JNPDD
Journal of Natural Product for Degenerative Diseases
https://journal.univpancasila.ac.id/index.php/Natural

Development and Optimization of Facial Wash Gel with Okra Fruit (*Abelmoschus esculentus*) Extract: a Study on HPMC Concentration Variations

Ana Yulyana[1,2*], Annisya Maulidia Putri[2], Eko Mugiyanto[3]

[1]*Department of Pharmacy, Faculty of Pharmacy, Pancasila University, South Jakarta, Indonesia*
[2]*Faculty of Pharmacy, Institut Sains dan Teknologi Nasional (ISTN) Jakarta, Indonesia*
[3]*Professional Educational Program in Pharmacy, Faculty of Health Sciences, University of Muhammadiyah Pekajangan Pekalongan , Jawa Tengah, Indonesia*
*Corresponding Author: anaycantigi@gmail.com

Received: 24 January 2025 / Accepted: 20 March 2025

ABSTRACT: The stability of facial wash gel formulations is influenced by the concentration of Hydroxypropyl Methylcellulose (HPMC), which plays a crucial role in determining viscosity, homogeneity, spreadability, and foam stability. This study aimed to evaluate and optimize the physical stability of facial wash gel containing okra extract 3% (*Abelmoschus esculentus (L.) Moench*) by varying HPMC concentrations (1, 1.5, and 2%). The formulations were assessed for homogeneity, syneresis, pH stability, viscosity, spreadability, and foam stability over a 28-day storage period at room temperature (25°C). Statistical analysis was performed using SPSS version 27, including Shapiro-Wilk normality test, Levene's test for homogeneity, One-Way ANOVA, and Tukey's post-hoc test to determine significant differences among formulations. The results showed that HPMC concentration significantly influenced gel stability. F1 (1% HPMC) exhibited syneresis, excessive spreadability, and lower viscosity, indicating poor structural integrity. F2 (1.5% HPMC) maintained moderate stability but showed significant changes in spreadability over time. F3 (2% HPMC) demonstrated the best stability with optimal viscosity, minimal syneresis, controlled spreadability, and consistent foam formation. pH values for all formulations remained within the acceptable range (4.5–7.8, SNI 16-4380-1996). Foam stability (60–70%) met regulatory standards (SNI 16-4085-1996), with higher HPMC concentrations contributing to increased foam retention. The study confirms that HPMC concentration is a key determinant of gel stability. F3 (2% HPMC) exhibited the most stable formulation, balancing viscosity, spreadability, and foam stability, making it the optimal formulation for facial wash gel development. These findings highlight the importance of gelling agent optimization in cosmetic formulations, ensuring both product stability and consumer acceptability.

KEYWORDS: *Abelmoschus esculentus;* antioxidant; facial wash gel; HPMC; okra extract; skincare.

1. INTRODUCTION

Facial care products have seen remarkable growth globally, driven by increasing consumer awareness of skincare, advancements in cosmetic formulations, and the rising demand for natural and functional ingredients. The global facial care market is projected to expand significantly, with a surge in interest in herbal and plant-based skincare formulations [1]. This trend is particularly strong in Indonesia, where traditional medicine and natural remedies play a crucial role in skincare practices [2]. The growing preference for organic and chemical-free products has encouraged extensive research into botanical extracts for their therapeutic and aesthetic benefits. Among these, herbal-based facial wash gels have gained popularity due to their mildness, deep cleansing ability, and added skincare benefits [3]. Consumers seek facial wash products that not only cleanse the skin but also offer antioxidant protection, hydration, and soothing effects. Consequently, the development of innovative facial wash formulations with natural extracts has become a focal point in cosmetic research.

Gels are among the most preferred formulations in facial care due to their light texture, ease of application, and ability to deliver active ingredients efficiently [4]. Hydroxypropyl Methylcellulose (HPMC) is commonly used as a gelling agent in cosmetic formulations due to its excellent film-forming properties, stability, and biocompatibility [5]. HPMC-based gels exhibit desirable viscosity, spreadability, and stability,

How to cite this article: Ana Y, Annisya MP, Eko M. Development and optimization of facial wash gel with okra fruit (Abelmoschus esculentus) extract: a study on HPMC concentration variations. JNPDD. 2025; 2(2): 71-84.

https://doi.org/10.58511/jnpdd.v2i2.8392
ISSN: 3031-6847

making them suitable for use in facial wash formulations [6]. The concentration of HPMC in a formulation plays a vital role in determining the texture, consistency, and efficacy of the final product. An optimal concentration of HPMC ensures the gel remains stable over time, does not undergo phase separation, and provides a smooth application experience. Studies have demonstrated that varying HPMC concentrations can significantly influence the physical and rheological properties of gel-based formulations, impacting their usability and effectiveness [6], [7]. Thus, optimizing the concentration of HPMC in a facial wash gel is crucial to achieving the desired performance and consumer acceptance.

Okra (*Abelmoschus esculentus L. Moench*) is a widely recognized medicinal plant valued for its diverse biological activities and rich phytochemical profile. Traditionally used as a functional food, okra is now gaining attention for its potential applications in skincare due to its high content of flavonoids, polyphenols, and mucilage [8]. These bioactive compounds contribute to okra's antioxidant, anti-inflammatory, and moisturizing properties, making it a promising ingredient for cosmetic formulations [9]. The antioxidant activity of okra extract helps combat oxidative stress, a major factor in skin aging and damage caused by environmental pollutants. Additionally, the mucilage present in okra provides hydration and forms a protective barrier on the skin, enhancing moisture retention [10]. The presence of polysaccharides and vitamins in okra further supports its use in skincare by promoting skin elasticity and protecting against dryness [11]. Given these beneficial properties, incorporating okra extract into facial wash formulations offers a natural approach to skin protection and rejuvenation.

The combination of okra extract with HPMC in a gel-based facial wash presents an opportunity to develop a stable and effective skincare product with enhanced functional benefits. Prior research on okra-based formulations has highlighted its potential in moisturizing and anti-aging products, but limited studies have explored its application in facial wash gels [12]. The selection of an appropriate gelling agent, such as HPMC, is crucial for maintaining the stability and effectiveness of the formulation. The interaction between okra extract and HPMC needs to be carefully evaluated to ensure that the formulation maintains an optimal consistency while delivering the intended skin benefits. Moreover, previous studies suggest that variations in HPMC concentration can impact the viscosity, spreadability, and foam stability of gel-based cleansers [13]. Therefore, an in-depth investigation into the effect of different HPMC concentrations on the physical stability of an okra-based facial wash gel is essential to optimize its formulation. Lastly, this study aims to develop and optimize a facial wash gel incorporating okra fruit extract by evaluating the effect of HPMC concentration on its physical stability. The research focuses on determining the ideal concentration of HPMC to achieve the best balance of viscosity, homogeneity, foam height, and antioxidant efficacy. By assessing the formulation's performance based on established cosmetic standards, this study contributes to the growing body of research on herbal-based facial care products. The findings are expected to provide valuable insights into the formulation of plant-extract-based skincare products, paving the way for further innovation in natural cosmetics.

2. MATERIALS AND METHODS

2.1. Preparation of Okra Fruit Extract

The preparation of okra fruit extract begins with collecting fresh, green okra fruits, which are thoroughly washed, deseeded, and cut into smaller pieces for faster drying. The material is then oven-dried at 50°C for approximately 3 hours before being ground into a fine powder. The okra extract is obtained through maceration, where 400g of okra powder is soaked in 3L of ethanol in a sealed glass container for 5 days. The filtrate is then evaporated using a rotary evaporator to obtain a thick extract, which is further dried in an oven at 40°C until all ethanol evaporates [14].

2.2. Phytochemical Screening

Phytochemical screening was conducted to identify the bioactive compounds present in the okra fruit extract. The alkaloid test was performed by adding 0.5 g of the extract to 0.5 mL of 1% HCl, followed by 1–2 drops of Dragendorff's reagent. A positive result was indicated by the formation of a reddish-brown precipitate, while Mayer's reagent produced a white precipitate, and Bouchardat's reagent resulted in a dark brown precipitate [15], [16]. The flavonoid test involved mixing 0.5 g of the extract with 1–2 mL of hot water and magnesium powder, followed by 4–5 drops of concentrated HCl. A color change to red, yellow, or orange confirmed the presence of flavonoids [15], [16]. The tannin test was conducted by boiling 0.5 g of the extract

with 5 mL of distilled water for 15 minutes, followed by the addition of 1% $FeCl_3$ solution. The formation of a dark blue to blackish-green color indicated the presence of tannins. The saponin test was carried out by adding 5 mL of hot water to 0.5 g of the extract and shaking it for 1 minute. The presence of persistent foam, even after the addition of 2N HCl, confirmed a positive result for saponins [17]. To detect steroids and triterpenoids, the Liebermann-Burchard test was used. A 0.5 g sample of the extract was dissolved in chloroform and treated with Liebermann-Burchard reagent (acetic anhydride and concentrated H_2SO_4). The formation of a blue-green ring indicated steroids, while a brown-purple ring confirmed the presence of triterpenoids. Lastly, the phenolic test was conducted by mixing 0.5 g of the extract with 1–5 mL of distilled water and 10% $FeCl_3$ solution. A dark blue or black color change indicated the presence of phenolic compounds [18].

2.3. Formulation of Facial Wash Gel with Okra Extract

The required ingredients were accurately weighed according to the formulation. A beaker glass was calibrated before use, and HPMC was dispersed into preheated distilled water, then stirred using a magnetic stirrer until fully hydrated and homogeneous (referred to as Phase A). Separately, methylparaben, Na-EDTA, okra fruit extract, and glycerin were dissolved in propylene glycol and then added to Phase A. After thorough mixing, Sodium Lauryl Sulfate (SLS), Triethanolamine (TEA), and green tea oil were incorporated into the mixture and stirred until a uniform and homogeneous facial wash gel was obtained. The formulation was prepared as outlined in **Table 1**. The facial wash gel formulations were prepared using three different concentrations of Hydroxypropyl Methylcellulose (HPMC) as the gelling agent: 1% (F1), 1.5% (F2), and 2% (F3), while maintaining other ingredients at constant concentrations. The formulation was adapted from previous studies with necessary modifications [19].

Table 1. Formulation of Facial Wash Gel with Okra Fruit Extract.

Ingredients	Formula		
	F1	F2	F3
Okra Fruit Extract	3	3	3
Methylparaben (Nipagin)	0.2	0.2	0.2
Propylene Glycol	15	15	15
HPMC (Hydroxypropyl Methylcellulose)	1	1.5	2
Fragrance Oil (Green Tea)	0.1	0.1	0.1
Sodium Lauryl Sulfate (SLS)	1	1	1
Disodium EDTA (Na-EDTA)	0.1	0.1	0.1
Triethanolamine (TEA)	1	1	1
Glycerin	3	3	3
Aqua Destillata (Aquadest)	Ad 100	Ad 100	Ad 100

2.4. Physical Evaluation of Facial Wash Gel with Okra Fruit Extract

The organoleptic test was conducted to assess the color, odor, texture, and consistency of the formulation using sensory evaluation. According to SNI 06-4085-1996, an ideal facial wash should exhibit a liquid form with a characteristic aroma and color [20]. The homogeneity test was performed by microscopic observation, where 0.1g of the sample was placed between two glass slides and examined for coarse particles. A formulation was considered homogeneous if no visible coarse particles were observed. Further, the syneresis test was carried out by storing the gel at room temperature for 24 hours and visually inspecting for water separation. Each sample was placed in an evaporating dish to collect any exuded water on the gel surface [21]. The pH test was conducted using a pH meter, where 3.0 g of the sample was diluted with 30 mL of distilled water in a beaker glass. Calibration was performed using buffer solutions (pH 4.7–9.0), and the pH value was measured. The acceptable pH range for facial wash formulations is 4.5–7.8, aligning with SNI 16-4380-1996.

The viscosity test was determined using a Brookfield Viscometer, where 30.0 g of the sample was placed in a cone-shaped container, and spindle No. 4 was set at 12 rpm. Measurements were recorded by increasing the shear rate from 0.5/s to 100/s [22]. The spreadability test was conducted by placing 0.5 g of the formulation on a glass plate and applying a 50–150 g load for 1 minute. A good gel formulation should exhibit a spreadability of 5–7 cm [23]. Moreover, the foam stability test was performed by dissolving 0.5 g of the sample in 10 mL of distilled water in a test tube, followed by shaking. The initial foam height was measured, and after 5 minutes, the foam stability was re-evaluated [23]. Lastly, the physical stability test was conducted by storing

the facial wash gel for 28 days at room temperature (25°C). Physical characteristics, including organoleptic properties, homogeneity, syneresis, pH, viscosity, spreadability, and foam stability, were monitored throughout the study.

2.5. Data Analysis

The data analysis for organoleptic, homogeneity, and syneresis tests was conducted through visual observation, where the formulations were directly examined for physical characteristics. For pH, viscosity, spreadability, and foam stability tests, statistical analysis began with normality testing using the Shapiro-Wilk test. If the data were normally distributed, homogeneity of variance was assessed using Levene's test. When the data met both normality and homogeneity assumptions, a parametric One-Way ANOVA was performed to determine the effect of varying HPMC concentrations on the physical stability of the facial wash gel containing okra extract. If the data did not follow a normal distribution or exhibited heterogeneous variance, the non-parametric Kruskal-Wallis test was used instead.

3. RESULTS

3.1. Phytochemical Screening Results

Okra is a widely recognized plant known for its rich phytochemical composition and potential therapeutic applications. Various studies have reported that okra contains bioactive compounds such as flavonoids, alkaloids, tannins, phenols, saponins, and triterpenoids, which contribute to its antioxidant, anti-inflammatory, and antimicrobial properties [24]. The presence of these metabolites makes okra a promising candidate for incorporation into cosmetic and pharmaceutical formulations. In this study, six phytochemical screening tests were conducted to identify the presence of alkaloids, flavonoids, tannins, saponins, triterpenoids, and phenolic compounds in okra extract. The screening aimed to confirm the bioactive components that could contribute to the functional properties of the facial wash gel formulation. Based on the qualitative observations, okra extract tested positive for all six metabolites, confirming the presence of alkaloids, flavonoids, tannins, saponins, triterpenoids, and phenolic compounds. These findings align with previous studies that highlight the diverse chemical constituents of okra and its potential as an active ingredient in skincare formulations [25].

3.2. Stability Evaluation of Facial Wash Gel

The stability evaluation of the facial wash gel formulations was conducted by storing the samples at room temperature (25°C) for 1, 7, 14, 21, and 28 days. Observational analysis revealed distinct differences in the physical characteristics of the three formulations. F1 exhibited a yellowish-brown color with a less viscous gel texture and a characteristic green tea fragrance. F2 showed a yellowish-brown color, a moderately viscous gel texture, and the same green tea fragrance. Meanwhile, F3 had a yellowish-brown color with a thicker gel consistency and a green tea fragrance. The variations in gel texture among F1, F2, and F3 were influenced by the concentration of the gelling agent HPMC, where a higher HPMC concentration resulted in increased gel consistency and viscosity. Observations throughout the storage period indicated that F1 underwent physical changes, whereas F2 and F3 remained physically stable. The instability in F1 could be attributed to syneresis, which led to a reduction in viscosity and subsequently altered the formulation's consistency. This phenomenon highlights the importance of optimizing HPMC concentration to ensure formulation stability. The organoleptic evaluation results are presented in **Figure 1**, demonstrating the physical characteristics of each formulation over the storage period.

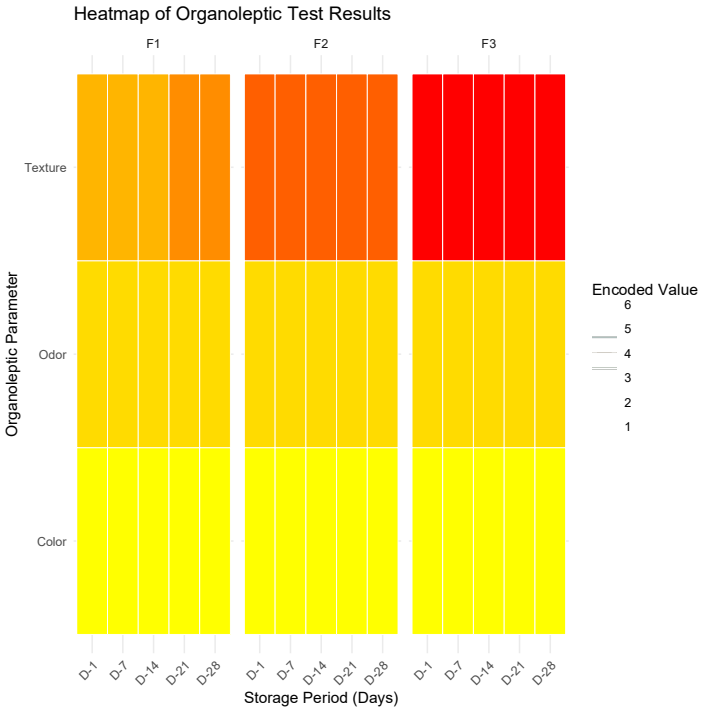

Figure 1. Heatmap visualization of organoleptic test results for facial wash gel with okra extract over a 28-day storage period. The heatmap represents changes in color, odor, and texture for each formulation (F1, F2, and F3). The encoded values correspond to different organoleptic characteristics, with color intensity indicating variations in consistency and stability across the storage period. The numerical encoding used in the heatmap represents the following attributes: ***1*** - Yellowish Brown (Color), ***2*** - Green Tea (Odor), ***3*** - Less Gel Thick (Texture), ***4*** - Liquid Gel (Texture), ***5*** - Slightly Consistent Gel (Texture), and ***6*** - Thick Gel (Texture). The transition in color intensity illustrates the gradual change in formulation properties over time, with darker shades indicating increased consistency and stability in the gel formulation.

3.3. Homogeneity Test Results

The homogeneity test was conducted to determine the presence of coarse particles in the facial wash gel with okra extract. Ensuring homogeneity in topical formulations is crucial, as these products are applied directly to the skin, requiring uniform dispersion of active ingredients to achieve optimal effectiveness [26]. A non-homogeneous formulation may lead to inconsistent product performance and reduced stability, impacting its overall efficacy. Based on observations, F1 (1% HPMC) and F2 (1.5% HPMC) exhibited syneresis after 28 days of storage, resulting in a loss of homogeneity and physical instability. Syneresis occurred due to water separation from the gel matrix, accumulating on the surface of the formulation. This instability was likely caused by the low concentration of the gelling agent, which was insufficient to retain water molecules during storage at room temperature. These findings are consistent with the previous study, which reported that low concentrations of gelling agents lead to excessive water absorption, resulting in weak gel structures that are more prone to syneresis [27]. Further, increasing the gelling agent concentration has been shown to reduce syneresis, as higher concentrations promote the formation of strong double-helix structures, enhancing water retention and preventing water loss from the gel matrix [28]. Several other factors can contribute to syneresis, including pH fluctuations, stirring technique and pressure, temperature changes, and high salt content. The *homogeneity test results and syneresis observations for each formulation are presented in **Figure 2**.

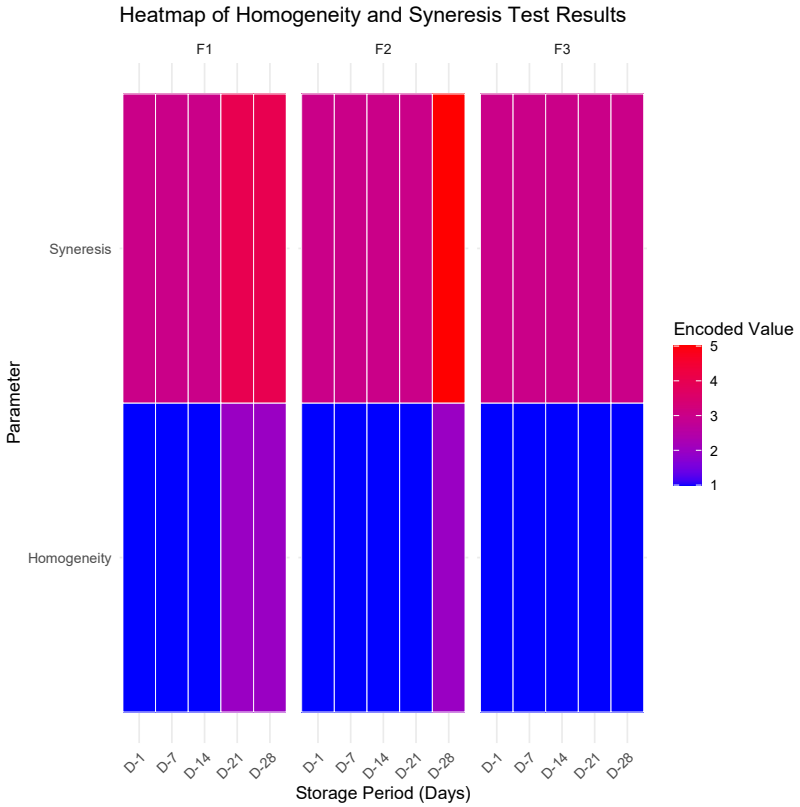

Figure 2. Heatmap visualization of homogeneity and syneresis test results for facial wash gel with okra fruit extract over a 28-day storage period. The heatmap represents the variations in homogeneity and syneresis for each formulation (F1, F2, and F3). The encoded values correspond to different stability conditions: ***1*** - Homogeneous (H), ***2*** - Not Homogeneous (TH), ***3*** - No Syneresis (TTS), ***4*** - Syneresis Occurred (TS), and ***5*** - Severe Syneresis (S). The color intensity indicates the degree of instability, with lower values (blue) representing more stable formulations and higher values (red) indicating increased phase separation and water release.

3.4. pH Stability Test Results

The pH analysis of F1, F2, and F3 revealed fluctuations in pH values throughout the storage period; however, all formulations remained within the normal skin pH range, indicating stability (**Figure 3**). Variations in pH values were likely influenced by environmental factors such as light exposure and handling during evaluation. This observation aligns with the findings of previous reported, who reported that pH changes can result from auto-oxidation reactions triggered by exposure to light and oxygen, as well as external factors such as temperature and humidity [29]. Despite these fluctuations, all three formulations maintained a pH range of 4.5 – 7.8, in accordance with SNI 16-4380-1996, confirming their stability throughout storage. Furthermore, ANOVA results showed significant differences ($p < 0.05$) in pH stability for F1 and F2, suggesting that HPMC concentration variations influenced pH changes over time, while F3 ($p = 0.172$, $p > 0.05$) did not exhibit significant differences during storage. Post-hoc Tukey's test further identified specific time points with significant differences in pH values. In F1, significant differences were observed between Day 1 vs. Day 7 ($p = 0.022$), Day 7 vs. Day 28 ($p = 0.00$), and Day 21 vs. Day 28 ($p = 0.00$). Meanwhile, F2 showed significant differences between Day 1 vs. Day 28 ($p = 0.019$), Day 7 vs. Day 28 ($p = 0.00$), Day 14 vs. Day 28 ($p = 0.00$), and Day 21 vs. Day 28 ($p = 0.00$).

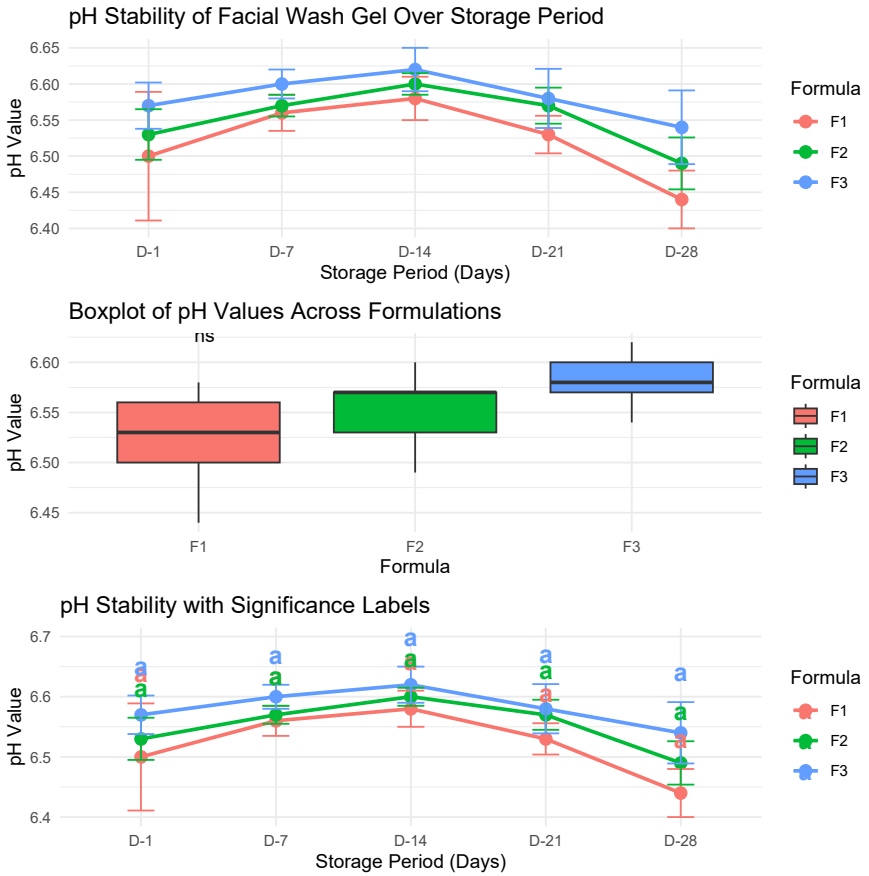

Figure 3. Line plot, boxplot, and statistical analysis of pH stability for facial wash gel with okra extract over a 28-day storage period. The line plot visualizes pH fluctuations across different storage periods for formulations F1, F2, and F3, with error bars representing standard deviations. The boxplot compares the distribution of pH values among the three formulations, with ANOVA results indicating significant differences. The final line plot incorporates Tukey's post-hoc significance labels, where different letters ("a", "b", "c") indicate statistically significant differences between formulations. Despite minor fluctuations, all formulations remained within the acceptable pH range (4.5 – 7.8) as per SNI 16-4380-1996, confirming their stability during storage.

3.5. Viscosity Test Results

Based on **Figure 4**, all formulations experienced changes in viscosity over the storage period; however, they remained within the acceptable viscosity range for facial wash gel (500–20,000 cP) as per Wahyuddin et al. (2023) [30]. Differences in viscosity among the formulations were influenced by the HPMC concentration, where a higher HPMC concentration resulted in a thicker gel. This finding aligns with Ruenraroengsak et al. (2005), who stated that higher HPMC concentrations increase gel viscosity due to the formation of hydrogen bonds between hydroxyl groups of HPMC and water molecules during dispersion [31]. The more hydroxyl groups available, the stronger the gel network formed, leading to higher viscosity. Among the formulations, F3 exhibited the most stable viscosity, with minimal fluctuations compared to F1 and F2, which showed more significant changes. The variations in viscosity during storage could be attributed to environmental factors, such as temperature fluctuations and storage conditions. This is consistent with Joshi (2011), who reported that viscosity changes in gels can be influenced by temperature and packaging conditions, where non-airtight containers may allow moisture absorption, increasing the water content in the gel and affecting its consistency [32]. Furthermore, ANOVA analysis revealed significant differences in viscosity stability among formulations (F1: $p = 0.00$, F2: $p = 0.00$, F3: $p = 0.045$, all < 0.05), indicating that HPMC concentration significantly affected viscosity stability during storage. Tukey's post-hoc test further identified specific time points with significant differences: in F1, no significant difference was observed between Day 7 and Day 14 ($p = 0.141$) or between Day 21 and Day 28 ($p = 0.726$). In F2, significant differences were found between Day 1 and Day 28 ($p = 0.00$), Day 7 and Day 28 ($p = 0.00$), and Day 21 and Day 28 ($p = 0.00$), while F3 showed no significant differences throughout the 28-day storage period, confirming its stability.

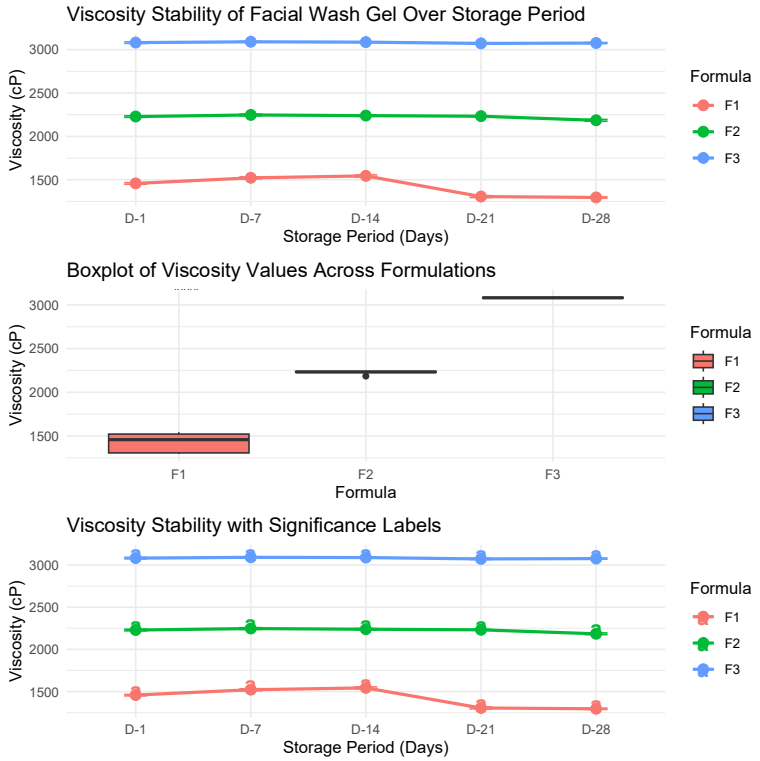

Figure 4. Line plot, boxplot, and statistical analysis of viscosity stability for facial wash gel with okra extract over a 28-day storage period. The line plot illustrates viscosity changes across different storage periods for formulations F1, F2, and F3, with error bars representing standard deviations. The boxplot compares the distribution of viscosity values among the three formulations, with ANOVA results indicating significant differences. The final line plot includes Tukey's post-hoc significance labels, where different letters ("a", "b", "c") indicate statistically significant differences between formulations.

3.6. Spreadability Test Results

Based on **Figure 5**, the spreadability test results for all three formulations indicate that an increase in HPMC concentration leads to a decrease in spreadability. The spreadability test further showed that F1 did not meet the required spreadability range of 5–7 cm, as per SNI No. 06-02588, due to excessive spreading beyond the acceptable limit. Further, ANOVA analysis revealed that F1 ($p = 0.84$) and F3 ($p = 0.23$) showed no significant differences in spreadability over the storage period, while F2 ($p = 0.00$) exhibited a significant change in spreadability. Further analysis using Tukey's post-hoc test confirmed that F2 had significant differences between Day 7 and Day 28 ($p = 0.00$) and between Day 14 and Day 28 ($p = 0.01$), highlighting a notable reduction in spreadability over time. These findings suggest that HPMC concentration plays a crucial role in controlling the spreadability of the gel, with lower concentrations allowing excessive spreading and higher concentrations limiting gel spreadability.

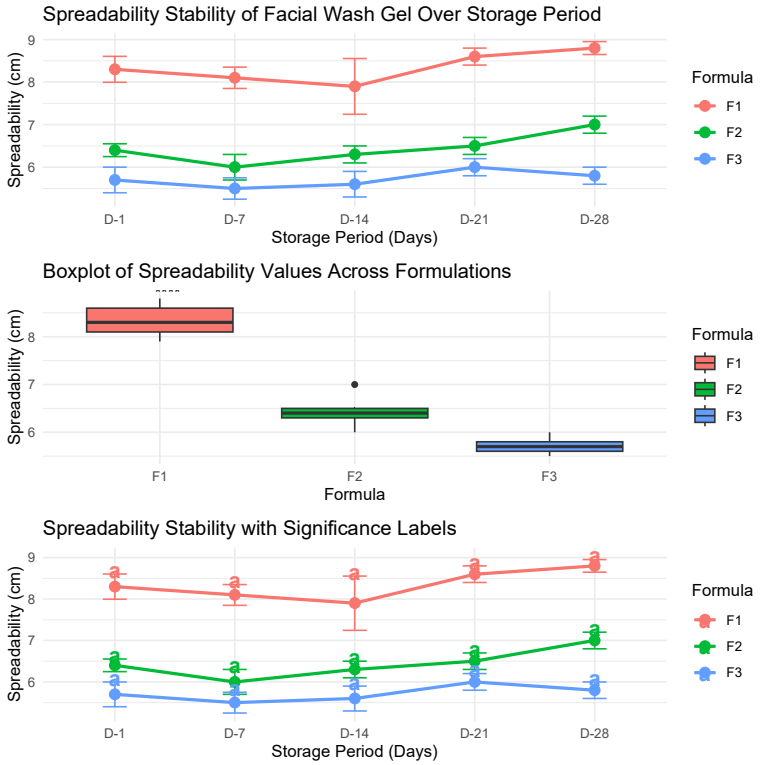

Figure 5. Line plot, boxplot, and statistical analysis of spreadability stability for facial wash gel with okra extract over a 28-day storage period. The line plot illustrates changes in spreadability across different storage periods for formulations F1, F2, and F3, with error bars representing standard deviations. The boxplot compares the distribution of spreadability values among the three formulations, with ANOVA results indicating significant differences. The final line plot includes Tukey's post-hoc significance labels, where different letters ("a", "b", "c") indicate statistically significant differences between formulations.

3.7. Foam Stability Test Results

The Foam stability test conducted over 28 days showed that the average foam stability for each formulation was F1: 65.64%, F2: 67.08%, and F3: 68.69% (**Figure 6),** all of which met the required foam stability range of 60–70%, as per SNI 16-4085-1996 (Evi Marlina et al., 2022) [33]. The HPMC concentration influenced foam stability, as a higher concentration increased surface tension and surface area, resulting in greater foam formation. This aligns with Buzzachi et al. (2006), who stated that foam formation is directly affected by surface tension, where higher surface tension increases foam volume [34]. ANOVA analysis for foam stability before 5 minutes showed significant differences between formulations (F1: $p = 0.02$, F2: $p = 0.02$, F3: $p = 0.03$, all < 0.05), indicating variations in foam stability at the initial stage. However, after 5 minutes, ANOVA results showed no significant differences (F1: $p = 0.08$, F2: $p = 0.08$, F3: $p = 0.12$, all > 0.05), suggesting that foam stability equalized over time. Tukey's post-hoc test revealed significant differences in F1 between Day 1 and Day 7 ($p = 0.02$), F2 between Day 21 and Day 7 ($p = 0.04$) and between Day 21 and Day 14 ($p = 0.03$), and F3 between Day 1 and Day 7 ($p = 0.03$), indicating formulation-dependent changes in foam stability over time. These results confirm that HPMC concentration influences initial foam stability, while long-term foam stability remains unaffected across formulations.

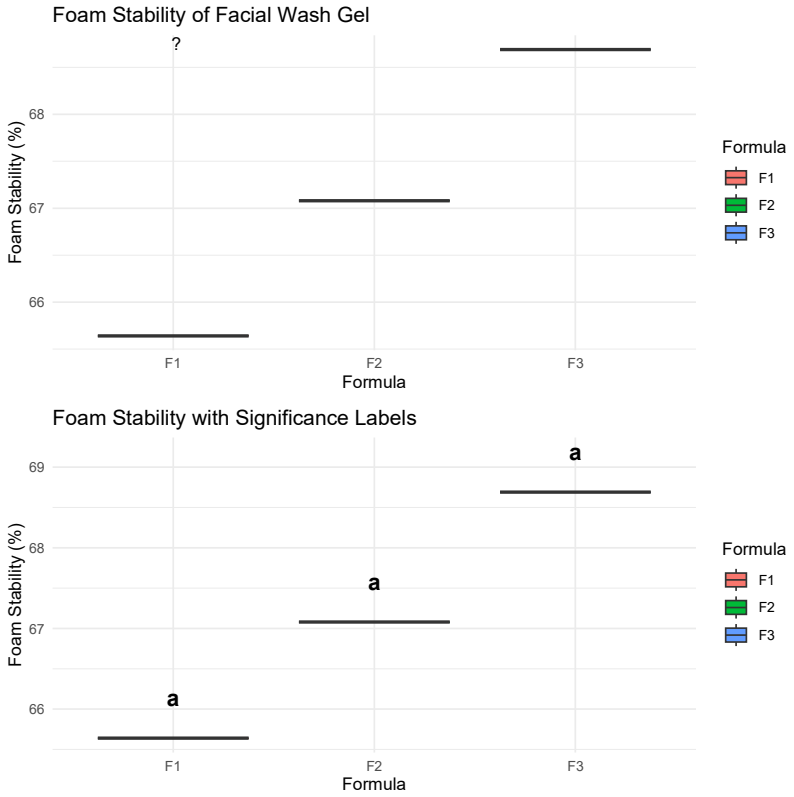

Figure 6. Boxplot and statistical analysis of foam stability for facial wash gel with okra extract. The first boxplot illustrates the distribution of foam stability values for formulations F1, F2, and F3, with ANOVA results indicating significant differences. The second boxplot includes Tukey's post-hoc significance labels, where different letters ("a", "b", "c") indicate statistically significant differences between formulations.

4. DISCUSSION

Okra is a nutrient-dense plant with a wide range of phytochemicals, making it highly valuable for various uses, including medicinal, nutritional, and cosmetic applications. Its fiber is composed of α-cellulose, lignin, and waxy substances, while its richness in bioactive compounds such as flavonoids, alkaloids, tannins, phenols, saponins, and triterpenoids contributes to its therapeutic and functional properties [35]. These bioactive compounds are known for their antioxidant, anti-inflammatory, antimicrobial, and skin-soothing effects, making okra a promising ingredient in pharmaceutical and cosmetic formulations [35]. Additionally, the plant is abundant in other beneficial components like pectin, mucilage, proteins, fats, and essential minerals such as potassium, sodium, magnesium, and calcium, which further enhance its nutritional and functional value. The mucilage found in okra fruits, which contains flavonoids, d-galactose, l-rhamnose, and d-galacturonic acid, plays a key role in its moisturizing and stabilizing properties, making it suitable for use in skincare products. Ripe okra seeds provide 10–22% edible oil, while essential oils extracted from the pods and seeds contain compounds such as aliphatic alcohols, cyclohexanol, citral, and β-sitosterol, which contribute to its antioxidant and anti-aging potential [36]. Ethanolic and aqueous extracts of okra fruits also reveal the presence of carbohydrates, gums, mucilages, phytosterols, tannins, phenolic compounds, and volatile oils, all of which are beneficial for skin health and stability in formulations. Recent research has further expanded the understanding of okra's bioactive potential by identifying two new pentacyclic triterpenes and three unique glycosides, underscoring its versatility and applicability in various industries [37]. These findings highlight okra's potential as a natural, multifunctional ingredient for health, wellness, and cosmetic products.

Facial wash gel formulations must maintain physical stability throughout storage to ensure effectiveness and consumer acceptability. One of the key factors affecting the stability of gel-based formulations is the concentration of the gelling agent, in this case, HPMC. The role of HPMC in gel formulations extends beyond providing viscosity; it also influences homogeneity, syneresis, pH stability, spreadability, and foam stability [38]. The results of this study demonstrate that varying the HPMC concentration (1%, 1.5%, and 2%) had a

significant impact on multiple physicochemical properties. A well-balanced formulation should optimize viscosity and gel consistency while maintaining spreadability and foam stability within acceptable limits.

One of the most crucial indicators of formulation stability is homogeneity and syneresis. A gel formulation that is not homogeneous may lead to poor dispersion of active ingredients, reducing product effectiveness. The occurrence of syneresis in F1 (1% HPMC) and F2 (1.5% HPMC) highlights the importance of adequate gelling agent concentration in stabilizing the gel structure. Syneresis typically results from insufficient water retention within the gel matrix, which occurs when the polymer network is too weak to hold water molecules, leading to phase separation [39]. Increasing HPMC concentration forms a stronger hydrogen-bonded network, effectively reducing syneresis. Previous studies have shown that higher polymer concentrations create a more stable gel structure, preventing water loss and maintaining uniformity over time [40].

Another critical aspect of formulation stability is pH maintenance, as variations in pH may affect the safety and efficacy of the product. The results indicate that while minor pH fluctuations were observed over time, they remained within the acceptable pH range for facial wash gels (4.5–7.8, as per SNI 16-4380-1996). Environmental factors such as light exposure and oxidation could contribute to pH shifts. However, the presence of buffering agents and the formulation's overall composition likely helped maintain pH stability across storage conditions [41]. Statistical analysis confirmed that pH stability was significantly affected by HPMC concentration, reinforcing the importance of polymer selection in maintaining pH balance throughout storage.

Spreadability and viscosity are two interrelated factors that determine ease of application and user experience. Higher HPMC concentrations resulted in increased viscosity, which subsequently reduced the spreadability of the gel. This aligns with the fundamental principle that viscosity and spreadability share an inverse relationship as viscosity increases, the ability of the gel to flow and spread decreases [42]. Formulations with lower viscosity (F1, 1% HPMC) exhibited excessive spreadability, exceeding the acceptable range (5–7 cm), while F2 (1.5% HPMC) and F3 (2% HPMC) met the standard. These findings indicate that optimizing HPMC concentration is crucial in achieving an ideal balance between thickness and spreadability, ensuring both stability and ease of use.

Finally, foam stability is a key attribute in cleansing formulations, as it affects consumer perception and cleansing efficiency. The presence of SLS as a foaming agent ensured that all formulations met the required foam stability range (60–70%). Interestingly, higher HPMC concentrations led to increased foam stability, likely due to surface tension modification by the polymer network. This supports previous research indicating that higher polymer content enhances foam retention by stabilizing air bubbles within the gel matrix.

Although this study provides valuable insights into the effect of HPMC concentration on the stability and physical properties of facial wash gel formulations, there are several limitations to consider. One major limitation is the absence of a formulation containing 0% okra in the experimental design. This restricts our understanding of the independent role of okra in influencing the stability and physical properties of the gel. As a nutrient-dense plant rich in bioactive compounds, okra may have significant effects on viscosity, homogeneity, pH stability, and other properties. Without a control formulation (0% okra), it is difficult to isolate the effects of okra from those of HPMC or other ingredients in the formulation. Additionally, the lack of a 0% okra formulation hinders the evaluation of potential synergies or antagonisms between okra and HPMC. For instance, the mucilage present in okra is known to have natural thickening and stabilizing properties, which may interact with HPMC in influencing the viscosity and stability of the gel. Without a control formulation, these interactions cannot be accurately measured. This limitation suggests the need for further research that includes a 0% okra formulation as a control, allowing for a more comprehensive evaluation of the individual effects and interactions between okra and HPMC. Such an approach would provide a deeper understanding of the contributions of each component in the facial wash gel formulation.

5. CONCLUSION

This study demonstrates that HPMC concentration significantly influences the physical stability of facial wash gel formulations containing okra extract. Variations in HPMC concentration (1%, 1.5%, and 2%) impacted key stability parameters, including homogeneity, syneresis, pH, viscosity, spreadability, and foam stability. Formulations with lower HPMC concentrations (F1, 1%) were more prone to syneresis and excessive spreadability, indicating insufficient gel matrix formation. In contrast, higher HPMC concentrations (F3, 2%)

resulted in higher viscosity, improved gel stability, and optimal spreadability. pH fluctuations remained within the acceptable range (4.5–7.8), ensuring formulation safety and skin compatibility. Overall, F3 (2% HPMC) exhibited the most stable formulation with minimal syneresis, consistent viscosity, optimal spreadability, and stable foam formation. These findings highlight the critical role of gelling agents in ensuring the long-term stability of gel-based cosmetic formulations. Future research may explore alternative polymer combinations or extended storage conditions to further enhance formulation performance.

Acknowledgements: none.

Author contributions: Concept – A.Y, A.M.P.; Design – A.Y.; Supervision – E.M.; Resources – A.Y.; Materials – A.Y., E.M.P..; Data Collection and/or Processing – E.M.P.; Analysis and/or Interpretation – E.M.; Literature Search – E.MP.; Writing – A.Y, E.M.; Critical Reviews – E.M.

Conflict of interest statement: The authors declared no conflict of interest.

REFERENCES

[1] A. Selwyn and S. Govindaraj, "Study of plant-based cosmeceuticals and skin care," South African Journal of Botany, vol. 158, pp. 429–442, Jul. 2023, doi: 10.1016/j.sajb.2023.05.039.

[2] Y. Y. S. Rahayu, T. Araki, and D. Rosleine, "Factors affecting the use of herbal medicines in the universal health coverage system in Indonesia," J Ethnopharmacol, vol. 260, p. 112974, Oct. 2020, doi: 10.1016/j.jep.2020.112974.

[3] P. Kumar, N. Karam, and D. Choudhury, "Assessment of the Phytochemical Constituents and Metabolites in the Medicinal Plants and Herbal Medicine Used in the Treatment and Management of Skin Diseases," 2024, pp. 1–41. doi: 10.1007/978-3-031-21973-3_21-1.

[4] V. B. Patravale and S. D. Mandawgade, "Novel cosmetic delivery systems: an application update," Int J Cosmet Sci, vol. 30, no. 1, pp. 19–33, Feb. 2008, doi: 10.1111/j.1468-2494.2008.00416.x.

[5] N. N. Fajriyah et al., "Soursop Leaf Extract Gel: A Promising Solution for Skin Bacterial Infections," 2024, pp. 1166–1175. doi: 10.2991/978-2-38476-273-6_120.

[6] N. N. Fajriyah, M. Muhtadi, F. N. Rosyidand, and E. Mugiyanto, "Characterization of nano-hydrogel chitosan-annona muricata extract by using ionic gelation," 2024, p. 020008. doi: 10.1063/5.0198874.

[7] A. Filimon, M. D. Onofrei, A. Bargan, I. Stoica, and S. Dunca, "Bioactive Materials Based on Hydroxypropyl Methylcellulose and Silver Nanoparticles: Structural-Morphological Characterization and Antimicrobial Testing," Polymers (Basel), vol. 15, no. 7, p. 1625, Mar. 2023, doi: 10.3390/polym15071625.

[8] R. Agregán et al., "Biological activity and development of functional foods fortified with okra (Abelmoschus esculentus)," Crit Rev Food Sci Nutr, vol. 63, no. 23, pp. 6018–6033, Sep. 2023, doi: 10.1080/10408398.2022.2026874.

[9] H. Sipahi et al., "A comprehensive study to evaluate the wound healing potential of okra (Abelmoschus esculentus) fruit," J Ethnopharmacol, vol. 287, p. 114843, Apr. 2022, doi: 10.1016/j.jep.2021.114843.

[10] K. Khatreja and D. Santhiya, "Physicochemical characterization of novel okra mucilage/hyaluronic acid-based oral disintegrating films for functional food applications," Int J Biol Macromol, vol. 278, p. 134633, Oct. 2024, doi: 10.1016/j.ijbiomac.2024.134633.

[11] Y. Gao, J. Tan, Y. Sang, J. Tang, X. Cai, and H. Xue, "Preparation, structure, and biological activities of the polysaccharides from fruits and vegetables: A review," Food Biosci, vol. 54, p. 102909, Aug. 2023, doi: 10.1016/j.fbio.2023.102909.

[12] B. Păcularu-Burada, A.-I. Cîrîc, and M. Begea, "Anti-Aging Effects of Flavonoids from Plant Extracts," Foods, vol. 13, no. 15, p. 2441, Aug. 2024, doi: 10.3390/foods13152441.

[13] M. Kumar, S. Chopra, S. Mahmood, M. A. Mirza, and A. Bhatia, "Formulation, Optimization, and Evaluation of Non-Propellent Foam-Based Formulation for Burn Wounds Treatment," J Pharm Sci, vol. 113, no. 9, pp. 2795–2807, Sep. 2024, doi: 10.1016/j.xphs.2024.07.004.

[14] M. S. Qulub, W. Wirasti, and E. Mugiyanto, "Perbedaan aktivitas antioksidan ekstrak etanol daun, daging buah, dan biji mengkudu (Morinda citrifolia L.) dengan metode DPPH (1, 1–Diphenyl-2-picrylhydrazyl)," in Prosiding University Research Colloquium, 2019, pp. 454–462.

[15] E. Mugiyanto and R. Fatmala, "Karakterisasi Simplisia Dan Ekstrak Anti Piretik Daun Dadap Serep (Erythrina Lithosperma Miq) Dari Kabupaten Pekalongan".

[16] A. P. Ratu and E. Mugiyanto, "Uji Toksisitas Daun Ketepeng (Cassia Alata L.), Kulit Buah Pisang Ambon (Musa Paradisiaca L. Var Sapientum) Dan Kulit Rimpang Kencur (Kaempferia Galanga Linn.) Dengan Metode Brine Shrimp Lethality Test (BSLT)".

[17] Y. W. Permadi and E. Mugiyanto, "Formulation And Evaluation Of Physical Properties Of Anti Dandruff Shampoo Extract," 62 Jurnal Farmasi Sains Dan Praktis, vol. 4, no. 2, pp. 62–66, 2018.

[18] A. Yulyana, C. Amin, P. Simanjuntak, S. Abdillah, A. Rohman, and E. Mugiyanto, "Assessing the Antimetabolite Activity of Anthocyanins in Cantigi Fruits from Two Conservation Sites in Indonesia," Indonesian Journal of Pharmacy, Sep. 2023, doi: 10.22146/ijp.8788.

[19] H. Shah, A. Jain, G. Laghate, and D. Prabhudesai, "Pharmaceutical excipients," in Remington, Elsevier, 2021, pp. 633–643. doi: 10.1016/B978-0-12-820007-0.00032-5.

[20] S. Widyaningsih, M. Chasani, H. Diastuti, and Novayanti, "Formulation of Antibacterial Liquid Soap from Nyamplung Seed Oil (Calophyllum inophyllum L) with Addition of Curcuma heyneana and its Activity Test on Staphylococcus aureus," IOP Conf Ser Mater Sci Eng, vol. 349, p. 012062, Apr. 2018, doi: 10.1088/1757-899X/349/1/012062.

[21] A. O. W. Kaya, M. L. Wattimena, E. E. E. M. Nanlohy, and S. Lewerissa, "Pengaruh Perbandıngan Dan Konsentrası Bahan Pembentuk Gel Terhadap Sıfat Fısıko-Kımıa Gel Kombınası Karagenan Dan Patı Sagu," INASUA: Jurnal Teknologi Hasil Perikanan, vol. 2, no. 1, pp. 100–107, Jan. 2022, doi: 10.30598/jinasua.2022.2.1.100.

[22] U. Waznah, N. Mufrodah, W. Wirasti, and E. Mugiyanto, "Evaluation of the mucolytic activity of ethanol extract of Temu Ireng (Curcuma aeruginosa Roxb.)," Farmasains : Jurnal Farmasi dan Ilmu Kesehatan, vol. 9, no. 2, pp. 59–68, Dec. 2024, doi: 10.22219/farmasains.v9i2.34760.

[23] N. N. Fajriyah et al., "Topical nano hydrogel formulation of annona muricata extract enrich with zinc for improved therapy design and evaluation," 2023, p. 020141. doi: 10.1063/5.0120738.

[24] Tri Putri Wahyuni and Atyka Trianisa, "Bioactivity and Benefits of the Okra Plant (Abelmoschus Esculentus (L.) Moench.) : Literature Review," Science Get Journal, vol. 1, no. 3, pp. 30–41, Aug. 2024, doi: 10.69855/science.v1i3.48.

[25] A. A. Elshafy, M. Abou-Ellail, and M. El-Sayed, "Metabolic profiling of bioactive phytochemicals of two okra genotypes and their F1 and backcrosses," International Journal of Vegetable Science, vol. 30, no. 2, pp. 198–224, Mar. 2024, doi: 10.1080/19315260.2024.2354773.

[26] P. L. Tan et al., "Formulation and Physicochemical Evaluation of Green Cosmeceutical Herbal Face Cream Containing Standardized Mangosteen Peel Extract," Cosmetics, vol. 9, no. 3, p. 46, Apr. 2022, doi: 10.3390/cosmetics9030046.

[27] S. Banerjee and S. Bhattacharya, "Compressive textural attributes, opacity and syneresis of gels prepared from gellan, agar and their mixtures," J Food Eng, vol. 102, no. 3, pp. 287–292, Feb. 2011, doi: 10.1016/j.jfoodeng.2010.08.025.

[28] L. Zhang et al., "Rheological and gel properties of hydroxypropyl methylcellulose/hydroxypropyl starch blends," Colloid Polym Sci, vol. 293, no. 1, pp. 229–237, Jan. 2015, doi: 10.1007/s00396-014-3407-5.

[29] A. Garg, R. Sharma, P. Dey, and A. Kumar, "Food auto-oxidation: An overview," in Antioxidants Effects in Health, Elsevier, 2022, pp. 43–68. doi: 10.1016/B978-0-12-819096-8.00013-6.

[30] Wahyuddin Jumardin, Sirajul Firdaus, and Andi Ulfiana Utari, "Formulasi dan Uji Aktivitas Antibakteri Sediaan Gel Facial Wash Ekstrak Etanol Daun Belimbing Wuluh (Averrhoa Bilimbi L.) Terhadap Pertumbuhan Propionibacterium Acnes Penyebab Jerawat," INHEALTH : INDONESIAN HEALTH JOURNAL, vol. 2, no. 2, Aug. 2023, doi: 10.56314/inhealth.v2i2.156.

[31] P. Ruenraroengsak and A. T. Florence, "The diffusion of latex nanospheres and the effective (microscopic) viscosity of HPMC gels," Int J Pharm, vol. 298, no. 2, pp. 361–366, Jul. 2005, doi: 10.1016/j.ijpharm.2005.01.044.

[32] S. C. Joshi, "Sol-Gel Behavior of Hydroxypropyl Methylcellulose (HPMC) in Ionic Media Including Drug Release," Materials, vol. 4, no. 10, pp. 1861–1905, Oct. 2011, doi: 10.3390/ma4101861.

[33] Evi Marlina, Naelaz Zukhruf Wakhidatul Kiromah, and Titi Pudji Rahayu, "Formulası Sedıaan Antıoksıdan Facıal Wash Ekstrak Metanol Daun Ganıtrı (*Elaeocarpus ganitrus* Roxb.) dengan Varıası Sodıum Laurıl Sulfat sebagaı Surfaktan," Jurnal Ilmiah Manuntung, vol. 8, no. 1, pp. 181–190, May 2022, doi: 10.51352/jim.v8i1.599.

[34] M. Buzzacchi, P. Schmiedel, and W. von Rybinski, "Dynamic surface tension of surfactant systems and its relation to foam formation and liquid film drainage on solid surfaces," Colloids Surf A Physicochem Eng Asp, vol. 273, no. 1–3, pp. 47–54, Feb. 2006, doi: 10.1016/j.colsurfa.2005.06.074.

[35] N. Jain, R. Jain, V. Jain, and S. Jain, "A review on: Abelmoschus esculentus," Pharmacia, vol. 1, no. 3, pp. 84–89, 2012.

[36] M. A. M. Abdel-Razek, M. F. Abdelwahab, U. R. Abdelmohsen, and A. N. E. Hamed, "A Review: Pharmacological Activity and Phytochemical Profile of Abelmoschus esculentus (2010–2022)," RSC Adv, vol. 13, no. 22, pp. 15280–15294, 2023, doi: 10.1039/D3RA01367G.

[37] Y. Zhou, X. Jia, J. Shi, Y. Xu, L. Jing, and L. Jia, "Two New Pentacyclic Triterpenes from Abelmoschus esculentus," Helv Chim Acta, vol. 96, no. 3, pp. 533–537, Mar. 2013, doi: 10.1002/hlca.201200275.

[38] N. W. G. Young, "Emulsifiers and stabilisers," in Fats in Food Technology 2e, Wiley, 2014, pp. 253–287. doi: 10.1002/9781118788745.ch7.

[39] S. Mizrahi, "Syneresis in food gels and its implications for food quality," in Chemical Deterioration and Physical Instability of Food and Beverages, Elsevier, 2010, pp. 324–348. doi: 10.1533/9781845699260.2.324.

[40] F. Tian, S. Baldursdottir, and J. Rantanen, "Effects of Polymer Additives on the Crystallization of Hydrates: A Molecular-Level Modulation," Mol Pharm, vol. 6, no. 1, pp. 202–210, Feb. 2009, doi: 10.1021/mp800142z.

[41] L. G. M. B. Becking, I. R. Kaplan, and D. Moore, "Limits of the Natural Environment in Terms of pH and Oxidation-Reduction Potentials," J Geol, vol. 68, no. 3, pp. 243–284, May 1960, doi: 10.1086/626659.

[42] D. R. Kryscio et al., "Spreadability Measurements to Assess Structural Equivalence (Q3) of Topical Formulations—A Technical Note," AAPS PharmSciTech, vol. 9, no. 1, pp. 84–86, Mar. 2008, doi: 10.1208/s12249-007-9009-5.