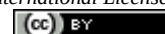


Formulation and Evaluation Of Nanogel Facial Cleanser Containing Raspberry Fruit (*Rubus rosifolius* Sm.) Extract As Antibacterial Agent

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ABSTRACT

Raspberry fruit (*Rubus rosifolius* Sm.) contains bioactive compounds with potential antibacterial activity. This study aimed to formulate and evaluate a nanogel facial cleanser containing raspberry fruit extract and assess its in vitro antibacterial activity against *Staphylococcus aureus*. An experimental laboratory design was used. Raspberry fruit was extracted by maceration with 96% ethanol. Four formulations were prepared: F0 without extract and F1, F2, and F3 containing 0.5%, 1%, and 2% extract, respectively. Organoleptic properties, homogeneity, pH, viscosity, spreadability, adhesiveness, foam height, and particle size were evaluated in four replicates. Antibacterial activity was assessed in triplicate using disk diffusion, with DMSO as the negative control (K⁻) and a commercial facial cleanser as the positive control (K⁺). Mean particle sizes were 881.13 ± 16.10 , 807.10 ± 5.55 , 896.83 ± 7.04 , and 1086.00 ± 18.19 nm for F0–F3, respectively. Mean inhibition zones were 4.83 ± 0.15 , 6.38 ± 0.15 , 7.32 ± 0.10 , and 8.05 ± 0.13 mm, respectively. One-way ANOVA revealed significant differences among groups ($p < 0.001$). Tukey's post hoc test indicated significant differences in the order K⁻ < F0 < K⁺ < F1 < F2 < F3. F3 exhibited the highest antibacterial activity, classified as moderate under the study's criteria, although its mean particle size exceeded 1000 nm. Raspberry fruit extract formulations demonstrated measurable in vitro antibacterial activity against *S. aureus*, supporting further investigation of their formulation characteristics and potential application as facial cleansers.

1. Introduction

Facial skin hygiene is an important aspect of maintaining skin health. Daily outdoor activities expose facial skin to sunlight, air pollution, dust, and vehicle exhaust, which may contribute to increased sebum production and the accumulation of impurities on the skin surface. These conditions can increase the risk of acne development [1]. Acne commonly occurs during adolescence and early adulthood, particularly between 12 and 25 years of age. Although the severity of acne varies, approximately 15–20% of cases are classified as moderate to severe acne, indicating the importance of appropriate preventive and treatment strategies [2].

Acne development is influenced by several factors, including genetic predisposition, psychological conditions, hormonal changes, bacterial activity, and excessive sebaceous gland activity. Increased sebum production may contribute to follicular obstruction and create favorable conditions for microbial growth and inflammation. Although *Cutibacterium acnes* is widely recognized as one of the principal microorganisms associated with acne vulgaris, other skin-associated bacteria, including *Staphylococcus epidermidis* and *Staphylococcus aureus*, have also been detected in acne-related skin conditions. The interaction between bacterial activity, sebum accumulation, and inflammatory responses may contribute to follicular damage and the progression of acne lesions. Therefore, evaluating antibacterial activity against skin-associated

bacteria such as *S. aureus* may provide relevant information regarding the antibacterial potential of a facial cleansing formulation, although the results should not be interpreted as direct evidence of clinical anti-acne efficacy.

Facial cleansers are commonly used to remove dirt, excess sebum, and other impurities from the skin surface while maintaining skin cleanliness. Conventional facial cleansing products may contain synthetic antibacterial ingredients, such as benzoyl peroxide, which is widely used in acne-related preparations because of its ability to inhibit or eliminate acne-associated bacteria. However, prolonged or inappropriate use of benzoyl peroxide may cause undesirable effects, including dryness, erythema, irritation, and scaling of the skin [3]. These limitations have encouraged the exploration of natural ingredients that may provide antibacterial activity with better suitability and comfort for repeated topical use. One potential natural ingredient is raspberry fruit (*Rubus rosifolius* Sm.), a member of the Rosaceae family.

Plants belonging to the genus *Rubus* have been reported to possess various biological activities, including antioxidant, antimicrobial, antiallergic, antiatherogenic, and anti-inflammatory effects [4]. The biological potential of raspberry fruit is associated with its secondary metabolites, particularly phenolic compounds, flavonoids, anthocyanins, and other bioactive constituents. These compounds may contribute to antibacterial activity through several mechanisms, including disruption of bacterial cell membranes, alteration of membrane permeability, inhibition of bacterial enzymes, and interference with essential cellular processes. *Rubus rosifolius* was selected in the present study because it represents a potentially valuable natural resource that has not been as extensively developed into topical facial cleansing preparations as other commonly investigated raspberry species. Nevertheless, the antibacterial potential of plant extracts may vary depending on the plant species, extraction method, solvent, extract concentration, and formulation vehicle. Therefore, further investigation is required to determine the feasibility of incorporating *R. rosifolius* fruit extract into a suitable topical dosage form.

The incorporation of natural bioactive compounds into conventional pharmaceutical or cosmetic formulations may be limited by poor solubility, inadequate physical stability, degradation during storage, and restricted bioavailability. Phenolic compounds, for example, may possess valuable biological activities but can be affected by environmental and formulation-related factors. Consequently, nano-based delivery systems, including nanoparticles, nanosuspensions, and nanogels, have been developed to improve the physicochemical stability, distribution, skin interaction,

and delivery of active compounds. The nanoscale size of these systems provides a larger surface area and may improve the interaction between the active ingredient and the target biological environment [5].

Nanogels are three-dimensional polymeric networks with nanoscale dimensions that combine the characteristics of nanoparticles and hydrophilic gels. Compared with conventional gels or conventional facial cleansing preparations, nanogels may offer advantages such as improved dispersion of active compounds, increased surface area, enhanced contact with the skin surface, and greater flexibility in controlling particle size and drug release. The cross-linked polymeric structure may also support the gradual and controlled release of incorporated active compounds, while the hydrophilic gel matrix may provide suitable characteristics for topical application [6]. In addition, nanogel systems may improve the physical distribution of plant extracts within the formulation and help maintain contact between the active ingredient and the skin surface during use.

The performance of a nanogel formulation is strongly influenced by the concentration of the active extract and the composition of its polymeric matrix. Increasing the extract concentration may improve the antibacterial potential of the formulation; however, it may also alter viscosity, spreadability, adhesiveness, homogeneity, foam formation, and particle size. Excessive active-material concentration may increase the possibility of particle aggregation and reduce the physical stability of the system. Therefore, the development of a nanogel facial cleanser requires a balance between antibacterial activity and acceptable physical characteristics. A suitable particle-size distribution is particularly important because it reflects the quality and stability of the nanosized delivery system.

Recent developments in nanoparticle-based delivery systems have demonstrated their potential to overcome several limitations associated with natural bioactive compounds, including low solubility, instability, limited bioavailability, and rapid degradation. Advances in polymeric, biodegradable, inorganic, hybrid, and stimuli-responsive nanocarriers have further expanded the application of nanotechnology in pharmaceutical and topical delivery systems [7]. However, the application of nanogel technology specifically for the incorporation of *R. rosifolius* fruit extract into a facial cleanser remains insufficiently investigated. Previous studies have generally focused either on the biological activity of plant extracts or on the development of nano-based delivery systems using different plant materials and dosage forms. Thus, the relationship between raspberry extract concentration, physical characteristics, particle size, and antibacterial activity within a single nanogel facial cleanser formulation requires further clarification.

The research gap addressed in this study is the limited information concerning the development of a nanogel-based facial cleanser containing *R. rosifolius* fruit extract at different concentrations and the simultaneous evaluation of its physical properties, particle size, and *in vitro* antibacterial activity against *S. aureus*. In particular, it remains important to determine whether increasing extract concentration improves antibacterial activity while maintaining acceptable formulation characteristics. Therefore, this study aimed to formulate and evaluate a nanogel facial cleanser containing *R. rosifolius* fruit extract at concentrations of 0.5%, 1%, and 2%. The formulations were evaluated based on organoleptic properties, homogeneity, pH, viscosity, spreadability, adhesiveness, foam height, and particle size, followed by an *in vitro* antibacterial assay against *S. aureus* using the disk diffusion method. This study is expected to contribute scientific data regarding the effect of extract concentration on the physical characteristics, nanoscale particle properties, and antibacterial potential of a nanogel facial cleansing preparation.

2. Research Method

2.1. Research Design

This experimental study was conducted to formulate and evaluate a nanogel facial cleanser containing raspberry fruit (*Rubus rosifolius* Sm.) extract as an antibacterial agent. Four formulations were prepared with different concentrations of raspberry fruit extract: F0 (0%), F1 (0.5%), F2 (1%), and F3 (2%). Each evaluation was performed in triplicate.

2.2. Preparation of Raspberry Fruit Extract

Fresh raspberry fruits were prepared as simplicia and extracted using the maceration method with 96% ethanol. The simplicia-to-solvent ratio was 1:10 (w/v). A total of 400 g of dried simplicia was used for the extraction process. The simplicia was soaked in 96% ethanol for 3 × 24 h with periodic stirring. The maceration process was repeated to maximize the extraction of active compounds. The obtained filtrate was concentrated using a rotary evaporator at 60°C to obtain a thick extract. The extraction process produced 110 g of thick extract with a yield of 27.5%.

2.3. Preparation of Nanogel

The nanogel was prepared using sodium alginate and calcium chloride as the nanogel-forming components. Sodium alginate was dispersed in distilled water and stirred until a homogeneous dispersion was obtained. Calcium chloride solution was then added gradually while stirring to form the nanogel system.

Carbopol 940 was dispersed in distilled water and allowed to swell before use. The swollen Carbopol was subsequently neutralized using triethanolamine until a gel base was formed. The raspberry fruit extract was

incorporated into the nanogel system according to the concentration of each formulation. The mixture was stirred using a magnetic stirrer at 500–700 rpm until a homogeneous nanogel preparation was obtained.

2.4. Formulation of Facial Cleanser

The nanogel preparation was incorporated into a facial cleanser base containing decyl glucoside, cocamidopropyl betaine, glycerin, propylene glycol, sodium metabisulfite, triethanolamine, and distilled water. Four formulations were prepared with different

concentrations of raspberry fruit extract, namely F0 without extract, F1 containing 0.5% extract, F2 containing 1% extract, and F3 containing 2% extract.

The formulation was prepared by mixing the gel base with the nanogel preparation, followed by the gradual addition of the remaining ingredients while stirring until a homogeneous facial cleanser preparation was obtained. The final volume of each formulation was adjusted to 100 g using distilled water.

2.5. Characterization of the Nanogel Facial Cleanser

The physical characteristics of the formulations were evaluated through organoleptic observation, homogeneity, pH, spreadability, adhesiveness, foam height, viscosity, and particle size analysis.

Organoleptic evaluation included observations of color, odor, and consistency. Homogeneity was evaluated by visually observing the presence or absence of coarse particles in the preparation.

The pH of each formulation was measured using a calibrated pH meter. Spreadability was evaluated by placing a predetermined amount of the preparation between two glass plates and measuring the diameter of the spread under a specified load. Adhesiveness was evaluated by measuring the time required for two glass slides containing the preparation between them to separate under a specified load.

Foam height was determined by dispersing a specified amount of the facial cleanser in a graduated cylinder containing water, shaking the mixture, and measuring the foam height.

Viscosity was measured using a viscometer with spindle number 5 after 10 min of measurement. Particle size was determined using a Particle Size Analyzer (PSA).

2.6. Antibacterial Activity Test

The antibacterial activity of the nanogel facial cleanser formulations was evaluated using the disk diffusion method against *Staphylococcus aureus*. The mean inhibition zones were 0.00 ± 0.00 mm for the negative control (K–), 4.83 ± 0.15 mm for F0, 5.58 mm for the positive control (K+), 6.38 ± 0.15 mm for F1, 7.32 ± 0.10 mm for F2, and 8.05 ± 0.13 mm for F3. The

inhibition zone increased progressively with increasing raspberry fruit extract concentration.

Ten percent DMSO was used as the negative control because it functioned as the solvent for the extract and was not expected to produce antibacterial activity at the concentration used. Accordingly, no inhibition zone was observed for K⁻. F0, which did not contain raspberry fruit extract, produced a relatively small inhibition zone of 4.83 ± 0.15 mm. This activity may be associated with the presence of surfactants in the facial cleanser base, particularly decyl glucoside and cocamidopropyl betaine, which may contribute to disruption of microbial membrane integrity or improve contact between the formulation and bacterial cells. However, this explanation should be interpreted cautiously because the antibacterial contribution of each excipient was not separately evaluated in the present study.

The positive control consisted of a commercial Purbasari Cherry facial cleanser and was included as a market-comparison control to compare the antibacterial activity of the developed formulation with an available commercial facial cleansing product. However, because the specific antibacterial active constituents and their concentrations in the commercial product were not standardized in this study, the positive control should not be interpreted as a pharmacological reference standard. Its use provides a practical comparison with a marketed product rather than a comparison with a defined antibacterial agent.

The formulations containing raspberry fruit extract showed higher inhibition zones than F0, with F3 producing the largest inhibition zone at 8.05 ± 0.13 mm. The increase in antibacterial activity may be related to the increasing amount of bioactive constituents present as the extract concentration increased. Phenolic compounds, flavonoids, and tannins may contribute to antibacterial activity through mechanisms such as disruption of bacterial cell membranes, alteration of membrane permeability, protein denaturation, enzyme inhibition, and interaction with bacterial cell-wall components. Nevertheless, because the individual phytochemical constituents were not quantified in the present study, these mechanisms should be regarded as possible explanations rather than directly confirmed mechanisms.

The antibacterial results indicate that F3 exhibited the highest antibacterial activity among the tested formulations. However, the inhibition zone of 8.05 ± 0.13 mm should be interpreted as limited to moderate *in vitro* antibacterial activity and should not be equated with clinical anti-acne effectiveness. The results demonstrate the antibacterial potential of the formulation against *S. aureus* under the experimental conditions used, but further studies using standardized antibacterial reference agents, additional acne-associated microorganisms, cytotoxicity testing, and

clinical evaluation are required before therapeutic or clinical efficacy can be established.

2.7. Data Analysis

Statistical analysis was performed using IBM SPSS Statistics version 27 to analyze the antibacterial activity data. The inhibition zone measurements obtained from the negative control (K⁻), positive control (K⁺), and facial cleanser formulations F0, F1, F2, and F3 were expressed as mean $\pm$ standard deviation (SD), with three replications for each group ($n = 3$).

The normality of the antibacterial inhibition zone data was assessed using the Shapiro–Wilk test because the number of observations in each group was less than 50. Homogeneity of variance was evaluated using Levene’s test. Data were considered normally distributed and homogeneous when the significance value was greater than 0.05 ($p > 0.05$).

The Shapiro–Wilk test showed significance values of 0.637, 0.637, 0.637, 0.463, and 0.363 for the positive control, F0, F1, F2, and F3 groups, respectively, indicating that the data were normally distributed. The negative control did not produce a significance value because all inhibition zone measurements were 0 mm, resulting in no variation within the group. Levene’s test showed a significance value of 0.122, indicating homogeneous variances among the groups.

Because the normality and homogeneity assumptions were fulfilled, the antibacterial data were analyzed using One-Way Analysis of Variance (ANOVA) at a 95% confidence level. A p-value of less than 0.05 was considered statistically significant. When a significant difference was found, Tukey’s Honestly Significant Difference (Tukey HSD) post-hoc test was performed to determine significant differences between individual groups.

The physical evaluation parameters, including organoleptic characteristics, homogeneity, pH, spreadability, adhesiveness, foam height, viscosity, and particle size, were presented descriptively in tables based on the measurement results obtained during the evaluation period. These parameters were not subjected to inferential statistical analysis but were assessed to describe the physical characteristics and stability of the formulations.

3. Result and Discussion

3.1. Extraction Yield of Raspberry Fruit Extract

The raspberry fruits (*Rubus rosifolius* Sm.) used in this study were collected from the roadside of Simpang Nangka, Selupu Rejang District, Curup Selatan Village, Rejang Lebong Regency. The collected fruits were subjected to wet sorting and washed under running water to remove dirt and foreign materials. The samples were then dried at room temperature until dry simplicia was obtained. The drying process was

intended to reduce moisture content, thereby inhibiting microbial growth and minimizing deterioration during storage.

Extraction was performed using the maceration method with 96% ethanol as the extraction solvent. A total of 400 g of dried simplicia was macerated using 4 L of 96% ethanol, corresponding to a simplicia-to-solvent ratio of 1:10 (w/v). Maceration was selected because it is relatively simple, economical, and does not require excessive heating, making it suitable for extracting thermolabile bioactive compounds while minimizing their degradation during extraction [8], [9]. Ethanol 96% was selected because it can dissolve a broad range of secondary metabolites with polar and semipolar characteristics, including phenolic compounds, flavonoids, tannins, and anthocyanins. These compounds have been associated with antioxidant and antibacterial activities and may contribute to the potential application of raspberry extract in facial cleanser formulations [10].

The maceration process was conducted for five days at room temperature with occasional stirring to increase contact between the solvent and the simplicia and facilitate the diffusion of extractable compounds into the solvent. The resulting macerate was separated from the residue using filter paper and concentrated using a rotary evaporator at 60°C and 80 rpm until a thick extract was obtained. The concentration process was performed to remove the solvent and obtain a more concentrated extract. Raspberry fruit (*Rubus rosifolius* Sm.) contains various bioactive constituents, including flavonoids, ellagic acid, anthocyanins, and other phenolic compounds, which have been reported to exhibit antibacterial activity against several pathogenic bacteria [11].

The extraction process produced 110 g of thick extract from 400 g of dried simplicia, corresponding to an extraction yield of 27.5%. This yield indicates that the extraction process was capable of recovering a considerable proportion of extractable components from the raspberry simplicia. However, extraction yield should not be interpreted solely as an indicator of extract quality or bioactive compound concentration. A higher yield may also result from the extraction of non-active components, such as sugars, organic acids, pigments, and other soluble constituents. Therefore, a high extraction yield does not necessarily indicate a higher concentration of antibacterial compounds or superior pharmacological activity.

The extraction yield is influenced by several factors, including solvent type and concentration, solvent-to-sample ratio, extraction duration, extraction temperature, particle size, and the chemical characteristics of the plant material [12]. The use of 96% ethanol in this study may have contributed to the relatively high yield because ethanol is capable of extracting compounds with a wide range of polarity,

particularly semipolar constituents. However, the solvent concentration also affects extraction selectivity. A solvent with a different water-to-ethanol proportion may produce a different yield because water can improve the swelling of plant tissues and facilitate the release of polar compounds, whereas ethanol can improve the solubilization of semipolar compounds.

The solvent-to-simplicia ratio of 1:10 (w/v) used in this study provided sufficient solvent volume to ensure adequate contact between the solvent and plant material. An increased solvent volume generally enhances the concentration gradient between the compounds in the plant matrix and the solvent, thereby supporting mass transfer and diffusion [13]. Nevertheless, an excessively high solvent ratio does not always result in a proportional increase in yield and may increase the amount of solvent required during the concentration process. The five-day extraction duration also provided sufficient time for the solvent to penetrate the plant matrix and dissolve extractable compounds. Longer extraction times may increase compound recovery; however, prolonged exposure may also promote oxidation or degradation of certain sensitive constituents.

Extraction temperature is another important factor affecting yield and extract quality. Maceration at room temperature minimizes the risk of thermal degradation of thermolabile compounds, particularly anthocyanins and some phenolic constituents. In contrast, higher extraction temperatures may accelerate diffusion and increase extraction efficiency but may also cause degradation of heat-sensitive compounds [14]. In this study, room-temperature maceration was therefore selected to maintain the stability of temperature-sensitive constituents, while the rotary evaporation process was conducted at 60°C to remove the solvent under controlled conditions.

Differences in extraction yield compared with previous studies may also be associated with the characteristics of the raw material, including plant species or variety, maturity stage, geographical origin, environmental conditions, moisture content, drying method, particle size, and the distribution of secondary metabolites in the plant tissue. Differences in these factors can affect the amount and type of compounds extracted. Therefore, the yield of 27.5% obtained in this study should be interpreted in relation to the extraction conditions and raw-material characteristics rather than being considered an absolute indicator of extract quality.

The thick extract obtained in this study was dark reddish-brown in color and had a characteristic raspberry odor, with a thick and sticky consistency. These organoleptic characteristics are consistent with the presence of concentrated pigments and other secondary metabolites extracted from the fruit. However, moisture content or loss on drying and

phytochemical screening were not performed in this study. Consequently, the presence and concentration of specific secondary metabolites were not directly confirmed through experimental screening. The discussion of flavonoids, phenolic compounds, anthocyanins, tannins, and ellagic acid in this study is therefore based on findings reported in previous studies rather than on direct phytochemical analysis of the extract produced in the present research.

3.2. Particle Size of Nanogel

Table 1. Particle Size of Nanogel Facial Cleanser Formulations

Formulation	Extract concentration (%)	Particle size (nm), mean $\pm$ SD
F0	-	881.13 $\pm$ 16.10
F1	0,5%	807.10 $\pm$ 5.55
F2	1%	896.83 $\pm$ 7.04
F3	2%	1086.00 $\pm$ 18.19

The particle size analysis was performed using a Particle Size Analyzer (PSA) to characterize the dispersed particle system in the nanogel facial cleanser formulations. The results are presented as mean $\pm$ standard deviation in Table 1. Formula F1 exhibited the smallest average particle size, measuring 807.10 $\pm$ 5.55 nm, followed by F0 at 881.13 $\pm$ 16.10 nm and F2 at 896.83 $\pm$ 7.04 nm. Formula F3 showed the largest average particle size, measuring 1086.00 $\pm$ 18.19 nm.

Although F0 did not contain raspberry fruit extract, it still contained the nanogel-forming components, including alginate, calcium chloride, and Carbopol. Therefore, the particle size detected in F0 represented the size of the dispersed colloidal or polymeric carrier system formed by the nanogel components, rather than the particle size of the raspberry fruit extract. Thus, F0 functioned as an extract-free carrier control for evaluating the particle characteristics of the base nanogel system.

F0, F1, and F2 showed average particle sizes below 1000 nm, whereas F3 exhibited an average particle size above 1000 nm. The increase in particle size observed in F2 and F3 may be associated with the increasing concentration of raspberry fruit extract incorporated into the nanogel system. A higher extract concentration increases the amount of dispersed material within the polymeric matrix and may intensify interactions between the extract constituents and the polymer network, thereby increasing the possibility of particle aggregation [15].

The larger particle size observed in F3 may indicate a reduction in dispersion efficiency at the highest extract concentration. This finding suggests that increasing the concentration of raspberry fruit extract does not always result in smaller particles, but may instead affect the physical organization and stability of the nanogel system. Therefore, particle size should be considered together with other physical characteristics when determining the most appropriate formulation.

3.3. Spreadability

The spreadability results of the nanogel facial cleanser formulations are presented in Table 2.

Table 2. Spreadability of Nanogel Facial Cleanser Formulations

Formulation	Spreadability (cm), Mean $\pm$ SD	Acceptance Criterion
F0	6.41 $\pm$ 0.17	5–7 cm
F1	5.73 $\pm$ 0.17	5–7 cm
F2	5.34 $\pm$ 0.14	5–7 cm
F3	5.03 $\pm$ 0.07	5–7 cm

The spreadability values decreased progressively with increasing raspberry extract concentration. Formula F0 showed the highest spreadability value of 6.41 $\pm$ 0.17 cm, followed by F1 at 5.73 $\pm$ 0.17 cm, F2 at 5.34 $\pm$ 0.14 cm, and F3 at 5.03 $\pm$ 0.07 cm. All formulations remained within the acceptance range of 5–7 cm, indicating that the preparations were still capable of spreading adequately over the skin surface.

The reduction in spreadability was associated with the increase in extract concentration and the corresponding increase in viscosity. The viscosity values increased from F0 to F3, indicating that the addition of a higher concentration of raspberry extract contributed to a thicker and more resistant formulation. A preparation with higher viscosity generally requires greater force to spread, resulting in a lower spreadability value. Therefore, the inverse relationship observed between viscosity and spreadability in this study is consistent with the physical behavior of semisolid and gel-based preparations [16].

The decrease in spreadability may also be related to the presence of additional solid and dissolved extract components within the formulation. Increasing the extract concentration can increase the internal resistance of the system and reduce the mobility of the formulation during the spreadability test. This effect was most apparent in F3, which contained the highest extract concentration and exhibited the highest viscosity as well as the lowest spreadability value.

Although F3 had the lowest spreadability, its value of 5.03 $\pm$ 0.07 cm was still within the specified acceptance range. This indicates that the addition of 2% raspberry extract did not cause the formulation to fall outside the acceptable spreadability criteria. Similar relationships have been reported in gel and facial cleanser formulations, in which an increase in polymer or active-ingredient concentration tends to increase viscosity and consequently decrease spreadability. Thus, the spreadability results obtained in this study demonstrate that the formulations maintained acceptable application characteristics despite the increase in raspberry extract concentration.

3.4. Adhesiveness

The adhesiveness results of the nanogel facial cleanser formulations are presented in Table 3.

Table 3. Adhesiveness of Nanogel Facial Cleanser Formulations

Formulation	Adhesiveness (Mean, s)	SD (s)
F0	96.40	0.16
F1	97.01	0.17
F2	97.31	0.13
F3	97.85	0.18

All formulations exhibited adhesiveness values above 4 s, indicating that the preparations fulfilled the acceptance criterion for topical semisolid preparations. The mean adhesiveness values were 96.40 ± 0.16 s for F0, 97.01 ± 0.17 s for F1, 97.31 ± 0.13 s for F2, and 97.85 ± 0.18 s for F3. The adhesiveness values tended to increase with increasing raspberry extract concentration, with F3 showing the highest adhesiveness value.

The increase in adhesiveness may be associated with the increase in formulation viscosity following the addition of raspberry extract. Carbopol 940 and sodium alginate function as gel-forming polymers that produce a cohesive three-dimensional network within the formulation. This network increases the resistance of the preparation to separation from the test surface, thereby increasing its adhesiveness. In addition, glycerin and propylene glycol may help maintain moisture within the system and support prolonged contact between the formulation and the surface.

The results indicate a relationship between viscosity and adhesiveness, in which an increase in viscosity tends to increase the ability of the preparation to adhere to a surface. A more viscous formulation generally requires more time or force to separate from the surface because of its greater internal cohesion. The trend observed in this study is consistent with the physical characteristics of gel-based topical preparations, in which increased polymer concentration or increased viscosity can improve adhesiveness and prolong contact time.

However, the interpretation of high adhesiveness should consider the intended use of the product. Unlike leave-on topical preparations, facial cleansers are rinse-off products that are applied for a relatively short period and subsequently removed with water. Therefore, high adhesiveness does not necessarily mean that the product must remain on the skin for a prolonged period. In the present formulation, adequate adhesiveness may help the cleanser remain in contact with the skin during the washing process and facilitate interaction with dirt, excess sebum, and the skin surface. Nevertheless, excessively high adhesiveness could potentially produce a sticky sensation or make the product more difficult to rinse off.

The adhesiveness values of all formulations remained relatively consistent throughout the four-week storage period, indicating that the formulations maintained their adhesive characteristics during storage. Since the adhesiveness test was evaluated descriptively, no inferential statistical analysis was performed for this

parameter. The results were interpreted based on the mean values, standard deviations, acceptance criteria, and changes observed during the storage period.

3.5. Foam Height

The foam height of each nanogel facial cleanser formulation during the storage period is presented in Table 4.

Table 4. Foam Height of Nanogel Facial Cleanser Formulations During Storage

Formulation	Foam Height During Storage (cm)	Mean $\pm$ SD (cm)
F0	4.5; 4.5; 4.4; 4.5	4.48 ± 0.05
F1	4.6; 4.7; 4.7; 4.8	4.70 ± 0.08
F2	4.8; 4.8; 4.9; 5.0	4.88 ± 0.10
F3	5.3; 5.5; 5.6; 5.6	5.50 ± 0.14

The mean foam heights were 4.48 ± 0.05 cm for F0, 4.70 ± 0.08 cm for F1, 4.88 ± 0.10 cm for F2, and 5.50 ± 0.14 cm for F3. The foam height showed a gradual increase with increasing raspberry extract concentration. However, the changes observed during storage were relatively small, indicating that all formulations maintained their foam-forming characteristics and demonstrated good physical foam stability throughout the four-week observation period.

The increase in foam height from F0 to F3 may be associated with changes in the physical characteristics of the formulation following the incorporation of raspberry extract nanogel. Nevertheless, the effect of the extract concentration was not considered the primary determinant of foam formation because the concentrations of the surfactants were kept constant in all formulations, namely 10% decyl glucoside and 5% cocamidopropyl betaine. Decyl glucoside contributes to foam formation, while cocamidopropyl betaine acts as a foam booster and foam stabilizer, helping maintain the foam structure during the evaluation [17].

It is important to emphasize that foam height reflects the volume and persistence of foam produced by the formulation, rather than directly representing its cleaning effectiveness. A higher foam volume does not necessarily indicate superior cleansing performance because cleaning ability is primarily influenced by surfactant type, concentration, micelle formation, and the ability to remove sebum, dirt, and other impurities from the skin surface. Therefore, although F3 produced the highest foam height, this result should be interpreted as an improvement in foaming characteristics and not as direct evidence of greater cleansing effectiveness. Overall, the four formulations maintained relatively stable foam heights during storage, and the addition of raspberry extract up to 2% did not negatively affect the foam-forming ability of the facial cleanser.

3.6. Viscosity

The viscosity results of the nanogel facial cleanser formulations are presented in Table 5.

Table 5. Viscosity of Nanogel Facial Cleanser Formulations

Formulation	Mean $\pm$ SD (cP)	Acceptance Criterion
F0	4440 $\pm$ 232.43	2,000–50,000 cP
F1	4820 $\pm$ 62.45	2,000–50,000 cP
F2	4920 $\pm$ 60.00	2,000–50,000 cP
F3	5165 $\pm$ 45.46	2,000–50,000 cP

The viscosity values increased with increasing raspberry extract concentration. The control formulation (F0) showed the lowest viscosity, at 4440 $\pm$ 232.43 cP, while F3 containing 2% extract showed the highest viscosity, at 5165 $\pm$ 45.46 cP. All formulations remained within the specified viscosity range for facial cleanser preparations.

The increase in viscosity may be related to the incorporation of the raspberry extract-containing nanogel into the facial cleanser system. The nanogel contains Carbopol 940, which forms a three-dimensional polymeric network capable of increasing the consistency of the preparation. In addition, the extract and other nanogel components may increase the total solid content and strengthen intermolecular interactions within the formulation, resulting in greater resistance to flow. The progressive increase from F0 to F3 indicates that the higher extract concentration contributed to an increase in the structural consistency of the preparation.

The viscosity results were inversely related to spreadability. As viscosity increased from F0 to F3, spreadability decreased from 6.41 $\pm$ 0.17 cm to 5.03 $\pm$ 0.07 cm. A more viscous preparation generally exhibits greater resistance to deformation and therefore spreads less easily under the same applied load. Nevertheless, all formulations remained within the acceptable spreadability range of 5–7 cm, although F3 was close to the lower limit.

In contrast, adhesiveness tended to increase along with viscosity. The mean adhesiveness values were 96.40 $\pm$ 0.16 s, 97.01 $\pm$ 0.17 s, 97.31 $\pm$ 0.13 s, and 97.85 $\pm$ 0.18 s for F0, F1, F2, and F3, respectively. The increase in viscosity may enhance the interaction between the preparation and the measurement surface, allowing the formulation to remain attached for a longer period. Thus, the increase in viscosity was associated with reduced spreadability but slightly improved adhesiveness. These findings indicate that the addition of raspberry extract-containing nanogel modified the rheological characteristics of the facial cleanser while maintaining the physical properties within the acceptable limits.

3.7. Antibacterial Activity

The antibacterial activity of the nanogel facial cleanser formulations against *Staphylococcus aureus* is presented in Table 6.

Table 6. Antibacterial Activity of Nanogel Facial Cleanser Formulations Against *Staphylococcus aureus*

Treatment Group	Inhibition Zone	Replicates (n)	Activity Classification
Negative control (DMSO)	0.00 $\pm$ 0.00	3	Weak
F0	4.83 $\pm$ 0.15	3	Moderate
Positive control	5.58 $\pm$ 0.08	3	Moderate
F1	6.38 $\pm$ 0.15	3	Moderate
F2	7.32 $\pm$ 0.10	3	Moderate
F3	8.05 $\pm$ 0.13 ^f	3	Strong

Values are presented as mean $\pm$ standard deviation (SD), n = 3. Different superscript letters indicate statistically significant differences between groups based on Tukey's post-hoc test ($p < 0.05$). The inhibition zones were measured in millimeters (mm). Activity classification was based on the inhibition-zone criteria reported by Davis and Stout (1971): weak activity = ≤ 5 mm, moderate activity = 5–10 mm, and strong activity = 10–20 mm.

The antibacterial activity increased with increasing raspberry extract concentration. F3 produced an inhibition zone of 8.05 $\pm$ 0.13 mm and showed the highest inhibition among the tested formulations. However, this inhibition zone remains within the moderate activity range according to the classification used and should not be interpreted as evidence of strong or fully effective antibacterial activity without an appropriate comparator.

The negative control showed no inhibition, confirming that DMSO did not contribute antibacterial activity under the test conditions. The positive control produced an inhibition zone of 5.58 $\pm$ 0.08 mm, whereas F1, F2, and F3 produced larger inhibition zones than the positive control. The statistical analysis showed a significant difference among treatments (one-way ANOVA, $p < 0.001$), and Tukey's post-hoc test indicated that each treatment group differed significantly from the others. The increasing inhibition zones may be associated with the higher concentration of bioactive compounds in the raspberry extract, including phenolic and flavonoid compounds, which may interfere with bacterial cell-wall integrity, membrane function, and intracellular processes [18].

Although F3 demonstrated the largest inhibition zone, its activity should be described cautiously as the formulation with the highest antibacterial inhibition among the tested formulations rather than simply being described as "effective." The result indicates a concentration-dependent trend, but the relatively limited inhibition zone suggests that further optimization may be required to improve antibacterial performance.

3.8. Statistical Analysis of Antibacterial Activity

The results of the one-way ANOVA for the antibacterial activity of the tested formulations are presented in Table 7.

Table 7. One-Way ANOVA Results for Antibacterial Activity

Source of Variation	df	F-value	Interpretation
Between groups	5	1833.493	Significant
Within groups	12	3.000	-
Total	17	3.000	-

One-way ANOVA was performed using IBM SPSS Statistics version 27. The result indicated a statistically significant difference in inhibition-zone diameter among the treatment groups ($F(5,12) = 1833.493$, $p < 0.001$).

The results of Tukey's HSD post-hoc test for pairwise comparisons among the treatment groups are presented in Table 8.

Table 8. Tukey HSD Post-Hoc Test Results for Antibacterial Activity

Treatment Group	Mean (mm)	Inhibition Zone	Tukey group
Negative control (DMSO)		0.00 ± 0.00	A
F0		4.83 ± 0.15	B
Positive control		5.58 ± 0.08	C
F1		6.38 ± 0.15	D
F2		7.32 ± 0.10	E
F3		8.05 ± 0.13	F

Values are expressed as mean $\pm$ SD, $n = 3$. Different superscript letters indicate significant differences between groups according to Tukey's HSD post-hoc test at $p < 0.05$. All pairwise comparisons between groups were statistically significant.

The one-way ANOVA demonstrated a statistically significant difference in inhibition-zone diameter among the six groups, with $F(5,12) = 1833.493$ and $p < 0.001$. However, this result only indicates that at least one group differed from another and does not independently establish that the increase was specifically caused by the extract concentration. Therefore, Tukey's HSD post-hoc test was conducted for pairwise comparisons.

The Tukey HSD results showed that all treatment groups differed significantly from one another ($p < 0.05$). The inhibition-zone diameter increased in the following order: negative control $<$ F0 $<$ positive control $<$ F1 $<$ F2 $<$ F3. F1, F2, and F3 produced significantly larger inhibition zones than F0, while F3 showed the highest inhibition among the tested formulations. The significant differences between F1, F2, and F3 indicate that increasing raspberry extract concentration was associated with a statistically significant increase in antibacterial inhibition under the experimental conditions.

Nevertheless, the inhibition zone produced by F3 was 8.05 ± 0.13 mm, which remains relatively limited in

magnitude. Therefore, F3 should be described as the formulation that showed the highest inhibition among the tested formulations rather than being categorically described as "effective." The statistical findings demonstrate a significant difference between formulations, but the magnitude of antibacterial activity should still be interpreted in relation to the inhibition-zone classification and the positive control.

4. Conclusion

The raspberry extract was successfully formulated into facial cleanser preparations at concentrations of 0.5%, 1%, and 2%. The formulations showed varying physical characteristics, including pH, viscosity, spreadability, adhesiveness, foam height, and particle size. Antibacterial activity against *Staphylococcus aureus* increased significantly with increasing extract concentration, with F3 producing the largest inhibition zone of 8.05 ± 0.13 mm.

However, F3 was not conclusively identified as the optimum formulation because it exhibited a particle size exceeding 1000 nm. Considering the balance between antibacterial activity and physical characteristics, F1 and F2 may be considered promising candidates for further optimization. Further studies involving formal stability testing, particle-size optimization, and safety evaluation are required.

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