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Formulation of lip cream with anthocyanin extract from butterfly pea flowers (*Clitoria ternatea*) as a natural dye

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Abstract
Background: Butterfly pea (*Clitoria ternatea*) is a tropical plant rich in anthocyanins, particularly from the flavonoid group, which has potential as a natural dye and antioxidant in cosmetic formulations.
Objective: This study aims to investigate the phytochemical characteristics of anthocyanin extract from butterfly pea flowers and the physical and chemical stability of lip cream formulated with the extract.
Method: Anthocyanin extract from butterfly pea flowers was formulated into a lip cream base at concentrations of 0, 2, 4, and 6%, followed by a physical stability test conducted over a period of one month on days 0, 7, 14, 21, and 28. The results were then compared with established standards.
Results: The anthocyanin extract of butterfly pea flower contains flavonoids, saponins, tannins, and terpenoids. Four lip cream formulations prepared with varying concentrations of the extract exhibited a thick texture, a grape-like aroma, and colors ranging from ivory to purple. The formulations had viscosities between 5,500 and 13,000 cP, adhesion times ranging from 7.10 to 26.8 seconds, and spreadability values between 5 and 7.5 cm.
Conclusion: All stability tests of the butterfly pea flower extract lip cream formulations met the required criteria, except for the homogeneity test. Formulation 1 (2%) was identified as the most optimal. All stability tests for the butterfly pea flower extract lip cream formulations met the required criteria, except for the homogeneity test. Formulation 1 was identified as the most optimal, containing 2% extract concentration.
Keywords: Butterfly pea, anthocyanin, lip cream, natural dye

1. Introduction

The cosmetics industry continues to grow rapidly, driven by increasing demand for safe, effective, and environmentally friendly products. Cosmetics are products used to enhance appearance without significantly altering the structure of the body (Azizah *et al.*, 2021). Lip cream is one of the most popular lip cosmetic formulations due to its function of providing color, maintaining moisture, and protecting the lips from UV radiation and pollution (Ariestanti *et al.*, 2023). However, the use of synthetic colorants in cosmetics remains a concern due to their potential side effects, such as allergies and irritations (Syakri, 2017), as well as the presence of heavy metals like lead and cadmium. Consequently, the development of natural dyes has become an increasingly attractive alternative in the cosmetics industry (Yugatama, 2019).

Natural dyes offer several advantages, including non-toxicity, biodegradability, and environmental friendliness (Pujilestari, 2015). Although they have certain limitations, such as low color stability, their use in cosmetic formulations continues to increase (Amantika *et al.*, 2021). One promising local plant with potential as a natural dye is butterfly pea flower (*Clitoria ternatea*), which contains anthocyanins as its main pigments. Anthocyanins not only provide a bluish-purple hue but

also possess antioxidant and anti-inflammatory properties. Additionally, they are pH-sensitive, allowing for color changes when applied to the lips (Yurisna *et al.,* 2022).

This study aims to evaluate the phytochemical characteristics of anthocyanin extract from butterfly pea flower and the physicochemical stability of the extract in a lip cream formulation. The study examines the impact of different extract concentrations on color stability, adhesion, spreadability, viscosity, and other physical properties during storage. This development is expected to provide a safe and natural lip cream formulation that promotes sustainable cosmetics.

2. Method

2.1. Tools and material

The tools used include, stirring rod, spray bottle, dark glass bottle, vial bottle, bulb, petri dish, FRU WR-10QC colorimeter, glass funnel, beaker glass, heidolph rotary evaporator laboratory 4000 efficient, hot plate, glass preparate, filter paper, measuring flask, mortar and pestle, drip pipette, measuring pipette, spatula, UV-Vis spectrophotometer Orion AquaMate 8100, analytical scale, viscometer-RION VT-06 spidel no 1 rotor, Vortex Miscrospin FV-2400, wrapping, and lip cream container.

The material used include, aquadest (H_2O), hydrochloric acid (HCl) (Smart Lab, Indonesian), ammonia (NH_3) (Smart Lab, Indonesian), citric acid ($C_6H_8O_7$) (Smart Lab, Indonesian), sulfuric acid (H_2SO_4) (Smart Lab, Indonesian), iron (III) chloride ($FeCl_3$), bismuth nitrate (BiN_3O_9), butterfly pea flower (*Clitoria ternatea L.*), castor oil, carnauba wax, cocoa oleum, dimethicone, ethanol 96% (C_2H_6O), essense, potassium chloride (KCl) (Smart Lab, Indonesian), kaolin, chloroform (Smart Lab, Indonesian), sodium acetate (CH_3COONa) (Smart Lab, Indonesian), sodium hydroxide (NaOH), phenoxyethanol, titanium dioxide, tocopherol, wagner reagent, Mayer reagent, and dragendorf reagent.

2.2. Sample preparation

The butterfly pea flowers (*C. ternatea*) used for extraction and phytochemical screening were collected from Jambeyan Subdistrict, Sambirejo District, Sragen Regency. A total of 500 grams of dried butterfly pea flowers were used, with the petals separated from the calyxes. The petals were macerated using a solvent mixture of 3% citric acid and 96% ethanol. The maceration process was carried out for 3 × 24 hours in a closed container protected from light. The resulting macerate was then evaporated using a rotary evaporator at 40 °C until a thick extract was obtained (Husna & Lubis, 2022). This extract was subsequently used for phytochemical screening to identify secondary

metabolites such as flavonoids, alkaloids, tannins, saponins, and terpenoids, which contribute to both biological activity and pigmentation properties.

2.3. Qualitative test of anthocyanins

Anthocyanin identification was carried out by adding 2M HCl dropwise to the butterfly pea flower extract, followed by heating for 120 seconds. The stability of the resulting red coloration indicated the presence of anthocyanin compounds (Herlina *et al.*, 2023). Subsequently, 2 mL of the extract was added with 2M NaOH dropwise. A color change to blue or green, accompanied by color fading, indicated the presence of anthocyanin compounds in the extract (Giyatmi *et al.*, 2024).

2.4. Quantitative test of anthocyanins

Anthocyanin quantification was performed using the pH differential method with buffer solutions at pH 1.0 and pH 4.5. The procedure employed a UV-Vis spectrophotometer within the wavelength range of 520 nm and 700 nm, maintaining absorbance values within the range of 0.2–0.8 or below 1.2 to ensure accuracy. A total of 0.01 g of the concentrated butterfly pea flower extract was dissolved separately in 9 mL of pH 1.0 and pH 4.5 buffer solutions. The samples were then analyzed using a UV-Vis spectrophotometer to determine the maximum absorption wavelength, followed by absorbance measurements at 520 nm and 700 nm. The total absorbance (A) was calculated using the following equation (Teng *et al.*, 2020):

$$A=(A_{520}\text{-}A_{700})\text{pH1,0-}(A_{520}\text{-}A_{520})\text{pH 4,5}$$

Subsequently, the total anthocyanin content in the extract was calculated using the following equation:

$$\text{Total Anthocyanin } (\frac{\text{mg}}{\text{L}})=\frac{(\text{A}\times\text{MW}\times\text{DF}\times 1000)}{(\varepsilon\times 1\text{ cm})}$$

Where:
A = total absorbance
MW = molecular weight of sianidin-3-glukosida (449,2 g/mol)
DF = dilution factor
ε = molar absorptivity sianidin-3-glukosida (26.900 $L/mol^{-1}.cm^{-1}$)

2.5. Formulation of lip cream containing butterfly pea flower anthocyanin extract

The preparation of the lip cream began with melting candelilla wax and carnauba wax, followed by the addition of castor oil, cocoa oleum, and dimethicone. Once the oil phase became homogeneous, kaolin and titanium dioxide were added and mixed until completely dissolved. During the cooling stage, tocopherol, phenoxyethanol, fragrance (essence), and butterfly pea flower anthocyanin extract were added according to the formulation concentration (Nanda *et al.*, 2024), as presented in **Table 1**.

Table 1. Lip cream formulation

Ingredients	Formulation (g)				Description
	F0	F1	F2	F3	
Extract Butterfly pea	0	2	4	6	Colorant
Candelilla wax	2	2	2	2	Thickening agent
Carnauba wax	1	1	1	1	Thickening agent
Castor oil	29.60	29.60	29.60	29.60	Humectant
Cocoa oleum	3.93	3.93	3.93	3.93	Emollient
Kaolin	3	3	3	3	Anti-cracking agent
Dimethicone	9.85	9.85	9.85	9.85	Moisturizer
Tocopherol	0.05	0.05	0.05	0.05	Antioxidant
Titanium dioxide	0.5	0.5	0.5	0.5	Opacifying agent
Phenoxyethanol	0.05	0.05	0.05	0.05	Preservative
Essence	0.02	0.02	0.02	0.02	Fragrance

2.6. Evaluation of lip cream containing butterfly pea flower anthocyanin extract

The evaluation of the lip cream formulations was conducted over a 28-day period, with assessments performed on days 0, 7, 14, 21, and 28 at room temperature (20–30°C) (Tanjung *et al.,* 2022).

2.6.1 Homogeneity

The test was conducted by applying the lip cream formulation onto a glass slide. The formulation was considered homogeneous if no coarse particles were observed on the surface of the glass slide (Nanda *et al.,* 2024*)*.

2.6.2 Spread power

One gram of the lip cream formulation was weighed and placed on a petri dish, then subjected to a graduated weight ranging from 50 to 170 grams for 1 minute to measure the spreadability of the preparation (Witanti & Endriyatno, 2024).

2.6.3 Sticking power

A total of 0.5 grams of the formulation was applied between two stacked glass slides and subjected to a 20 g weight for 5 minutes (Witanti & Endriyatno, 2024). After removing the weight, the time until the two glass slides separated was recorded. The formulation was considered to have satisfactory adhesion if the adhesion was >4 seconds (Tanjung *et al*., 2022).

2.6.4 Color

Color analysis was performed using a chromameter with the CIE Lab measurement system. The *L* parameter represents lightness (0 = black, 100 = white), the a* value indicates the green-red color axis, and the b* value represents the blue-yellow color axis (Annazhifah *et al*., 2024).

2.7. Effect of pH on color

The test was conducted by first preparing buffer solutions at pH 1.0, 4.5, 7.0, and 10.0. A total of 0.1 g of the concentrated extract and lip cream were each dissolved in 5 mL of the respective buffer solution in test tubes. The mixtures were stirred, and the color changes in each tube were observed.

2.8. Viscosity

The viscosity of the lip cream formulations was measured using a RION VT 06 viscometer with spindle no. 1. According to SNI 16-4339-1996, the standard viscosity test range for the spindle is between 2,000 and 50,000 cP (Nanda *et al*., 2024).

3. Result and discussion

3.1. Extraction of anthocyanins from butterfly pea flower (Clitoria ternatea)

Extraction was carried out using the maceration method, which aims to optimize the active compounds from butterfly pea flowers. The maceration method was chosen because it's the simplest technique, which involves soaking the simplicial in a solvent at room temperature and in conditions protected from light for a certain period of time (Surya *et al*., 2021). Extraction was performed using the maceration method for 3 × 24 hours with a solvent mixture of 96% ethanol and 3% citric acid under light-protected conditions. Ethanol was chosen due to its polarity and safety for use in cosmetic formulations, while citric acid served as an acidifying agent to stabilize the anthocyanins (Husna & Lubis, 2022). The filtrate obtained from the extraction was evaporated using a rotary evaporator at 40°C to yield a thick purple extract with a yield of 20.08%. This process aimed to maintain the stability of the anthocyanin compounds. The yield obtained was higher compared to previous studies Pertiwi *et al.*, (2022). A total of 94.5 g of thick extract was obtained with a yield of 9.45%, which may have been influenced by differences in the plant's growing location and environmental conditions.

Tabel 2. Result of phytochemical screening of butterfly pea flower extract

No	Phytochemical screening	Result
1	Flavonoids	+
2	Alkaloids	-
3	Saponins	+
4	Tannins	+
5	Terpenoids	+

Phytochemical screening revealed the presence of flavonoids, saponins, tannins, and terpenoids, as presented in **Table 2**. In the flavonoid identification process, the addition of concentrated HCl aims to hydrolyze flavonoid compounds into aglycone forms by breaking the O-glycosyl bonds. Because the acid is electrophilic, it replaces the glycosyl groups with ions. The next step involves a reduction reaction using magnesium powder (Mg) in an acidic environment, which

produces a red coloration (Muawanah *et al.,* 2023). The red color indicates the presence of flavonoid compounds with the reaction shown in **Figure 1**. Saponin is a triterpene glycoside that tends to be polar due to its glycosidic bonds. This foam occurs because of the presence of glycosides that have the ability to form foam in water that is hydrolyzed into glucose (Muawanah *et al*., 2023). Testing of tannin compounds showed positive results, because tannins contain many hydroxyl groups that are soluble in polar solvents. Testing using 10% $FeCl_3$ showed that the hydroxyl groups in tannins form a blue-black complex compound (Rati *et al*., 2024). Terpenoids were detected by the appearance of a purple color upon reaction with H_2SO_4.

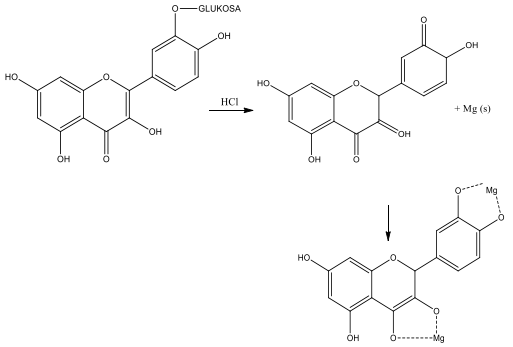

Figure 1. Reaction of flavonoid with HCl and Mg (Nugrahani *et al.,* 2016)

3.2. Anthocyanins butterfly pea (Clitoria ternatea)

Qualitative testing of the butterfly pea flower anthocyanin extract was performed using 2M HCl and 2M NaOH to create acidic and basic conditions, respectively. The results showed a red color change under acidic conditions and a green color change under basic conditions, which are characteristic features of anthocyanin compounds (Ramdan & Wulandari, 2023), as shown in **Figure 2**. Under acidic conditions, anthocyanins transform into the flavylium ion form, which is the most stable species at low pH. This results in a red color due to increased π-electron conjugation caused by the protonation of phenolic hydroxyl groups (Kunnaryo & Wikandari, 2021). Conversely, the addition of NaOH creates a basic environment, causing deprotonation and structural transformation into quinoidal, anhydro-base, or chalcone forms, resulting in a green coloration (Meganingtyas & Alauhdin, 2021).

Figure 2. Butterfly pea flower extract+HCl (red) and butterfly pea flower extract+NaOH (green)

Quantification of anthocyanins in the butterfly pea flower extract was carried out using a UV-Vis spectrophotometer in the wavelength range of 400–800 nm. The samples were dissolved in distilled water (pH 1.0) and pH 4.5 solvents, each exhibiting characteristic color changes: light purple (distilled water), pink (pH 1), and bluish-purple (pH 4.5), as shown in **Figure 3**. The absorption spectra showed shifts in the maximum peak wavelengths at 574 nm in distilled water, 546 nm at pH 1.0, and 574 nm at pH 4.5, reflecting the structural transformations of anthocyanins under different pH conditions, as illustrated in **Figure 3**.

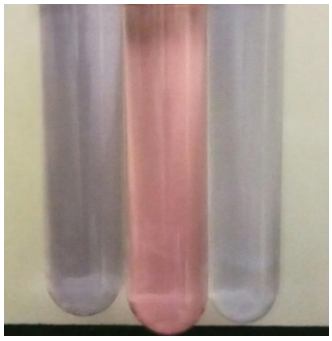

Figure 3. Quantitative color of anthocyanin extract from butterfly pea flowers with H_2O, pH 1.0, and pH 4.5

The extract solution and pH buffer were analyzed using UV-Vis spectrophotometry at wavelengths of 400-800 nm, as shown in **Figure 4**. The spectrum results of the anthocyanin extract from butterfly pea flowers (*C. ternatea*) showed differences in light absorption in the 400-800 nm wavelength range, depending on the pH conditions. These three spectra each display different absorption patterns due to changes in environmental conditions. At the black peak, as shown in **Figure 4**, there is a maximum absorption (λmax) at a wavelength of 574 nm, indicating that the anthocyanins in the aqueous solvent are in a nearly neutral state. Under these conditions, most anthocyanins exist in the flavylium ion form, although they are not entirely stable due to the absence of buffer or strong acid addition. The purple color of the solution indicates that the active compounds are still at optimal concentration. Meanwhile, at the red peak, the maximum absorption shifts to a wavelength of 546 nm. This trend is due to the highly acidic conditions, where anthocyanins are entirely in the most stable flavylium ion form. This stability is caused by strong ionic interactions between anthocyanins and the acidic medium (HCl), resulting in a red color with slightly lower absorbance compared to the H_2O solvent (Chu *et al*., 2016). At the blue peak, maximum absorption is obtained at a wavelength of 574 nm. This effect is because the flavylium begins to transform into a pseudobase carbinol or chalcone, which is colorless. This color change causes the solution to appear more faded or bluish, indicating a decrease in anthocyanin stability (Ramdan & Wulandari, 2023).

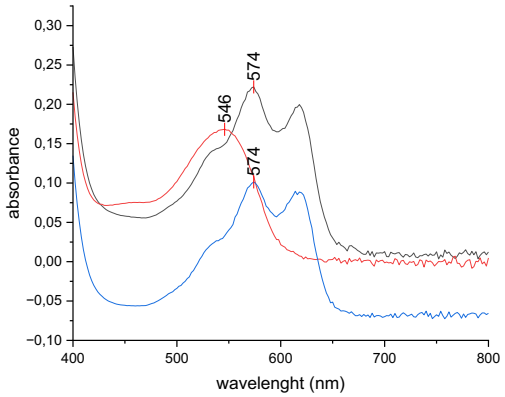

Figure 4. Anthocyanin spectra of butterfly pea flower in H_2O (black), buffer pH 1.0 (red), and buffer pH 4.5 (blue)

The difference in the spectra in **Figure 4** shows the variation in anthocyanin stability, with the black spectrum being the most stable, red being the medium, and blue being the lowest. Total anthocyanin content was measured at wavelengths of 520 and 700 nm using the differential pH method, resulting in a concentration of 12.81 mg/L. This value is lower than that reported by Utami *et al.* (2023), which was 17.76 mg/L, possibly influenced by environmental and technical factors such as extraction temperature, light exposure, pH stability, and glycoside hydrolysis processes.

3.3. Formulation lip cream

The lip cream formulations consisted of a base (F0) and incremental additions of butterfly pea extract at 2% (F1), 4% (F2), and 6% (F3). Visual evaluation revealed clear color differences: F0 appeared ivory, F1 light purple, F2 purple, and F3 dark purple, corresponding to the increasing extract concentration. The purple coloration is characteristic of anthocyanins present in the ethanolic extract of butterfly pea (*C. ternatea)* (Tonapa *et al*., 2021). A higher concentration of extract resulted in a darker shade, confirming the role of anthocyanins as natural colorants in lip cream formulations (Nanda *et al.*, 2024). This finding emphasizes the intriguing possibility of butterfly pea flower extract as a safe and effective alternative to synthetic dyes in cosmetic products, as shown in **Figure 5**.

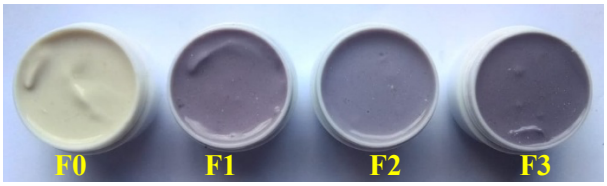

Figure 5. Lip cream

3.4. Evaluation of lip cream preparations

3.4.1 Homogeneity

Based on **Table 3**, lip cream preparations F0 and F1 show homogeneous characteristics. This is indicated by the absence of coarse particles, particle aggregation, or separation between the active ingredient and the base.

Table 3. Lip cream homogeneity test result

Day	Formula			
	F0	**F1**	**F2**	**F3**
0	Homogen	Homogen	Homogen	Not Homogeneous
7	Homogen	Homogen	Homogen	Not Homogeneous
14	Homogen	Homogen	Not Homogeneous	Not Homogeneous
21	Homogen	Homogen	Not Homogeneous	Not Homogeneous
28	Homogen	Homogen	Not Homogeneous	Not Homogeneous

All components in the formulation are evenly distributed, with no clumps or color differences when applied to the slide. Meanwhile, the F2 and F3 lip cream formulations are not homogeneous due to the presence of particles. This condition indicates that the mixing of the active ingredient with the base has not been optimized (Tonapa *et al.*, 2021).

3.4.2 Spread power

The results indicate that all formulations have spreadability values that meet the standards during 28 days of storage. Formulation F0 (base) shows a significant increase in spreadability from 5 to 7.5 cm, as shown in **Table 4.** This advantage is likely due to its lower viscosity. Formulations F1 to F3, which contain extracts, also showed stable and satisfactory spreadability, indicating that the addition of extracts does not interfere with the comfort of use. This is influenced by the interaction of anthocyanins with the base material, which maintains the consistency of the lip cream during storage (Tanjung *et al*., 2022).

Table 4. Lip cream stability based on spreadability

Formulation	Spread power (cm)				
	Day				
	0	**7**	**14**	**21**	**28**
F0	5.0	5.5	6.2	6.4	7.5
F1	6.0	5.5	6.8	6.8	6.9
F2	6.0	5.8	6.5	6.5	7.0
F3	6.0	5.6	6.0	6.8	7.2

3.4.3 Sticking power

Based on the results presented in **Table 5**, all formulations showed adequate adhesion, i.e., no more than 4 seconds (Tanjung *et al*., 2022). Adhesion indicates how long the lip cream stays on the lips. F0 does not contain anthocyanin extract and consists only of anhydrous bases such as wax and oil. The decrease in adhesion strength in F0 is due to the absence of active ingredients that enhance

adhesion, resulting in an unstable system (Huang *et al*., 2021). In F1 and F2, fluctuations occur due to suboptimal interactions between anthocyanins and the base, and the system is still undergoing internal physical changes. Meanwhile, F3 shows a significant increase because the optimal composition of anthocyanins forms a stable system with a strong anhydrous matrix and high adhesion capability (Thu Dao *et al.*, 2021).

Table 5. lip cream stability based on adhesive strength

Formulation	Day (Second)				
	0	**7**	**14**	**21**	**28**
F0 (0%)	14.3	12.9	11.0	11.7	9.8
F1 (2%)	21.8	23.9	10.8	25.1	9.0
F2 (4%)	14.9	14.2	26.8	15.8	12.0
F3 (6%)	7.10	7.50	13.7	10.0	23.9

3.4.4 Color

Color evaluation of lip cream preparations was measured using a colorimeter capable of performing comprehensive color analysis with the CIE Lab* system to evaluate color stability during storage on days 0, 7, 14, 21, and 28. The CIE Lab system uses three coordinates, namely L*, a*, and b*. The L coordinate indicates the level of brightness (light), with a value of 0 representing black and a value of 100 representing white (Sung-Ha *et al.*, 2022). Meanwhile, the a* value indicates the intensity of red-green, and the b* value describes the intensity of yellow-blue color, where colors can range from red (+a*) and yellow (+b*) to green (-a*) and blue (-b*) (Chudy *et al.*, 2020).

Based on the data presented in **Table 6**, the L* value decreased during the 28 days of storage, indicating that the base became darker. The value tends to increase, indicating a slight increase in redness. Meanwhile, the value of b fluctuates, decreasing until day 14 and then increasing again on day 28. The changes in the color values of the base indicate color instability, which can affect the product during storage (Kassebi *et al.,* 2022).

Table 6. Color stability of lip cream in formulation 0

Day	Formulation 0 (basis)		
	L*	**a***	**b***
0	70.43±2.87	2.22±0.20	11.47±0.28
7	68.11±0.38	2.26±0.06	11.56±0.04
14	66.54±0.08	2.49±0.05	9.61±0.03
21	64.80±0.56	2.37±0.12	10.64±0.12
28	64.76±0.74	2.46±0.19	10.28±0.46

Meanwhile, in the F1 (2%) formulation, the L* value tends to be stable with small fluctuations, indicating no significant change in brightness. The a* value shows a decrease in red color intensity, while the b* value increases, indicating a tendency toward a yellowish color, as presented in **Table 7**.

Table 7. Color stability of lip cream in formulation 1

Day	Formulation 1 (2%)		
	L*	a*	b*
0	51.52±2.06	4.98±0.22	0.35±0.30
7	53.69±0.16	4.70±0.02	0.16±0.12
14	52.61±0.06	4.38±0.02	1.35±0.04
21	51.92±0.10	4.34±0.00	2.44±0.01
28	51.68±0.09	4.15±0.05	1.66±0.06

These changes indicate that the addition of 2% extract affects the color stability of the lip cream during storage. In the data for formulation 2 (4%), as shown in **Table 8**, the L* value remains relatively stable with minor fluctuations during storage, indicating no significant changes in brightness. The a* value decreased, indicating a reduction in red color intensity. Meanwhile, the b* value underwent a drastic change from positive to negative and back to positive, indicating color instability in the yellow-blue range. This change may be caused by pigment degradation or chemical reactions during storage that affect color stability (Passos *et al.*, 2024).

Table 8. Color Stability of lip cream in formulation 2

Day	Formulation 2 (4%)		
	L*	a*	b*
0	51.21±0.37	5.09±0.03	0.24±0.18
7	54.00±0.08	3.89±0.03	-1.36±0.01
14	53.85±0.09	3.75±0.03	-0.39±0.013
21	53.20±0.12	3.52±0.04	0.36±0.03
28	51.98±0.04	3.33±0.06	0.52±0.03

Meanwhile, in formulation 3 (6%), the L* value remained fairly stable from day 0 to day 28, as shown in **Table 9**, indicating the stability of the product's brightness. The a* value shows a decrease in redness, but it is more stable compared to formulation 2 (4%). The b* value shows an increase, indicating a color change from bluish to yellowish, which may be caused by changes in pigment structure or interactions between active ingredients during storage. The colors obtained from the CIE Lab measurements can be presented in **Figure 5.**

Table 9. Lip cream stability based on color

Day	Formulation 3 (6%)		
	L*	a*	b*
0	55.06±0.32	5.87±0.01	-1.69±0.04
7	54.47±0.12	5.50±0.06	-1.62±0.16
14	54.22±0.03	5.28±0.02	-0.62±0.02
21	53.78±0.05	4.90±0.03	0.64±0.01
28	54.11±0.07	4.91±0.04	0.84±0.09

Figure 5. Lip cream color with CIE Lab calculator

3.5. Effect of pH on lip cream

This test uses the best formula, namely F1 (2%), by adding anthocyanin extract solution to the buffer at various pH levels, including distilled water (neutral), buffer pH 1.0 (strong acid), buffer pH 4.5 (weak acid), buffer pH 7 (neutral), and buffer pH 10 (strong base). The color changes that occur are related to the structure of anthocyanins, which can undergo shape transformations depending on the pH, as shown in **Figure 6**.

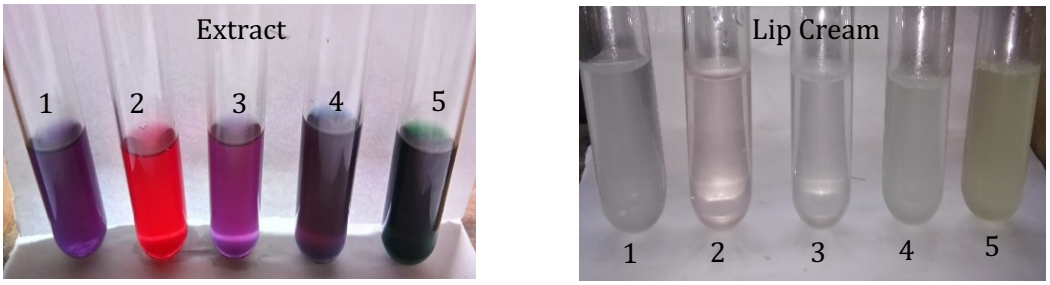

Figure 6. Anthocyanin extract solution and lip cream from butterfly pea flowers in distilled water (1), pH 1.0 (2), buffer pH 4.5 (3), buffer pH 7 (4), and buffer pH 10 (5)

The anthocyanin solution dissolved in distilled water (H_2O) exists in the form of a quinoidal base, which produces a purple color. This structure is stable at pH levels close to neutral but it can break down over time or be affected by light and temperature (Passos *et al.,* 2024). Under strong acidic conditions (pH 1), anthocyanins exist in the form of flavilium ions (H+), which are red in color. This structure is stable at very low pH due to protonation of the pyrrole ring, resulting in a more dominant red color (Tarone *et al.,* 2020). Under weak acidic conditions (pH 4.5), anthocyanins undergo a partial structural change from the flavilium form to the carbinol pseudo-base form, causing the color to change to purple. At a pH of 4.5, there is an equilibrium between the H+ form and the hydrated form, resulting in a lighter purple color (Chu *et al.,* 2016). At a buffer pH of 7, the anthocyanin structure changes to the quinoidal anhydrobase form, which tends to produce a dark purple to blue color. The stability of anthocyanins at a buffer pH of 7 decreases compared to acidic conditions, so the color may appear darker or slightly faded depending on environmental conditions. Under strong alkaline buffer conditions (pH 10), anthocyanins undergo further deprotonation and form colorless or blue-green chalcone compounds (Tarone *et al.,* 2020). This form is highly unstable

and undergoes oxidative degradation, causing significant color changes and even loss of color activity over time (Hasanah *et al*., 2023).

3.6. Viscosity

The viscosity test findings for lip cream formulations with butterfly pea flower anthocyanin extract indicated that all formulations, F0 to F3, exhibited viscosity values within the SNI range of 5,500 to 11,000 cP, as detailed in **Table 10**. Formulation F0 (lacking extract) showed the lowest viscosity, whereas the incorporation of anthocyanin extract in F1 (2%) resulted in a maximum rise in viscosity. This interaction between anthocyanin compounds with phenolic hydroxyl groups and the solid components of the lip cream, including wax and emollients, occurs via the formation of hydrogen bonds or intermolecular forces. This interaction strengthens the system's internal structure and enhance flow resistance (Tungadi *et al.,* 2023). At elevated concentrations (F2 and F3), viscosity diminishes significantly due to an excess of extract liquid that fails to completely integrate with the lip cream matrix, consequently disrupting structural integrity and lowering viscosity (Estikomah *et al*., 2021). Nonetheless, the viscosity stability demonstrated by all formulations signifies that the resulting system is adequately stable and appropriate for use as a natural pigment-based lip cream.

Table 10. Viscosity of lip cream preparations

Formulation	dPa.s	cP
F0 (0%)	55	5.500
F1 (2%)	130	13.000
F2 (4%)	120	12.000
F3 (6%)	110	11.000

4. Conclusion

The anthocyanin extract derived from butterfly pea flowers (*Clitoria ternatea*) via maceration comprised flavonoids, saponins, tannins, and terpenoids, with a total anthocyanin concentration of 12.81 mg/L. The anthocyanins demonstrated distinct pH-dependent color variations, with the flavylium ion form being stable in acidic environments. Lip cream formulations using 2% extract (F1) exhibited superior physicochemical stability, encompassing homogeneity, viscosity, adherence, and color stability over a 28-day storage period, suggesting its viability as an excellent natural dye formulation for cosmetic applications. Future research should include stearic acid to improve the stability and color intensity of the lip cream, and clinical trials should be conducted to verify its safety for use on lip skin.

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