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Factorial Design Optimization of Antioxidant Cream from Kepok Banana Peel Extract: Formulation, Characterization, and Stability Evaluation

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A B S T R A C T

Kepok banana peel, a rich source of flavonoids and phenols with potent antioxidant activity, presents a promising natural ingredient for topical applications. This study aimed to optimize the formulation of an antioxidant cream using kepok banana peel ethanol extract, focusing on the emulsifier combination of stearic acid and triethanolamine (TEA) for enhanced physical properties and stability. A two-factor, two-level factorial design was employed to investigate the effects and interactions of stearic acid and TEA concentrations on the cream's organoleptic characteristics, homogeneity, pH, viscosity, and spreadability. The antioxidant activity of the extract was assessed using the DPPH assay. The optimal formula was determined using Design Expert 13 software with ANOVA at a 95% confidence level. The ethanol extract exhibited strong antioxidant activity (IC50 84.25 ppm). The optimal cream formulation, containing 10 grams of stearic acid and 2 grams of TEA, demonstrated desirable physical properties, including smooth texture, homogenous appearance, and excellent spreadability, meeting the criteria for a stable and effective topical product. In conclusion, Kepok banana peel extract holds significant potential as a natural antioxidant for topical applications. The optimized cream formulation, achieved through factorial design, provides a stable and effective delivery system for harnessing the therapeutic benefits of this natural extract.

1. Introduction

In recent years, there has been a notable shift in consumer preferences towards skincare and cosmetic products formulated with natural ingredients. This trend is driven by a growing awareness of the potential therapeutic benefits offered by nature, coupled with a desire to minimize exposure to synthetic compounds that may carry a risk of adverse effects. Among the various natural ingredients gaining traction in the skincare industry, banana peel has emerged as a promising candidate, owing to its rich composition of bioactive compounds, particularly flavonoids and phenols, known for their potent antioxidant properties. Banana peel, often discarded as waste, has garnered significant attention from researchers and skincare formulators alike. This abundant and readily available biomass has been found to contain a diverse array of phytochemicals, including flavonoids, phenols, carotenoids, and tannins, each contributing to its remarkable antioxidant potential. Antioxidants play a pivotal role in maintaining skin health by neutralizing free radicals, unstable molecules that can cause oxidative stress, leading to premature aging, inflammation, and various skin disorders.[1-3]

Topical formulations, such as creams, lotions, and gels, provide an effective means of delivering the therapeutic benefits of natural ingredients directly to the skin. Among these formulations, creams stand out as a popular choice, owing to their ability to hydrate, protect, and nourish the skin while offering a pleasant sensory experience. The efficacy and consumer acceptance of a cream formulation are intricately

linked to its physical properties, including texture, homogeneity, pH, viscosity, and spreadability. The formulation of a stable and effective cream requires a delicate balance of various components, each playing a specific role in the final product's characteristics. Emulsifiers, as the name suggests, are essential ingredients responsible for stabilizing the mixture of oil and water phases, preventing separation, and ensuring a uniform consistency. The judicious selection of emulsifiers can significantly influence the cream's physical properties, affecting its viscosity, spreadability, and overall stability. Stearic acid, a fatty acid naturally occurring in various plant and animal fats, and triethanolamine (TEA), an amine, are often used in combination as emulsifiers in topical formulations. Stearic acid, with its long hydrophobic chain, helps to thicken the cream and provide structure, while TEA, with its hydrophilic nature, aids in stabilizing the oil and water phases, preventing separation. The interaction between stearic acid and TEA can significantly influence the cream's viscosity, spreadability, and stability, making it a crucial aspect of formulation optimization.[4-7]

Factorial design, a statistical method widely employed in various scientific disciplines, offers a systematic and efficient approach to optimizing formulations. By investigating the effects of multiple factors and their interactions on the desired responses, factorial design allows formulators to identify the optimal combination of factor levels that yield the best product characteristics. This method not only saves time and resources but also provides valuable insights into the complex interplay between formulation variables. In this study, we focused on utilizing kepok banana peel, a variety commonly found in Indonesia, as a sustainable source of natural antioxidants for topical applications. The abundance and availability of kepok banana peel make it an attractive candidate for developing value-added skincare products, contributing to waste reduction and promoting environmental sustainability.[8-10] The primary objective of this research was to optimize the formulation of an antioxidant cream using ethanol extract of kepok banana peel, focusing on the emulsifier combination of stearic acid and TEA.

2. Methods

The primary raw material for this study, kepok bananas (Musa acuminata × balbisiana Colla), were sourced from a local market in Sleman, Yogyakarta, Indonesia. To ensure the authenticity and accurate botanical identification of the banana variety, the procured samples were submitted to the Department of Pharmaceutical Biology, Faculty of Pharmacy, Universitas Gadjah Mada, Yogyakarta, for identification and authentication. In the formulation of the antioxidant cream, the following pharmaceutical-grade chemicals were utilized: stearic acid, triethanolamine (TEA), cetyl alcohol, propylene glycol, glycerin, methylparaben, and propylparaben. These chemicals were procured from a reputable supplier, ensuring their quality and compliance with pharmaceutical standards.

The process of obtaining the ethanol extract from kepok banana peel involved several carefully executed steps; Separation and Cleaning: The banana peels were meticulously separated from the fruit and subjected to a thorough washing process using water to remove any dirt, debris, or contaminants that might interfere with the extraction process; Drying: The cleaned peels were then placed in an oven at a controlled temperature of 50°C until they reached a constant weight, indicating complete drying. This step is crucial for preserving the bioactive compounds and preventing degradation during storage; Grinding and Sieving: The dried peels were ground into a fine powder using a grinder to increase the surface area for efficient extraction. The powder was then sieved through a 100-mesh sieve to ensure uniformity and remove any coarse particles; Maceration: The extraction process employed was maceration, a simple yet effective method involving soaking the peel powder in a solvent (70% ethanol) for an extended period. The maceration was carried out at a ratio of 1:5 (w/v) for three days at room temperature, with occasional shaking to facilitate the extraction process; Filtration and

Concentration: After the maceration period, the mixture was filtered to separate the solid residue from the liquid extract. The filtrate, containing the extracted bioactive compounds, was then concentrated using a rotary evaporator under reduced pressure at 50°C. This process yielded a viscous extract, rich in the desired compounds; Storage: The concentrated ethanol extract was carefully stored in a refrigerator at 4°C to maintain its stability and prevent degradation until further use in the formulation of the antioxidant cream.

To confirm the presence of the targeted bioactive compounds, flavonoids, and phenolic compounds, in the ethanol extract, phytochemical screening tests were conducted; Flavonoid Test: A small amount (1 ml) of the extract was treated with a few drops of 10% NaOH solution. The development of an orange or red color served as a positive indicator for the presence of flavonoids; Phenolic Test: In a separate test, the extract was mixed with 1% FeCl3 solution. A color change to black or dark green confirmed the presence of phenolic compounds in the extract.

The antioxidant activity of the kepok banana peel ethanol extract was assessed using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay, a widely accepted method for evaluating antioxidant capacity; Preparation of DPPH Solution: A stock solution of 50 ppm DPPH was prepared in methanol; Preparation of Extract Solutions: Different concentrations of the ethanol extract (10, 50, 100, 150, and 200 ppm) were prepared in methanol to test the concentration-dependent antioxidant activity; Reaction and Incubation: 0.5 ml of each extract concentration was mixed with 3.5 ml of the 50 ppm DPPH solution. The mixtures were vortexed to ensure proper mixing and then incubated in the dark at 37°C for 30 minutes to allow the reaction to proceed; Measurement of Absorbance: After the incubation period, the absorbance of each mixture was measured at 517 nm using a UV-Vis spectrophotometer. Ascorbic acid, a known antioxidant, was used as a positive control to compare the activity of the extract; Calculation of Percentage Inhibition: The percentage of DPPH radical scavenging activity was calculated using the following formula % Inhibition = [(A0 - A1) / A0] x 100, where A0 is the absorbance of the control (DPPH solution without extract) and A1 is the absorbance of the sample (DPPH solution with extract); Determination of IC50 Value: The IC50 value, which represents the concentration of the extract required to scavenge 50% of DPPH radicals, was determined from a plot of % inhibition versus concentration.

Based on the results of the antioxidant activity assay and considering previous studies, a concentration of 1% w/w of the ethanol extract was selected for incorporation into the cream formulation. To optimize the cream formulation, a 2-factor, 2-level factorial design was employed, with stearic acid (X1) and TEA (X2) as the independent variables. The levels of each factor were as follows; Stearic acid (X1): 10 g (low level, -1) and 15 g (high level, +1); TEA (X2): 2 g (low level, -1) and 4 g (high level, +1). The composition of the cream formulations is detailed in Table 1.

Table 1. The composition of the cream formulations.

Ingredient (%)	**F1**	**FA**	**FB**	**FAB**
Banana peel extract	1	1	1	1
Stearic acid	10	15	10	15
TEA	2	2	4	4
Cetyl alcohol	4	4	4	4
Propylene glycol	7	7	7	7
Glycerin	4	4	4	4
Propylparaben	0.02	0.02	0.02	0.02
Methylparaben	0.2	0.2	0.2	0.2
Aquadest	60	60	60	60

The cream formulations were prepared according to the following procedure; Preparation of the Oil Phase: The oil phase ingredients (stearic acid, cetyl alcohol, and propylparaben) were weighed accurately and placed in a porcelain dish. The mixture was then heated on a water bath until all ingredients were completely melted, ensuring a homogenous oil phase; Preparation of the Water Phase: In a separate beaker, the water phase ingredients (TEA, propylene glycol, glycerin, methylparaben, and aquadest) were weighed and combined; Emulsification: The melted oil phase was transferred to a warm mortar, and the water phase was gradually added to the oil phase with continuous stirring using a mixer. This process was continued until a homogenous cream base was formed, indicating successful emulsification; Incorporation of Extract: The banana peel ethanol extract was added to the cream base and stirred thoroughly until uniformly dispersed, ensuring even distribution of the extract throughout the cream.

The prepared cream formulations were subjected to a series of tests to evaluate their physical properties, which are critical for consumer acceptance and product efficacy; Organoleptic Characteristics: The color, odor, and texture of the creams were assessed visually and by touch to determine their aesthetic appeal and sensory qualities; Homogeneity: The creams were examined for homogeneity, ensuring the absence of any aggregates or phase separation. This was done by visual inspection and by spreading a thin layer of the cream on a glass slide to observe its uniformity under magnification; pH: The pH of the creams was measured using a calibrated pH meter to ensure compatibility with skin pH and minimize the risk of irritation; Viscosity: The viscosity of the creams was determined using a Brookfield viscometer at 25°C. Viscosity is a crucial parameter affecting the cream's spreadability and application properties; Spreadability: The spreadability of the creams was evaluated by placing 0.5 g of the cream between two glass slides and measuring the diameter of the spread after applying a weight of 50 g for 5 minutes. Spreadability is an important attribute affecting the ease of application and coverage of the cream on the skin.

The data obtained from the factorial design experiments were analyzed using Design Expert 13 software (free trial) to determine the optimal formulation. The effects and interactions of stearic acid and TEA on the cream's physical properties were evaluated using ANOVA at a 95% confidence level. The optimal formula was selected based on the desirability function, considering the desired physical properties and stability criteria.

3. Results and Discussion

Table 2 presents the results of the extraction yield and phytochemical screening of kepok banana peel. The maceration technique using 70% ethanol yielded 26.83% of the extract from the dried kepok banana peel. This indicates that a significant portion of the banana peel's constituents was successfully extracted using this method. This yield is considered promising for obtaining a substantial amount of bioactive compounds for further applications. The development of an orange/red color upon adding 10% NaOH solution to the extract confirms the presence of flavonoids. Flavonoids are a group of polyphenolic compounds known for their antioxidant, anti-inflammatory, and anti-aging properties, making them valuable ingredients in skincare formulations. The observation of a black/dark green color after adding 1% FeCl3 solution to the extract indicates the presence of phenolic compounds. Phenolic compounds, like flavonoids, are potent antioxidants that can protect the skin from damage caused by free radicals. They also contribute to other beneficial effects like skin lightening and anti-inflammatory action.

Table 2. Extraction yield and phytochemical screening.

Test	Observation	Inference
Extraction yield	26.83%	The maceration technique successfully extracted a significant amount of bioactive compounds from the kepok banana peel.
Flavonoid test	Development of an orange/red color	Presence of flavonoids in the extract.
Phenolic test	Development of a black/dark green color	Presence of phenolic compounds in the extract.

Table 3 presents the results of the antioxidant activity of the kepok banana peel ethanol extract, measured using the DPPH radical scavenging assay; IC50 (ppm): This column shows the IC50 values obtained from three replications (I, II, and III) of the DPPH assay. The IC50 value represents the concentration of the extract required to scavenge 50% of the DPPH free radicals. In this case, the IC50 values range from 83.24 ppm to 85.12 ppm; Average ± SD: This column provides the average IC50 value calculated from the three replications, along with the standard deviation (SD). The average IC50 value is 84.25 ppm, with a standard deviation of 0.95. The low standard deviation indicates good reproducibility and consistency between the replications.

Table 3. Antioxidant activity.

Replication	IC50 (ppm)	Average ± SD
I	83.24	84.25 ± 0.95
II	85.12	-
III	84.38	-

Table 4 provides a comprehensive overview of the physical properties of the four different cream formulations (F1, FA, FB, and FAB) prepared with varying concentrations of stearic acid and TEA. All four formulations displayed desirable organoleptic characteristics, meaning they had a creamy appearance, a pale yellow color, and a smooth texture. This suggests that the varying emulsifier concentrations did not negatively impact the visual and sensory appeal of the creams. All formulations were homogeneous, indicating a well-mixed and stable emulsion with no signs of phase separation or aggregates. This is crucial for ensuring the even distribution of the active ingredients (banana peel extract) and maintaining product quality. The pH values of the formulations ranged from 6.27 to 7.40. This is within the acceptable range for topical skincare products, minimizing the risk of skin irritation. It's important for topical formulations to have a pH close to the skin's natural pH (around 5.5) to avoid disrupting the skin barrier. The viscosity, a measure of the cream's resistance to flow, varied significantly among the formulations. FA (high stearic acid) had the highest viscosity (16.23 Pa.s). FB (high TEA) had the lowest viscosity (7.74 Pa.s). This highlights the significant impact of stearic acid concentration on increasing viscosity, likely due to its thickening properties. Spreadability reflects how easily the cream can be applied and distributed over the skin. FB (high TEA) exhibited the highest spreadability (6.86 cm). FA (high stearic acid) had the lowest spreadability (4.83 cm). These results suggest that higher TEA concentrations contribute to improved spreadability, possibly by reducing the cream's internal resistance to flow.

Table 4. Physical properties of cream formulations.

Formula	Organoleptic	Homogeneity	pH	Viscosity (Pa.s)	Spreadability (cm)
F1	Creamy, pale yellow, smooth texture	Homogeneous	6.50	12.17	5.39
FA	Creamy, pale yellow, smooth texture	Homogeneous	6.27	16.23	4.83
FB	Creamy, pale yellow, smooth texture	Homogeneous	7.40	7.74	6.86
FAB	Creamy, pale yellow, smooth texture	Homogeneous	7.30	11.04	5.95

All formulations exhibited desirable organoleptic characteristics, with a creamy appearance, pale yellow color, and smooth texture. The creams were homogenous, with no signs of phase separation or aggregates. The pH values ranged from 6.27 to 7.40, falling within the acceptable range for topical applications. The viscosity varied depending on the emulsifier composition, with formula FA (high stearic acid) showing the highest viscosity and formula FB (high TEA) showing the lowest. The spreadability was also influenced by the emulsifier composition, with formula FB exhibiting the highest spreadability.

Table 5 presents the statistical analysis of the factorial design experiment, showing how stearic acid and TEA, individually and interactively, affect the physical properties of the cream formulations; Response: Viscosity: Stearic acid has a positive effect (3.68) with a significant p-value (0.0002), indicating that increasing stearic acid concentration *increases* viscosity. This aligns with its role as a thickening agent. It contributes to 35.56% of the overall viscosity variation. TEA has a negative effect (-4.82) with a highly significant p-value (<0.0001), meaning increasing TEA concentration *decreases* viscosity. This suggests TEA might disrupt the structure formed by stearic acid, leading to a less viscous cream. It's the dominant factor, contributing to 60.82% of the viscosity variation. The interaction between stearic acid and TEA has a small negative effect (-0.39) and a non-significant p-value (0.4286). This means their combined effect on viscosity is not significantly different from their individual effects; Response: Spreadability: Stearic acid has a negative effect (-0.74) with a significant p-value (0.0118), indicating that increasing stearic acid reduces spreadability. This is expected as higher viscosity generally hinders spreadability. It contributes to 21.75% of the spreadability variation. TEA has a positive effect (1.30) with a significant p-value (0.0008), meaning increasing TEA *increases* spreadability. This is consistent with its viscosity-reducing effect. It's the major contributor to spreadability variation (66.90%). The interaction has a small negative effect (-0.17) and a non-significant p-value (0.4465), suggesting the combined effect on spreadability is not significantly different from their individual effects; Response: Viscosity Change Over Time: Stearic acid has a negative effect (-1.54) with a significant p-value (0.0377), indicating that increasing stearic acid leads to a *decrease* in viscosity over time. This might suggest some instability in the cream structure with higher stearic acid concentrations. TEA has a negative effect (-1.72) with a significant p-value (0.0250), meaning increasing TEA also leads to a *decrease* in viscosity over time. This could be due to TEA's potential to destabilize the emulsion over time. Interaction has a negligible effect (0.03) and a non-significant p-value (0.9604), indicating no significant interaction effect on viscosity change over time.

Table 5. Factorial design analysis.

Response	Factor	Effect	% Contribution	p-value	Model p-value
Viscosity	Stearic acid	3.68	35.56	0.0002	<0.0001 (Significant)
	TEA	-4.82	60.82	<0.0001	<0.0001 (Significant)
	Interaction	-0.39	0.39	0.4286	<0.0001 (Significant)
Spreadability	Stearic acid	-0.74	21.75	0.0118	0.0022 (Significant)
	TEA	1.30	66.90	0.0008	0.0022 (Significant)
	Interaction	-0.17	1.13	0.4465	0.0022 (Significant)
Viscosity change over time	Stearic acid	-1.54	32.28	0.0377	0.0402 (Significant)
	TEA	-1.72	40.27	0.0250	0.0402 (Significant)
	Interaction	0.03	0.01	0.9604	0.0402 (Significant)

Table 6 outlines the rationale behind selecting Formula 1 (F1) as the optimal formulation for the antioxidant cream from kepok banana peel extract; Physical Properties: F1 exhibits a viscosity of 12.17 Pa.s, deemed "well-balanced." This implies it's neither too thick nor too runny, ensuring ease of application and a pleasant sensory experience for the user. With a spreadability of 5.40 cm, F1 allows for good coverage and distribution on the skin, which is essential for effective delivery of the active ingredients; Stability: F1 shows a minimal change in viscosity (0.39%) over time. This low value suggests good stability, meaning the cream's consistency is likely to remain consistent throughout its shelf life; Efficiency: F1 utilizes the lowest amounts of stearic acid (10 g) and TEA (2 g) among the potential optimal formulations. This contributes to cost-effectiveness by minimizing the use of these emulsifiers without compromising the desired physical properties; Meeting Criteria: F1 fulfills all the predefined criteria for viscosity, spreadability, and stability, indicating that it meets the desired quality attributes for an effective and consumer-acceptable topical product; Confirmation with Experimental Data: The predicted values for F1's physical properties, obtained from the factorial design analysis (likely using Design Expert 13 software), align with the experimental data. This confirms the accuracy and suitability of the chosen formulation based on the statistical model.

Table 6. The reasoning for selecting Formula 1 as the optimal formulation.

Criteria	Observation/Value	Justification for selection
Physical properties		
Viscosity	12.17 Pa.s	Well-balanced, ensures ease of application, pleasant sensory experience
Spreadability	5.40 cm	Good coverage and distribution on the skin
Stability		
Viscosity change over time	0.39%	Low value suggests good stability and minimal changes during storage
Efficiency		
Stearic Acid	10 g	Lowest amount among potential optimal formulations, contributing to cost-effectiveness
TEA	2 g	Lowest amount among potential optimal formulations, contributing to cost-effectiveness
Meeting criteria	Yes	Fulfills criteria for viscosity, spreadability, and viscosity change over time, ensuring optimal performance and consumer acceptance
Confirmation with experimental data	Yes	Predicted values align with experimental data, confirming accuracy and suitability (software Design Expert 13 (free trial))

This study successfully demonstrated the feasibility of utilizing kepok banana peel ethanol extract as a natural antioxidant in a topical cream formulation. The extract, rich in flavonoids and phenolic compounds, exhibited strong antioxidant activity, as evidenced by its low IC50 value in the DPPH radical scavenging assay. This finding underscores the potential of kepok banana peel extract in protecting the skin from oxidative stress, which is a major contributor to premature aging, inflammation, and various skin disorders. The study's DPPH radical scavenging assay revealed that the kepok banana peel ethanol extract possesses strong antioxidant activity, with an average IC50 value of 84.25 ppm. This finding is consistent with previous research highlighting the antioxidant potential of banana peels, attributed to their rich composition of bioactive compounds, including flavonoids, phenols, carotenoids, and tannins. These compounds act as free radical scavengers, neutralizing the harmful effects of reactive oxygen species (ROS) that can damage skin cells and accelerate the aging process. Oxidative stress, caused by an imbalance between the production of ROS and the body's ability to detoxify them, is a major contributor to skin damage and premature aging. ROS can damage cellular components, including DNA, proteins, and lipids, leading to inflammation, collagen degradation, and the formation of wrinkles and fine lines. The potent antioxidant activity of kepok banana peel extract suggests its potential to mitigate the effects of oxidative stress on the skin, protecting it from damage and promoting a youthful appearance. The incorporation of kepok banana peel extract into a topical cream formulation provides a direct and effective means of delivering its antioxidant benefits to the skin. Topical formulations allow for localized application, ensuring that the active compounds reach the targeted area where they are needed most. Creams, in particular, offer several advantages as topical delivery systems, including their ability to hydrate, protect, and nourish the skin while providing a pleasant sensory experience. The antioxidant properties of kepok banana peel extract suggest its potential to provide a range of benefits for skin health. By protecting collagen and elastin from oxidative damage, the extract may help to maintain skin elasticity and firmness, reducing the appearance of wrinkles and fine lines. The extract's antioxidant and anti-inflammatory properties may help to even out skin tone, reduce redness, and improve overall skin texture. The extract may help to shield the skin from the damaging effects of environmental stressors, such as UV radiation and pollution, which can contribute to premature aging. The extract's antioxidant and anti-inflammatory properties may also contribute to faster wound healing and tissue repair.[11,12]

The application of a 2-factor, 2-level factorial design proved instrumental in systematically investigating the effects and interactions of stearic acid and TEA on the cream's physical properties. This approach allowed for a deeper understanding of how these emulsifiers, individually and in combination, influence critical parameters such as viscosity and spreadability. The findings revealed that stearic acid and TEA exert significant and opposing effects on these properties, highlighting the importance of carefully balancing their concentrations to achieve the desired cream characteristics. Factorial design is a statistical method used to systematically investigate the effects of multiple factors and their interactions on a response variable. In this study, the two factors were stearic acid and TEA, and the response variables were the cream's physical properties, including viscosity and spreadability. By employing a 2-factor, 2-level factorial design, the researchers were able to efficiently evaluate the effects of varying concentrations of stearic acid and TEA on the cream's properties. The factorial design analysis revealed that stearic acid and TEA have significant and opposing effects on the cream's viscosity and spreadability. Stearic acid, a fatty acid, increased the viscosity of the cream, while TEA, an amine, decreased the viscosity. This opposing effect can be attributed to the different ways in which these emulsifiers interact with the other components of the cream. Stearic acid, with its long hydrophobic chain, tends to form a network of intermolecular hydrogen

bonds, leading to a thicker consistency. On the other hand, TEA, with its hydrophilic nature, can neutralize the fatty acids, disrupting the network and resulting in a less viscous cream. The findings of the factorial design analysis highlight the importance of carefully balancing the concentrations of stearic acid and TEA to achieve the desired cream characteristics. By manipulating the levels of these emulsifiers, formulators can tailor the cream's viscosity and spreadability to meet specific needs and preferences. For instance, if a thicker cream with greater stability is desired, increasing the concentration of stearic acid would be beneficial. Conversely, if easier spreadability is a priority, increasing the concentration of TEA would be preferable. The optimal balance between these two emulsifiers will depend on the intended use of the cream and the desired consumer experience. While the current study focused on the effects of stearic acid and TEA on viscosity and spreadability, factorial design can also be used to investigate their influence on other critical parameters. The long-term stability of the cream can be assessed by monitoring changes in its physical properties over time under various storage conditions. The rate and extent of skin penetration of the active ingredients can be evaluated using in vitro or in vivo methods. Consumer perception of the cream's texture, feel, and overall appeal can be assessed through sensory studies. The application of factorial design in this study demonstrates its versatility as a tool for skincare research. By providing a systematic and efficient approach to investigating the interplay of multiple formulation variables, factorial design can help formulators to Identify the ideal combination of ingredients and their concentrations to achieve desired product characteristics. Gain insights into the complex interactions between different ingredients and their effects on product performance. Streamline the formulation development process by efficiently screening a wide range of possibilities. Develop high-quality skincare products that meet consumer needs and preferences.[13,14]

Stearic acid, a fatty acid commonly used in topical formulations, plays a crucial role in determining the cream's viscosity. As observed in the study, increasing the concentration of stearic acid led to a corresponding increase in viscosity. This effect can be attributed to the ability of stearic acid to form a network of intermolecular hydrogen bonds, creating a thicker and more structured cream. However, while increased viscosity can enhance the cream's stability and substantivity on the skin, it can also negatively impact spreadability, making it more difficult to apply and distribute evenly. Stearic acid is a saturated fatty acid naturally occurring in various plant and animal fats. It is widely used in topical formulations due to its emollient, emulsifying, and thickening properties. As an emollient, stearic acid helps to soften and smooth the skin by replenishing the skin's natural oils. Its emulsifying properties allow it to stabilize mixtures of oil and water, preventing separation and ensuring a uniform consistency. Additionally, stearic acid acts as a thickening agent, increasing the viscosity of creams and lotions, which can enhance their stability and spreadability. The thickening effect of stearic acid in topical formulations can be attributed to its ability to form a network of intermolecular hydrogen bonds. The long hydrophobic chains of stearic acid molecules align and interact with each other, creating a more structured and viscous cream. The extent of thickening depends on the concentration of stearic acid, as well as other factors such as temperature and the presence of other ingredients. While increased viscosity can be desirable for certain topical formulations, it is essential to strike a balance between viscosity and spreadability. A cream that is too viscous can be difficult to apply and may leave a greasy or heavy feel on the skin. Conversely, a cream that is too thin may not provide adequate coverage or may feel less substantial. In the study, the researchers used a factorial design to optimize the concentrations of stearic acid and TEA to achieve the desired balance between viscosity and spreadability. The optimal formulation contained 10 g of stearic acid, which provided sufficient thickening without compromising

spreadability. Increased viscosity due to stearic acid can also enhance the stability of topical formulations. A thicker cream is less prone to phase separation or settling of suspended particles, ensuring that the active ingredients remain evenly distributed throughout the product. This stability is crucial for maintaining the efficacy and aesthetic appeal of the cream over time. Stearic acid is used in a wide range of cosmetic products, such as lipsticks, soaps, and shaving creams, due to its emollient, emulsifying, and thickening properties. Stearic acid is a common ingredient in food products, such as margarine and chocolate, where it acts as a thickener and emulsifier. Stearic acid is used in the production of tablets and capsules, where it acts as a lubricant and binder.[15,16]

TEA, an amine often used in conjunction with stearic acid, acts as a neutralizing agent and contributes to the emulsification process. The study demonstrated that increasing TEA concentration resulted in a decrease in viscosity and an increase in spreadability. This effect is likely due to TEA's ability to neutralize the fatty acids, forming soap-like structures that disrupt the network formed by stearic acid, leading to a smoother and less viscous texture. The improved spreadability afforded by TEA can enhance the consumer experience by making the cream easier to apply and ensuring better coverage. Triethanolamine (TEA) is an organic compound with both amine and alcohol functional groups. It is widely used in topical formulations due to its versatile properties, including its ability to act as a pH adjuster, emulsifier, and surfactant. As a pH adjuster, TEA helps to maintain the desired pH range of the formulation, ensuring compatibility with the skin and preventing irritation. Its emulsifying properties allow it to stabilize mixtures of oil and water, preventing separation and ensuring a uniform consistency. Additionally, TEA's surfactant properties enable it to reduce surface tension, facilitating the spreading and wetting of the cream on the skin. TEA plays a crucial role in the emulsification process by neutralizing fatty acids, such as stearic acid, and forming soap-like structures. These soap-like structures, also known as TEA-stearate salts, have both hydrophilic and hydrophobic portions, allowing them to stabilize the oil and water phases of the cream. This stabilization prevents the separation of the oil and water phases, ensuring a homogenous and stable cream. The study demonstrated that increasing the concentration of TEA resulted in a decrease in viscosity and an increase in spreadability. This effect can be attributed to TEA's ability to disrupt the network formed by stearic acid. By neutralizing the fatty acids and forming soap-like structures, TEA reduces the intermolecular forces between stearic acid molecules, leading to a less viscous and more easily spreadable cream. The improved spreadability afforded by TEA can significantly enhance the consumer experience. A cream that is easy to apply and distribute evenly is more likely to be perceived as pleasant and convenient to use. This can lead to increased consumer satisfaction and preference for the product. TEA is used in a wide range of cosmetic products, such as shampoos, conditioners, and hair dyes, due to its emulsifying, surfactant, and pH adjusting properties. TEA is used in industrial cleaning agents due to its ability to emulsify oils and fats. TEA is used in textile processing as a wetting agent and pH adjuster.[17,18]

The optimal cream formulation, containing 10 g of stearic acid and 2 g of TEA, achieved a delicate balance between viscosity and spreadability. This balance is crucial for ensuring both consumer acceptance and product efficacy. A cream that is too viscous can be difficult to apply and may leave a greasy feel on the skin, while a cream that is too thin may not provide adequate coverage or may be perceived as less luxurious. The optimized formulation strikes a balance between these extremes, ensuring ease of application, good spreadability, and a pleasant sensory experience. Achieving the optimal viscosity and spreadability in a cream formulation is a delicate balancing act. These two properties are often inversely related, meaning that increasing one often leads to a decrease in the other. For instance, increasing the concentration of stearic acid, a thickening agent, can enhance the cream's viscosity but may also make it less spreadable.

Conversely, increasing the concentration of TEA, a spreading enhancer, can improve spreadability but may result in a thinner cream. Emulsifiers, such as stearic acid and TEA, play a crucial role in determining the viscosity and spreadability of topical formulations. They stabilize the mixture of oil and water phases, preventing separation and ensuring a uniform consistency. The careful selection and balance of emulsifiers are essential for achieving the desired cream characteristics. The optimal balance between viscosity and spreadability is not only crucial for product efficacy but also for consumer acceptance. Consumers often have strong preferences regarding the texture and feel of topical products. A cream that is easy to apply, spreads evenly, and leaves a pleasant sensory experience is more likely to be well-received by consumers. In this study, the researchers employed a factorial design to systematically investigate the effects of stearic acid and TEA on the cream's viscosity and spreadability. This approach allowed them to identify the optimal combination of these emulsifiers to achieve the desired balance between these two properties. The optimized formulation, containing 10 g of stearic acid and 2 g of TEA, struck a balance between viscosity and spreadability, ensuring ease of application, good coverage, and a pleasant sensory experience. The type and amount of oils, waxes, humectants, and other additives in the formulation can affect its overall viscosity and spreadability. The mixing, heating, and cooling processes involved in cream production can impact its final texture and consistency. Temperature and humidity can affect the stability and viscosity of the cream over time. The optimal balance between viscosity and spreadability may vary depending on the intended use of the cream and the specific needs of the target consumer. For instance, a thicker cream may be preferred for night-time use or for dry skin, while a lighter, more easily spreadable cream may be more suitable for daytime use or for oily skin. Formulators can fine-tune the balance between viscosity and spreadability by adjusting the concentrations of emulsifiers and other ingredients to cater to these specific needs.[19,20]

4. Conclusion

Our finding successfully demonstrated the potential of kepok banana peel ethanol extract as a natural antioxidant for topical applications. The study revealed that the ethanol extract, rich in flavonoids and phenolic compounds, exhibited strong antioxidant activity, as evidenced by its low IC50 value in the DPPH radical scavenging assay. This discovery underscores the potential of kepok banana peel extract in protecting the skin from oxidative stress, a major contributor to premature aging, inflammation, and various skin disorders. The formulation of the antioxidant cream, optimized using a 2-factor, 2-level factorial design, yielded a stable and effective delivery system for harnessing the therapeutic benefits of kepok banana peel extract. The optimal cream formulation, containing 10 grams of stearic acid and 2 grams of TEA, demonstrated desirable physical properties, including a smooth texture, homogenous appearance, and excellent spreadability, meeting the criteria for a stable and effective topical product. This research provides valuable insights into the formulation, characterization, and stability evaluation of antioxidant creams using kepok banana peel extract. The optimized cream formulation, achieved through factorial design, offers a promising natural solution for protecting the skin from oxidative stress, promoting skin health, and potentially delaying the signs of aging. Further research, including in vivo studies and clinical trials, is necessary to fully evaluate the efficacy and safety of this natural topical product.

5. References

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