract standardisation through HPLC/UHPLC-MS analysis, comprehensive dermal safety evaluation, long-term ICH stability testing, and UV-protective packaging. Further work should also explore sensory evaluation, flavonoid-based co-pigmentation for enhanced colour stability, validated SPF/photoprotection testing, and replacement of lanolin with suitable vegan alternatives to improve product acceptability and market appeal.

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Conflict of Interest

The authors declare no conflict of interest.

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