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Formulation and evaluation of natural lip balm: Exploring the synergistic benefits of beetroot and *Kaempferia galanga* Linn

Nurhaslina Che Radzi[1*], Afiqah Dayana Ahmad Kamarul[2]

[1,2] *Faculty of Chemical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia*
[1] *Integrated Separation Technology Research Group (i-STRonG), Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia*

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ABSTRACT

Growing consumer concern over synthetic additives has intensified interest in plant-based lip care. This study formulated and evaluated a dual-extract lip balm using beetroot (*Beta vulgaris*) pigment and *Kaempferia galanga* Linn (KGL) essential oil as natural colourant and bioactive agents. Twenty-two formulations were prepared from coconut oil, beeswax, and candelilla wax, with varying beetroot:KGL ratios (0.5–2.5 g). Each formulation was assessed for pH (n=3), melting point, greasiness index, surface homogeneity, and accelerated colour stability (30 days at 40 °C/75 % RH and 4 °C). Among all tested formulations, F7 exhibited the most favourable balance of non-greasy texture, stable pH, and good melting point, supporting its potential as a safe and natural cosmetic alternative.

1. INTRODUCTION

The growing concern over synthetic ingredients in cosmetics linked to allergies, irritation, and long-term toxicity has accelerated the demand for natural, plant-based alternatives (Alias et al., 2023). Lip balm, an everyday product for protecting and moisturising lips, is increasingly being reformulated to replace petroleum-derived waxes and artificial dyes with bioactive botanical components. Consumer preference has shifted towards herbal formulations that not only fulfil functional needs but also align with environmental and ethical values (Gholap et al., 2023).

[1*]Corresponding author. *E-mail address*: nurhaslina483@uitm.edu.my
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Plants such as cinnamon (Kothari et al., 2018), carrot (Anisa et al., 2019), and beetroot (Azmin et al., 2020) have been studied for their potential as ingredients in natural cosmetics. Among these, *Beta vulgaris* (beetroot) and *Kaempferia galanga* Linn (KGL) offer unique synergistic benefits for lip care formulations. Beetroot contains betalains, vivid pigments with strong antioxidants, anti-inflammatory, and detoxifying properties, as well as phenolic compounds, vitamins, and amino acids (Nirmal et al., 2021; Sadowska-Bartosz & Bartosz, 2021). It functions as both a colourant and a protective barrier against oxidative damage (Azmin et al., 2020). Beetroot extract plays two critical roles in lip care: providing natural red pigmentation and offering antioxidant protection.

KGL, commonly known as aromatic ginger, is a rhizomatous plant native to Southeast Asia and widely used in traditional medicine and food applications (Rahman, 2004). Its essential oil is rich in compounds that exhibit antimicrobial, anti-inflammatory, cytotoxicity, and wound-healing properties, making it highly valuable in cosmetic applications (Srivastava et al., 2019; Chittasupho et al., 2022). The integration of KGL in lip balm enhances both its therapeutic efficacy and aromatic appeal.

While both beetroot and KGL have been individually explored, there remains limited research on their combined use in a stable, effective, and consumer-friendly lip balm formulation. Challenges such as achieving balanced texture, colour stability, and skin tolerability remain under-addressed in current literature. In this study, the aim was to investigate the synergistic formulation of a natural lip balm using beetroot powder and the essential oil of KGL. Synergy in this context refers to the enhanced functionality arising from the interaction between beetroot's antioxidative pigment and KGL's bioactive oil, aiming to achieve multifunctional lip protection. A total of 22 formulations were developed and analysed in terms of physicochemical stability, melting point, pH, and greasiness. The findings contribute to the formulation of herbal lip care products that align with clean-label, sustainable, and health-conscious cosmetic innovation.

2. METHODOLOGY

2.1 Materials

The beetroots (*B. vulgaris* L) were purchased from a local market at NSK Setia Alam, Selangor, while KGL was purchased from the market in Klang, Selangor. Table 1 shows all the ingredients and their functions. The ingredients were divided into two (2) phases: Phase A and Phase B. Phase A consisted of solid/waxy ingredients, which were melted first; Phase B consisted of liquid oils and active plant extracts added after emulsification.

2.2 Methods

Material preparation method

The preparation of plant-based ingredients was carried out under controlled conditions to ensure consistency and reproducibility of the lip balm formulation.

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Table 1. Ingredients of lip balm and function

Ingredients	Function
Phase A	
Beeswax	Emollient/thickener
Refined Coconut Oil	Emollient
Cocoa Butter	Emollient
Jojoba Oil	Consistency factor
Phase B	
Virgin Coconut Oil	Emollient
Olive Oil	Emollient
Beetroot	Colourant
KGL	Antioxidant

*All materials used in this study were commercially obtained in Malaysia, except for beetroot and KGL

Source: Author's own data

Beetroot (Beta vulgaris L.)

Fresh beetroots were thoroughly cleaned under running water to remove surface contaminants, followed by manual peeling. The peeled roots were sliced uniformly into thin pieces (approximately 2–3 mm thickness) and spread on aluminum-lined trays to ensure uniform airflow during drying. Dehydration was performed using a blast drying oven (Model FCO-30D, Taisite, China) at a constant temperature of 40 ± 1°C for 24 hours. The dried slices were subsequently ground into fine powder using a Panasonic MX-337 conventional countertop grinder (Panasonic, Japan), and the powder was immediately sealed in an airtight amber glass container to protect against light and moisture degradation. The powder was stored at ambient room temperature (25 ± 2°C) and used within one week to ensure freshness.

Kaempferia galanga Linn (KGL) rhizome

Fresh rhizomes of KGL were cleaned meticulously under tap water to eliminate soil particles, followed by manual peeling to remove the outer skin. The cleaned rhizomes were sliced uniformly and dried under identical conditions as the beetroot, using the same blast drying oven (Model FCO-30D) at 40 ± 1°C for 24 hours. The targeted final moisture content was maintained between 21% and 22%, aligning with optimal moisture levels for solvent-free extraction as referenced in Nurhaslina et al. (2022).

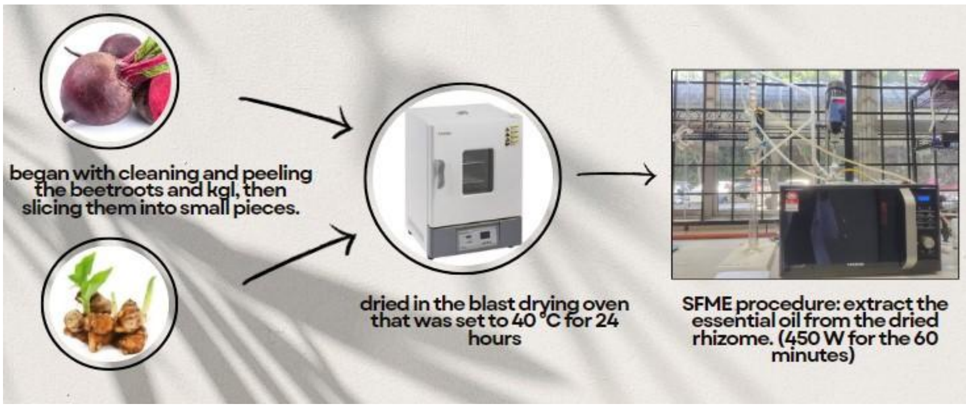

Fig. 1. Preparation of the material and ingredients

Source: Author's own data

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Essential oil extraction from KGL

The dried rhizomes (100 g) were subjected to Solvent-Free Microwave Extraction (SFME) using a modified Samsung microwave oven (model MS28F303TFK/SM) with a flat-bottomed flask attached to a Clevenger apparatus and linked with a water circulation system as shown in Fig. 1. The extraction was conducted at a constant microwave power of 450 W for 60 min, with occasional manual rotation to ensure uniform heating. No additional solvent or water was added during the process, maintaining the green extraction integrity of the method. The extracted condensate was immediately separated into essential oil and hydrosol, with the oil layer collected, dried over anhydrous sodium sulfate, and stored at 4 °C in sealed amber vials for subsequent use in the lip balm formulation. The beetroot powder and KGL powder were stored in amber glass containers at room temperature and used within one week to ensure freshness and reproducibility.

Formulation of the lip balm

In this work, the aim was to create lip balm with only natural components, including beeswax, refined coconut oil, cocoa butter, jojoba oil, virgin coconut oil (VCO), olive oil, plus essential beetroot powder for colouring, and KGL as an antioxidant. In this study, beetroot and KGL were considered variable active ingredients. Their quantities were systematically varied across formulations to evaluate their influence on lip balm properties. The composition and ratio of each component are listed in Table 2 for producing 20 g of lip balm. Ingredients were melted over a 70 °C water bath while stirring, followed by homogenization with a glass rod to ensure uniform consistency. The last stage was to pour the liquid into moulds that had been cleaned and lubed. Once cooled, the mixture would help the waxes compress, making it easier to remove the balm. The finished lip balm was placed in containers for further assessment, highlighting every component's careful arrangement and importance in creating this herbal lip balm.

Table 2. Composition and ratio of the ingredients for the formulation of lip balm

Formulation	Phase A	Phase B	KGL (g)	Beetroot (g)
1	Beeswax=6.18g	Virgin Coconut	0.5	0.5
2	Refined Coconut	Oil=0.5g		1.0
3	Oil=10.4g	Olive Oil=0.5g		1.5
4	Cocoa Butter=1.2g			2.0
5	Jojoba Oil=1.0g			2.5
6			1.0	0.5
7				1.0
8				1.5
9				2.0
10				2.5
11			1.5	0.5
12				1.0
13				1.5
14				2.0
15				2.5
16			2.0	0.5
17				1.0
18				1.5
19				2.0
20				2.5
21			2.5	-
22			-	2.5

Source: Author's own data

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Analysis of the formulated lip balm

The assessment and examination of the natural lip balm were conducted using the methodologies outlined by Kamble & Kamble (2021) and Kothari et al. (2018). These studies provided a comprehensive framework for evaluating the product's effectiveness, ingredients, and formulation. Table 3 presents a comprehensive overview of the 22 distinct lip balms formulated.

(i) Melting Point

The capillary tube method was used to analyse the lip balm formulation and determine its melting point. The lip balm sample, weighing about 0.5 g, was melted into a glass capillary tube open at both ends. A beaker of water was set on a heating plate with a magnetic stirrer, and a thermometer with a capillary was submerged in it. The melting point was determined by measuring the temperature at which the material in the capillary tube began to melt, and the heating and stirring operation started gradually at a fixed speed. The melting point of each formulation was measured in triplicate (n = 3) using the capillary tube method.

(ii) pH

The pH of the created natural lip balm was determined using standard pH paper. The pH value of the material was determined by dissolving 1 g of it in 100 ml of water. The pH measurement indicated the formulation’s compatibility with the skin. The lip balm should have a neutral pH because an acidic or alkaline pH could irritate.

(iii) Greasiness

The greasiness test effectively assessed the oil content in the lip balm formulation. In this investigation, 4 g of lip balm was placed on filter paper and allowed to sit at room temperature for 24 hours. The diameter of the resulting oily ring was then measured (Azmin et al., 2020).

(iv) Stability Test

For the stability assessment, all formulations were stored under two different conditions: refrigeration (4 ± 1 °C) and ambient room temperature (25 ± 2 °C) for a duration of three months. Samples were evaluated monthly for changes in colour, odour, texture, and physical integrity. Special attention was given to colour fading, particularly in beetroot-containing samples, and potential rancidity or separation in oil phases.

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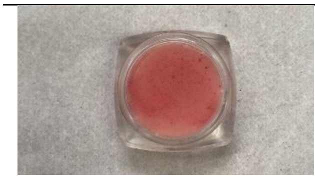
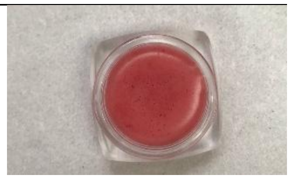
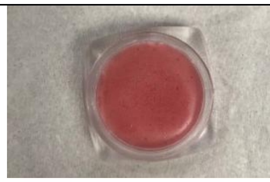
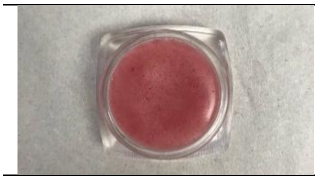
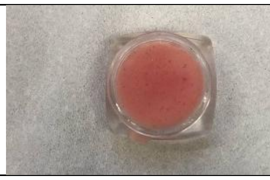
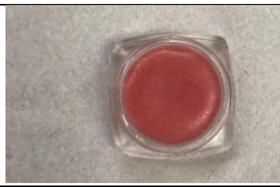
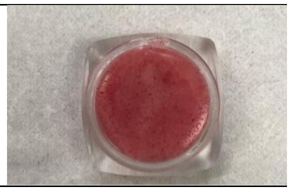
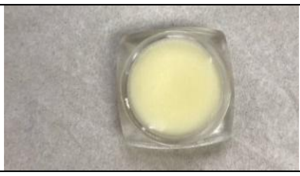
Table 3. Formulated lip balms

F1	F2	F3	F4
			
F5	F6	F7	F8
			
F9	F10	F11	F12
			
F13	F14	F15	F16
			
F17	F18	F19	F20
			
F21	F22		
			

Source: Author's own data

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3. RESULTS AND DISCUSSIONS

The extraction process using Solvent-Free Microwave Extraction (SFME) produced a total extraction yield of 3.53% (w/w) from dried *Kaempferia galanga* Linn (KGL) rhizomes. Prior to extraction, the dried samples were immersed in distilled water for one hour to enhance moisture distribution and dielectric responsiveness. This pre-treatment step was essential to facilitate efficient microwave absorption during the SFME process, which relies on internal moisture to generate thermal rupture and facilitate compound release. The reported yield reflects the combined mass of essential oil and hydrosol fractions recovered after 60 min of microwave exposure at 450 W. The yield is considered satisfactory and consistent with previous studies on microwave-based extraction of aromatic rhizomes (Nurhaslina et al., 2022), demonstrating the suitability of SFME for clean, solvent-free recovery of bioactive compounds. While the yield includes water-soluble components within the hydrosol, the integrity of heat-sensitive actives such as ethyl p-methoxycinnamate remains preserved, supporting downstream use in cosmetic applications. The relatively high extracted yield also suggests good potential for upscaling the method in sustainable botanical product development.

Table 4 details the results from the various evaluations and observations conducted on the lip balms infused with beetroot and KGL. The analysis of the lip balm formulations indicated that the colours, as captured in the photos, were complex to detect due to inconsistent lighting conditions during the day. Nonetheless, despite these lighting issues, the colour gradients of each formulation were still apparent, primarily due to the presence of beetroots. Formulations F1, F6, F11, and F16, which contain only 0.5 g of beetroot, display the lightest pink shades. In contrast, formulations F5, F10, F15, F20, and F22, containing the highest beetroot content of 2.5 g, exhibit the darkest pink hues. The colour variations are attributed to the different beetroot percentages, which are known to contain a significant red pigment called betalain (Chandran et al., 2014).

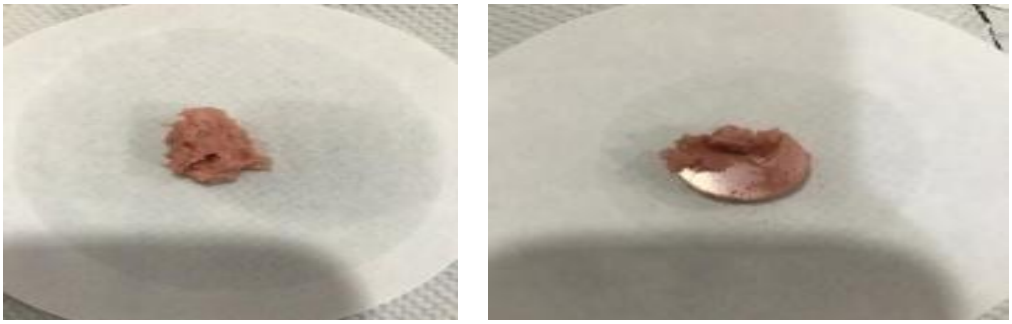
Betalains are pigments found in about 17 plant families of the *Caryophyllales* order. They are potent antioxidants that protect cells from oxidative damage, making them valuable in skincare to prevent aging. With anti-inflammatory properties, betalains soothe irritation, especially for chapped lips. They provide a vibrant red-purple colour to beetroot and serve as a natural colourant in cosmetic products like lip balm, avoiding synthetic dyes (Sadowska-Bartosz & Bartosz, 2021). Additionally, betalains support detoxification and contribute to skin health by protecting against pollutants, making them ideal for natural lip balms with functional and aesthetic benefits. Thus, the darker shades correspond to higher amounts of beetroot, while lighter shades are linked to lower beetroot content. This finding highlights the substantial influence that beetroot content has on the overall colour of the lip balm.

According to the data presented in Table 4, the formulated lip balm's melting point was between 49 and 52 °C. This finding suggests that the lip balm remained stable throughout the experiment. In contrast, Kusrini et al. (2020) reveals that the ideal melting point for lip balms typically falls within the range of 54 to 64 °C. The discrepancy in melting temperatures between the lip balm studied in this experiment and the optimal range cited in previous research can be attributed to the specific ratio of beeswax utilized in the formulation. It is well-documented that lip balms with a higher wax concentration tend to be firmer, raising their melting point (Athirah et al., 2018). F13 exhibited the highest melting point among all tested samples, positioning it closest to the established range for optimal lip balm consistency.

https://doi.org/10.24191/mjcet.v8i2.3901

The results for the pH test were recorded to be around pH 5 and pH 6, showing the lip balm was a weak acid. The pH value was influenced by the betalains from the beetroot and KGL, which are stable in the range of pH 3 to pH 7. Thus, it can be used to colour foods and cosmetics that range from sour to neutral (Esatbeyoglu et al., 2015). The pH range for the formulated lip balm is also suitable and safe to apply on the lips because cosmetic products usually have an ideal pH between 4 to 6.5 (Lambers et al., 2006). Moreover, lip skin has a physiological pH of 4.2–5.6 (Martini et al., 2011), while the normal skin pH is more acidic. For this reason, lip balm products with a pH of 4.5 to 7.0 are suggested. An ideal topical cosmetic should not irritate the lips' skin because the chance of irritation will occur when the preparation of the lip balm is either too acidic or too alkaline (Nurjanah et al., 2018).

The diameter of the oily ring produced by the lip balm sample on filter paper was measured after 24 hours at room temperature to assess greasiness. According to the data presented in Table 4, the diameter of the oily ring formed by the lip balm samples ranged from 5.8 cm to 10.2 cm. This variation can be attributed to the differences in the surface area of each lip balm, even though the same sample weight was applied to the filter paper, as demonstrated in Fig. 2.



a) F4 lip balm sample b) F5 lip balm sample

Fig. 2. Greasiness test showing oily ring diameters of selected formulations

Source: Author's own data

Overall, the greasiness levels of the lip balm were deemed acceptable, particularly compared to the diameter of a commercial lip balm, which measured 7.7 cm. This indicates that the texture of the lip balms falls within a reasonable range of greasiness (Azmin et al., 2020) except for the F1, F13, and F19. This is because the diameter of the oily ring for the three formulations was the highest, which means the lip balm will not be comfortable to apply due to the greasy texture. The lip balm with the closest diameter to the value of 7.7 cm, formulation 7 with a diameter of 7 cm, was the best because it is non-greasy and the most comfortable to wear on the lips.

For the stability test, the lip balm was observed after 3 months at refrigeration temperature and room temperature conditions. The results show that when the lip balm was kept in the refrigerator, it did not lose its stability or consistency. The lip balm appears to be in good condition for refrigeration in terms of texture, colour, and overall look. However, the lip balm samples kept at room temperature showed a noticeable degradation in colour. After three months, the pink colour from the beetroot extracts gradually faded and

https://doi.org/10.24191/mjcet.v8i2.3901

turned white, as shown in Fig. 3. It is hypothesised that colour degradation may be reduced by applying a double-boil method during preparation; however, this was not experimentally tested in the present study and should be validated in future research. Further research also showed that temperature variations, especially at room temperature, might have promoted the breakdown of the active ingredients in the beetroot extract (Kavitkar et al., 2017). Consequently, the colours exhibited a continuous and progressive transformation throughout the entire duration of the storage period.

This phenomenon involved a gradual shift in colour and variations in intensity, leading to a dynamic visual display that evolved consistently over time. The interplay of environmental factors, such as light exposure and surrounding conditions, significantly influenced this transformation, resulting in a complex array of colours that could be observed as the storage period extended from weeks into months. This ongoing change highlights the intricate relationship between the materials and their storage environment. In terms of colour, F21 lip balm was not considered because it is colourless, which means it does not have the beetroot extract in the formulation.

Fig. 3. F1 lip balm sample that changed to white colour

Source: Author’s own data

As for odour, lip balm formulations F16 to F21 have a notably strong scent of KGL herb due to their high KGL content, with 2 g of KGL included, which is significantly more than the other formulations, resulting in a more pronounced and distinctive herbal aroma. Among all the prepared formulations (Formula 1 through Formula 22), F7 emerged as the most suitable option for fulfilling the requirements of a lip balm compared to the other formulations. While F13 and F19 yielded acceptable results regarding melting point, pH, and surface anomalies, their greasiness results during application were unsatisfactory.

https://doi.org/10.24191/mjcet.v8i2.3901

Table 4. Evaluation and observation of the formulated lip balms

	F1	F2	F3	F4	F5
Melting Point (°C)	49	49	49.3	49.5	49
pH	6	6	6	6	6
Greasiness (cm)	10.2	9.4	8.4	10	6.4
Stability	colour degradation	colour degradation	colour degradation	colour degradation	colour degradation

	F6	F7	F8	F9	F10
Melting Point (°C)	49	50.2	50	49.7	50.3
pH	6	6	6	6	6
Greasiness (cm)	6.8	7	9.8	9.2	6.2
Stability	colour degradation	colour degradation	colour degradation	colour degradation	colour degradation

	F11	F12	F13	F14	F15
Melting Point (°C)	50	50	52	51.6	50
pH	6	6	5	5	5
Greasiness (cm)	6.8	9.4	10.2	5.8	9.6
Stability	colour degradation	colour degradation	colour degradation	colour degradation	colour degradation

	F16	F17	F18	F19	F20
Melting Point (°C)	50.2	50.2	51	51.2	51
pH	5	5	5	5	5
Greasiness (cm)	8.6	9.6	9.4	10.2	8
Stability	colour degradation	colour degradation	colour degradation	colour degradation	colour degradation

	F21	F22			
Melting Point (°C)	51.4	50.4			
pH	6	5			
Greasiness (cm)	9.8	8.2			
Stability	good	colour degradation			

Source: Author's own data

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4. CONCLUSION

This study successfully formulated and evaluated a natural lip balm incorporating beetroot powder and KGL essential oil, addressing the growing demand for sustainable, plant-based cosmetic alternatives. The formulation was assessed for physicochemical characteristics, including pH, melting point, and greasiness, revealing that beetroot and KGL offer complementary benefits in terms of lip protection, colour enhancement, and bioactivity. Among the 22 formulations tested, F7 emerged as the optimal candidate, demonstrating a well-balanced profile with stable pH, acceptable greasiness, favourable texture, and strong tolerability. While the product maintained structural integrity under refrigeration, notable colour degradation at room temperature suggests a need for further formulation optimisation to enhance pigment retention. This study contributes preliminary findings towards natural lip balm development. Future research should investigate encapsulation techniques or natural stabilisers to enhance thermal and oxidative stability, leading to scalable, clean-label lip balm products in the green cosmetics market.

5. ACKNOWLEDGEMENT

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6. CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted without any self-benefits or commercial or financial conflicts and declare the absence of conflicting interests with the funders. A preliminary skin compatibility observation involving three healthy adult volunteers was conducted without personal data collection or invasive procedures. As such, ethical approval was not required for this part of the study, in accordance with non-clinical cosmetic testing guidelines at the university level.

7. AUTHORS CONTRIBUTIONS

Nurhaslina Che Radzi: Conceptualisation, methodology, draft manuscript preparation, validation, supervision, and writing-review & editing; **Afiqah Dayana Ahmad Kamarul**: Methodology, investigation, formal analysis, and writing-original draft.

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