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OPTIMIZATION AND CHARACTERIZATION OF SNAIL MUCUS (*Achatina fulica*) PEEL-OFF GEL USING FACTORIAL DESIGN METHOD

Dwi Asih Ramadhani[1], Aji Winanta[1], Indra Putra Taufani[1]

[1]Department of Pharmacy, Faculty of Medicine and Health Science, Universitas Muhammadiyah Yogyakarta, Daerah Istimewa Yogyakarta, Indonesia, 55183.

dwi.asih@umy.ac.id

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ABSTRACT

Indonesia, a tropical country characterized by year-round sun exposure, faces increasing demand for innovative cosmetic formulations with stable and acceptable physicochemical properties. This study aimed to optimize the formulation of a snail mucus peel-off gel mask using a 2^2 factorial design approach. A peel-off gel snail mask containing 9% snail mucus combined with polyvinyl alcohol (PVA) and sodium carboxymethyl cellulose (CMC-Na) as gelling agents was developed and evaluated. The physical properties of the peel-off gel snail mask were evaluated through organoleptic observations, stickiness tests, spread ability assessments, drying speed measurements, viscosity analysis and pH determination. Subsequently, contour plots were generated and superimposed to delineate the feasible formulation region. Two formulations located within the feasible region were identified: F1 (4.25% CMC-Na and 14.89% PVA) and F2 (4.5% CMC-Na and 14.61% PVA). Rather than representing a single absolute optimum, these formulations exhibited different performance characteristics within the defined optimization constraints. Further investigation into the gelling agents indicated that CMC-Na significantly influenced stickiness and spread ability, while PVA primarily affected viscosity. Drying speed was influenced by the interaction between both polymers. The factorial design approach successfully defined a formulation space that satisfies predefined physicochemical criteria for peel-off gel masks, providing a rational basis for further formulation refinement.

Keywords: Peel-off gel mask; snail mucus; CMC-Na; PVA; factorial design

1. INTRODUCTION

Indonesia is a country that has a tropical climate with exposure to sunlight throughout the season. Sunlight emitted at a wavelength of 200-400 nm is called ultraviolet (UV) light (Delorme et al., 2020). UV light is defined as radiation emitted in the region of electromagnetic spectrum (EM) at wavelengths between 100-400 nm. It is categorized into three types: UVA (315-400 nm), UVB (280-315 nm), and UVC (100-280 nm) (Darré et al., 2022). UV rays play a crucial role in

human health, particularly in synthesizing vitamin D, which is essential for various bodily functions (Fauziyyah et al., 2023). Additionally, UV radiation has antimicrobial properties, making it effective in killing bacteria (Fauziyyah et al., 2023). Despite its benefits, prolonged exposure to UV radiation can lead to significant health risks including cell membranes damage, sunburn, skin aging, cellular mutations that may result in skin cancer and melanoma, then prolonged exposure can cause pigmentation changes, dry skin, and dullness (Fauziyyah et al., 2023; Fendy Wellen et al., 2023). UV radiation is known to cause immediate effects such as sunburn and delayed effects like photoaging, which includes the development of black spots and dry skin (Chng et al., 2021). Therefore, facial skin care is needed to minimize the risks that occur due to exposure to UV rays.

A widely recognized facial treatment that has gained popularity in recent years is the peel-off gel mask. The benefits of peel-off gel masks including their ability to relax facial muscles, clean, refresh, moisturize, and soften the skin (Rahmawanty et al., 2015). A peel-off gel mask is a cosmetic product applied to the skin that dries to create a film layer, which can be removed after use (Rahmawanty et al., 2015). These masks can enhance skin hydration and boost the effectiveness of active ingredients on the epithelial layer due to the occlusive nature of the polymer film created (Apriani et al., 2022). This research aims to develop a peel-off gel mask incorporating snail mucus as its active ingredient. The formulation of this snail mucus peel-off gel mask requires effective gelling agents, specifically Polyvinyl Alcohol (PVA) and Carboxymethylcellulose Sodium (CMC-Na). The use of Polyvinyl Alcohol (PVA) as a gelling agent is noted for forming an elastic and strong peel-off layer, which adheres well to the skin and dries easily without additional ingredients (Rahmawanty et al., 2015). CMC-Na is mentioned as a cost-effective and stable gelling agent compared to other materials like carrageenan and starch (Astri Sulastri, 2016). The use of snail mucus *(Achatina fulica)* as the active substance in this peel-off gel mask is because snail mucus contains the Allantoin compound which functions as a moisturizer for the face (Shaliz Aflatooni et al., 2023).

In previous research on the Optimization of PVA and CMC-Na Base Concentration on Snail Slime Peel-off Gel Formulation conducted by Dessy Ratnasari (2017), the study identified the dominant role of PVA in influencing physical characteristics of the formulation. However, the study did not obtain a superimposed contour plot, and therefore the optimal formulation region and feasible design space were not clearly established. The absence of a validated design space limited the predictive capability and reproducibility of the formulation process**.** Therefore, the present study applies a 2^2 factorial design approach to systematically evaluate the main and interaction effects between PVA and CMC-Na concentrations. Unlike the previous work, this study generates regression models, contour plots, and a superimposed contour plot to define a feasible formulation region (design space) based on predefined physicochemical criteria. This approach allows the identification of formulations that satisfy multiple response constraints simultaneously. By establishing a mathematically supported optimization framework and defining a reproducible design space, this study provides a methodological advancement in peel-off gel formulation development beyond simple base comparison.

2. METHODS

This study involves experimental research conducted at the G2 Pharmaceutical Technology Laboratory on the second floor of UMY, as well as the Taxonomy Laboratory for Animals at the Faculty of Biology UGM, the animals utilized in this study were snails. Snail mucus was collected from adult *Achatina fulica* using a non-invasive stimulation technique that did not injure, harm, or sacrifice the animals. The snails were kept in a sanitary controlled environment and returned unharmed after use. Ethical approval was obtained from the Ethics Committee of Universitas Muhammadiyah Yogyakarta (No. 016/EC-EXEM-KEPK FKIK UMY/XI/2019) to ensure compliance with animal welfare standards. Although *Achatina fulica* is an invertebrate species,

ethical clearance was obtained to ensure compliance with institutional animal welfare standards and humane handling procedures.

The research employs a two-factor factorial design, examining two factors: the concentration of CMC-Na and the concentration of PVA, each assessed at both high and low levels. Optimization of the formulation was achieved through factorial design analysis, resulting in regression modeling, contour plots, and a superimposed contour plot to identify the feasible formulation region. Based on the optimized design space, a series of physicochemical evaluations were conducted. The physical properties tests include assessments of spread ability, adhesion, viscosity, drying speed, organoleptic assessment and pH measurement. No in vivo or human subject testing was conducted in the present study.

The study was conducted under controlled laboratory conditions (temperature 25±2°C; humidity 60±5%). The finalized formulations used for physicochemical evaluation were freshly prepared and stored at ambient laboratory conditions (25 ± 2°C, protected from direct sunlight) prior to testing. Formal long-term stability testing was not included in the scope of this study.

Tools

Digital scale (Mettler Toledo®), label paper, parchment paper, 25 ml, 50 ml, 250 ml and 500 ml beakers (Iwaki pyrex®), handscoon, perforated jar, spatula, mortar and pestle, glass plate, 50 ml and 60 ml ointment pots, viscometer (VT-04 E), pH meter (mettler Toledo®), Digital Skin Moisture Oil Tester (Pinpoint Water-Oil Balance, RoHs SG-5D).

Materials

Snail slime (Achatina fulica), gel bases are PVA (Brataco®) and CMC-Na (Brataco®), gel preservatives use Propyl paraben (Brataco®), Methyl Paraben (Brataco®), humectants/gelling agents are Propylene glycol (Brataco®), aquadest (Brataco®).

3. RESULTS AND DISCUSSION

3.1. Determination of Snail

Snails in this study were obtained from Kasihan District, Bantul, Yogyakarta. Then snail determination is carried out in Animal Systematics Laboratory Faculty of Biology, UGM (Number of Snail Determination Certificate: BI/SH/50/IX/2019). The results of this determination stated that the snails obtained are in accordance with the materials the main thing to be used on this research is a species of snail (*Achatina fulica*).

3.2. Preparation of Snail Mucus

Physical stimuli such as rotation and shock are applied to the snails to extract the mucus. The mucus is then collected using a substantial amount of water, followed by filtration and centrifugation to remove various contaminants. This method was selected because, according to it does not harm the snails or compromise the therapeutic properties of the mucus. The preparation of extract snail mucus, begin by selecting healthy snails and thoroughly cleaning them with water to remove surface contaminants. Next, place the snails in a controlled environment were physical stimuli, such as manual rotation, can be applied to encourage mucus secretion. Add a substantial amount of clean water (0.5 liters per kilogram of snails) to the container and allow the snails to secrete mucus for 10 to 30 minutes. After collecting, filter the mucus solution using fine filter paper or sterilizing filters (0.25-micron) to eliminate larger impurities and microorganisms. Then, centrifuge the filtered solution at high speeds (8000 rpm for 12 minutes) to separate the clearer supernatant from any remaining solids. Finally, store the purified mucus in cold-resistant containers at temperatures between -15°C and -18°C for preservation. According to Palyukha A. S (2017), physical stimuli like rotation and shock are applied to snails to extract mucus, which is then collected with water and purified through filtration and centrifugation, is the best method to preserve the snails' well-being and the therapeutic properties of the mucus.

3.3. Formulation of Snail Mucus Peel-off Gel Mask

In this study, the determination of optimal response ranges was guided not only by mathematical contour plot intersections but also by literature-based acceptability criteria and practical formulation performance requirements for peel-off gel systems. The formulation of the gel mask was developed through a detailed analysis of mathematical equations derived from contour plots generated during various tests conducted in Dessy Ratnasari, (2017). The study of Dessy Ratnasari, (2017) demonstrated that a peel-off gel mask containing 9% snail mucus significantly enhanced skin moisture levels in five respondents. Additionally, the concentration of the PVA base (10% and 15%) was identified as the key factor influencing spread ability, drying speed, and viscosity, whereas the CMC-Na concentration (3% and 6%) predominantly affected adhesiveness. However, no optimal region, represented by a superimposed contour plot, was identified by Dessy Ratnasari, (2017). The following equations from Dessy Ratnasari's contour plot analysis summarize in **Table 1** of the physical property tests for the peel-off gel mask.

Table 1. Mathematical Equations of Dessy Ratnasari (2017)

Physical Properties	Mathematical Equations
Spread ability	Y= 7,409 -0,203 X1-0,121 X2 + 0,007 X1X2
Adhesiveness	Y= -32,8 + 1,24 X1+ 2,52 X2 + 0,292 X1X2
Drying Speed	Y= 135,69 -11,40X1-6,46 X2 + 0,67 X1X2
Viscosity	Y=210,11-203,37X1-34,01X2 + 26,67 X1X2

This optimization uses a factorial design method with 2 factors and 2 levels. So, the number of formulas made is (2^n), 2 is the level and n is the factor. The factors under investigation were CMC – Na and PVA. Therefore, the formulas made are 4 formulas. The composition of each formulation is presented in **Table 2**. .

Table 2. Formula of Snail Mucus Peel-off Gel Mask

Ingredients	Formula				Information
	F1	F2	F3	F4	
Snail Mucus	9%	9%	9%	9%	Active substance
CMC-Na	4.25%	4.5%	4.5%	4.25%	Basis, thickening agent
PVA	14.89%	14.61%	14.89%	14.61%	Basis, peeling agent
Methyl paraben	0.2%	0.2%	0.2%	0.2%	Preservatives
Propyl paraben	0.1%	0.1%	0.1%	0.1%	Preservatives
Propylene glycol	12%	12%	12%	12%	Humectant
Aquadest add	100	100	100	100	Solvent

Information:
F1: low CMC-Na concentration – high PVA concentration
F2: high CMC-Na concentration – low PVA concentration
F3: high CMC-Na concentration – high PVA concentration
F4: low CMC-Na concentration – low PVA concentration

From the four formulas, an evaluation of the spread ability, adhesiveness, drying speed and viscosity were then carried out. Following the preparation of the four formulations, their physical properties were evaluated, and the result are presented in Table 3.

Table 3. Average Response of The Formula

	F1	F2	F3	F4
Viscosity(cPas)	34016,67	3892	6064	29150
Drying Speed (minutes)	36.23	34.26	37.65	39.88
Spread Ability (cm)	4.67	5.3	5	4.93
Adhesiveness (Seconds)	27.38	28.21	29.62	25.59

Information:
F1: low CMC-Na concentration – high PVA concentration
F2: high CMC-Na concentration – low PVA concentration
F3: high CMC-Na concentration – high PVA concentration
F4: low CMC-Na concentration – low PVA concentration

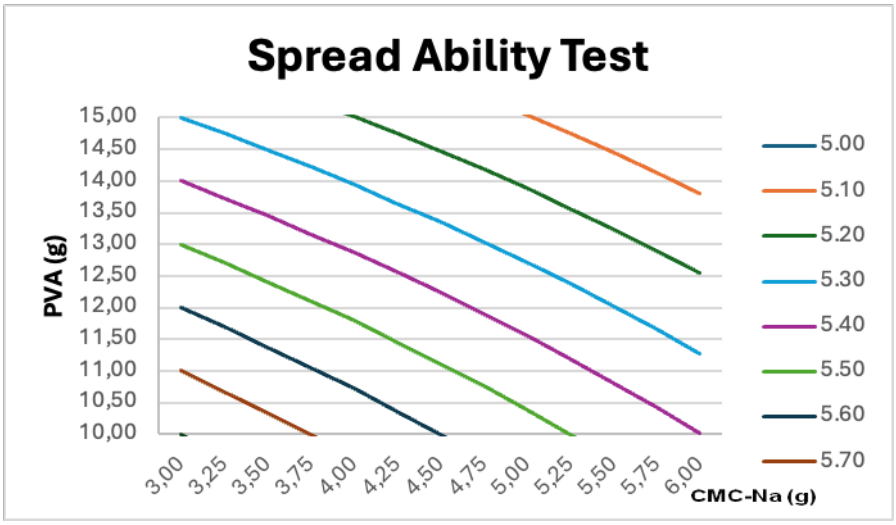
The regression equations used for contour plot generation were re-estimated using the present experimental data (F1–F4), with three independent replicates per formulation. A full 2^2 factorial design was applied, involving four design points and four regression parameters (b_0, b_1, b_2, b_{12}), resulting in a saturated model. Consequently, the regression model yields $R^2 = 1.000$ for each response variable, as the model exactly fits the mean response at each experimental point.

Due to the saturated nature of the design, lack-of-fit testing could not be performed. Therefore, model adequacy was evaluated based on replication variability (n = 3), as reflected by the standard deviation values shown in Table 3. The relatively low standard deviations indicate acceptable experimental reproducibility. The contour and superimposed plots presented were generated from these re-fitted regression equations to ensure applicability to the current material batches and experimental conditions.

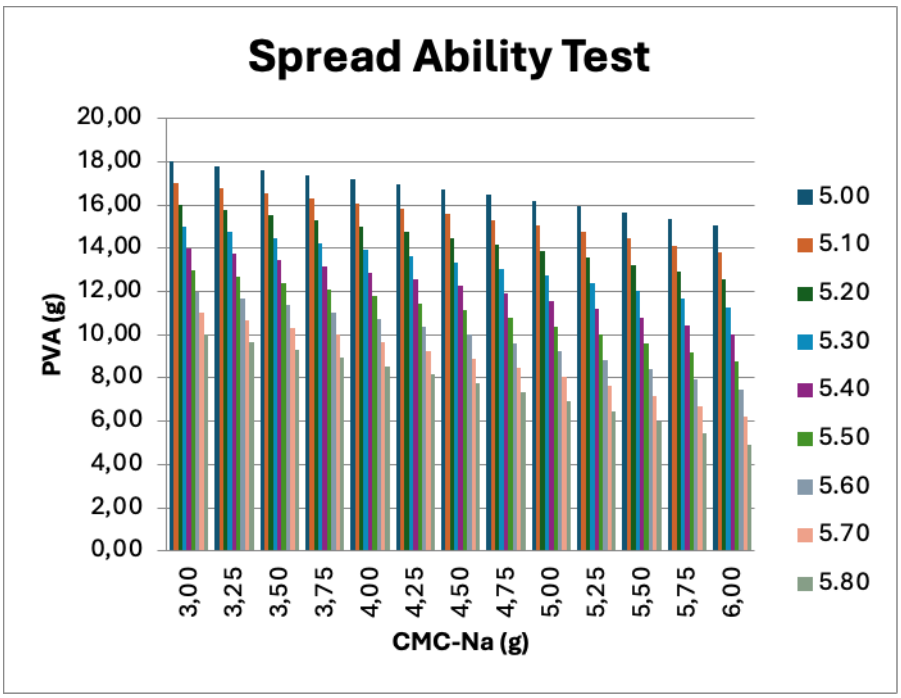
From the results of the mathematical equation of the contour plot, each test result is combined, so that a super imposed contour plot is obtained. From the super imposed contour plot, two points are taken which are suspected to be the optimum formula for this snail slime peel-off gel mask. The following is the calculation of the contour plot equation from each test:

3.3.1. Spread Ability Test

Y= 7.409 -0.203 X1 -0.121 X2 + 0.007 X1X2. Y is the spread ability response, X1 is the CMC-Na factor (3% to 6%), X2 is a factor PVA (10% to 15%). Using the equation, we can determine the concentration of X2 (the PVA factor). The equation for X2 is as follows: X2=(-Y+7.409-0.203X1)/(0.121-(0.007X1)). The contour plot and graph are presented in Figure 1.



(a)



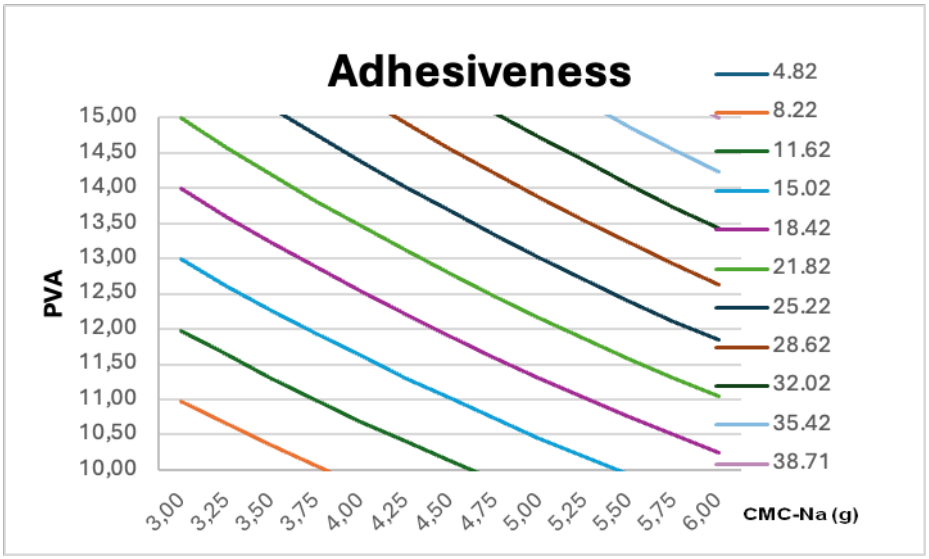
(b)

Figure 1. Contour plot of spread ability test of snail mucus peel-off gel mask (a), Graph of spread ability of snail mucus of peel-off gel mask (b)

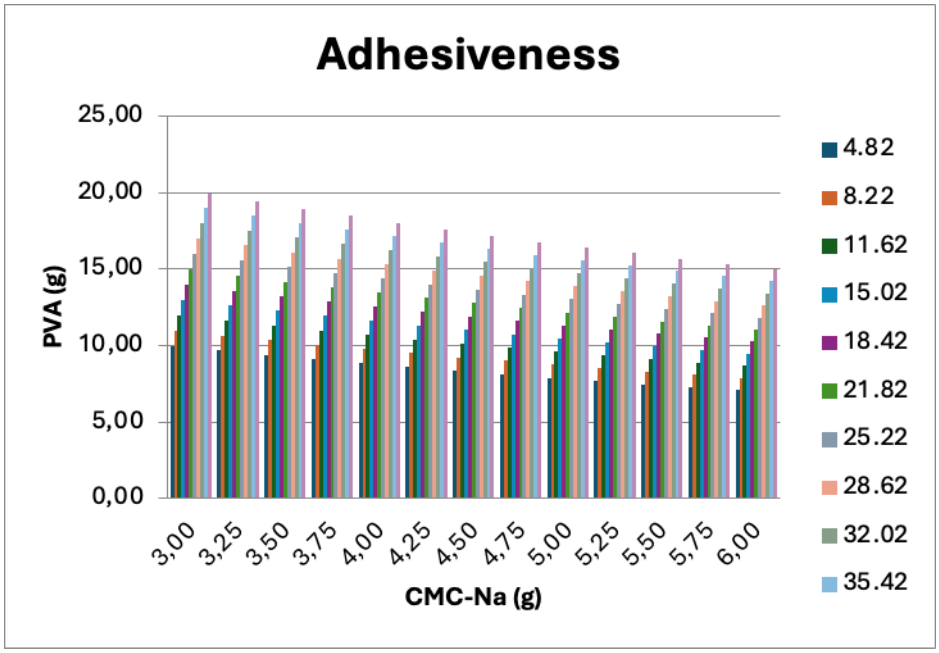
Based on the contour plot analysis, the optimal region for spreadability was defined within the range of 5.1–5.3 cm. This range was selected based on published acceptability criteria for semi-solid topical formulations, which generally recommend a spreadability range of 5–7 cm to ensure ease of application and uniform film distribution (Nirmala et al., 2023; Indriastuti et al., 2023). Spreadability values below this range may result in uneven film thickness and difficult application, whereas excessively high spreadability may indicate insufficient structural integrity, potentially leading to run-off during application. Therefore, the selected range was applied as a formulation optimization constraint to balance ease of application and product stability.

3.3.2. Adhesiveness

Y= -32,8 + 1,24 X1 + 2,52 X2 + 0,292 X1X2. Y is the adhesiveness response, X1 is the CMC-Na factor (3% to 6%), X2 is a factor PVA (10% to 15%). Using the equation, we can determine the concentration of X2 which meets the response range of good adhesiveness. The equation for X2 is as follows: X2=(-Y-32,8+1.24X1)/(-2.52-(0.292X1)). The contour plot and graph are presented in Figure 2.



(a)



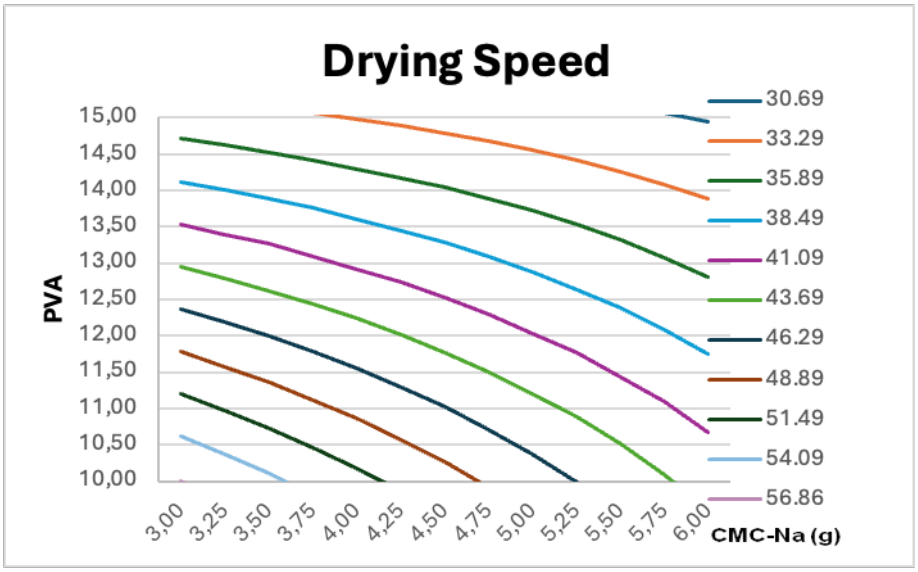
(b)

Figure 2. Contour plot of adhesiveness test of snail mucus peel-off gel mask (a), Graph of adhesiveness of snail mucus of peel-off gel mask (b)

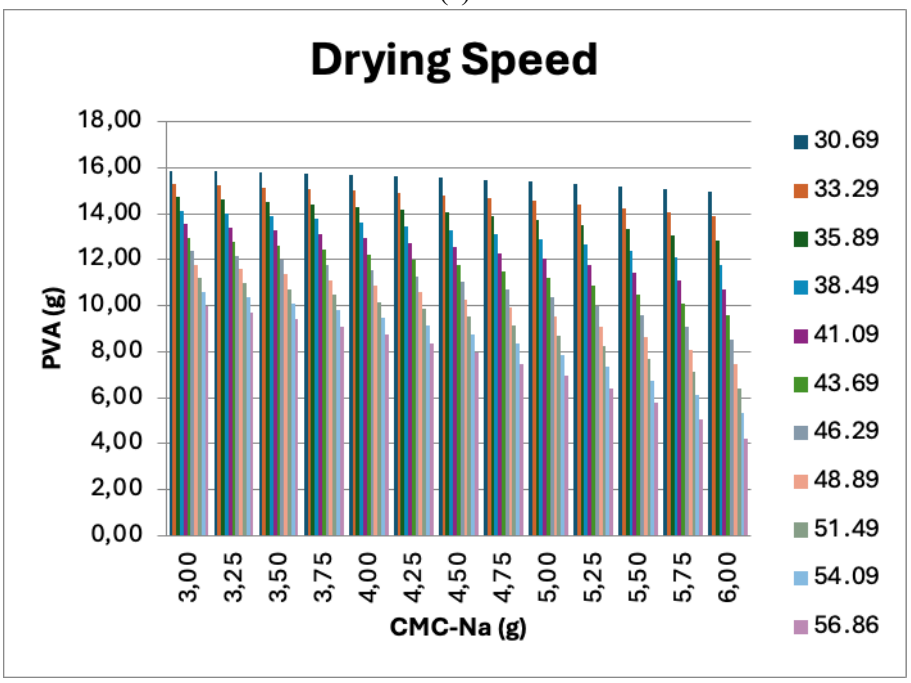
Based on the contour plot of the peel-off gel mask, we can identify the optimal area for adhesion, which corresponds to a response time of 25.22 to 32.02 seconds. The optimal adhesiveness range (25.22–32.02 seconds) was determined based on functional requirements for peel-off gel masks and literature recommendations stating that acceptable adhesion should exceed 4 seconds (Voigt, 1995). Adequate adhesiveness ensures sufficient contact between the gel and skin surface during drying, promoting uniform film formation. However, excessive adhesion may reduce user comfort during removal. Therefore, the selected range represents a balance between effective skin contact and peel comfort, rather than a strict clinical threshold.

3.3.3. Drying Speed

Y= 135,69 -11,40 X1 -6,46 X2 + 0,67 X1X2. Y is the drying speed response, X1 is the CMC-Na factor (3% to 6%), X2 is a factor PVA (10% to 15%). Using the equation, we can determine the concentration of X2 which meets the response range of good drying speed. The equation for X2 is as follows: X2==(-Y+135.69-11.40X1)/(6.46-(0.67X1)). The contour plot and graph are presented in Figure 3.



(a)



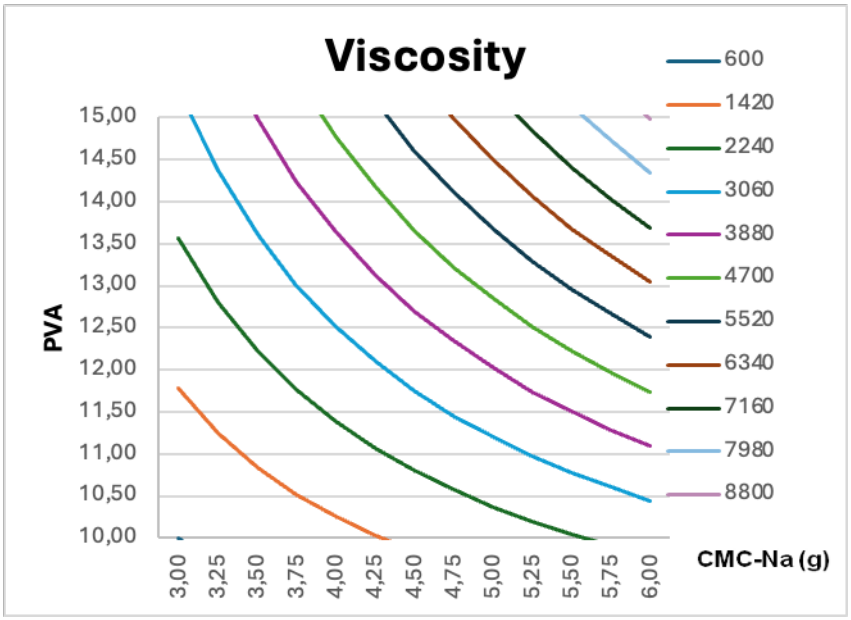
(b)

Figure 3. Contour plot of drying speed test of snail mucus peel-off gel mask (a), Graph of drying speed of snail mucus of peel-off gel mask (b)

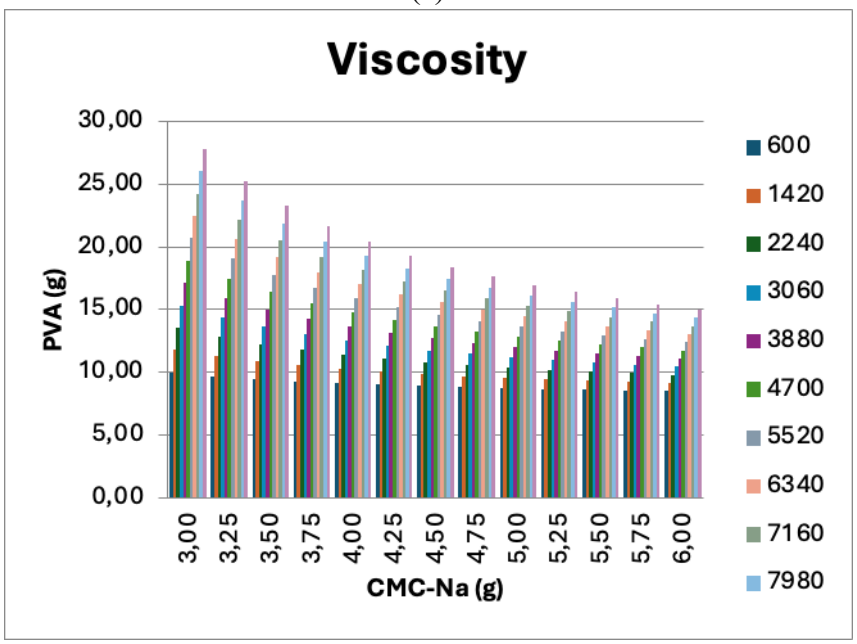
Based on the contour plot of the peel-off gel mask, we can identify the optimal area for drying speed, which corresponds to a response time of 30.69 to 35.89 minutes. The optimal drying time range (30.69–35.89 minutes) was selected to ensure consumer acceptability while allowing sufficient solvent evaporation for cohesive film formation. Excessively short drying times may compromise film integrity, whereas prolonged drying reduces practicality in cosmetic use. This range was therefore defined as a functional optimization criterion for peel-off gel performance.

3.3.4. Viscosity

Y= 210,11 -203,37 X1 -34,01 X2 + 26,67 X1X2. Y is the viscosity response, X1 is the CMC-Na factor (3% to 6%), X2 is a factor PVA (10% to 15%). Using the equation, we can determine the concentration of X2 which meets the response range of good viscosity. The equation for X2 is as follows: X2=(-Y+210.11-203.37X1)/(34.01-(26.67X1)). The contour plot and graph are presented in Figure 4.



(a)



(b)

Figure 4. Contour plot of drying speed test of snail mucus peel-off gel mask (a), Graph of drying speed of snail mucus of peel-off gel mask (b)

Based on the contour plot of the peel-off gel mask, we can identify the optimal area for viscosity, which corresponds to a response time of 4700 to 6340 cPas. The viscosity range of 4700–6340 cPas was selected to ensure adequate rheological performance for peel-off gel applications. Viscosity plays a critical role in maintaining uniform film thickness and preventing run-off during application. Formulations with excessively low viscosity may fail to form a coherent peelable film, whereas overly high viscosity may hinder spreading and reduce user comfort. Therefore, this range was defined as a formulation optimization constraint based on practical performance considerations.

3.4. Contour Plot Super-imposed and selected formula for Snail Mucus Peel-off Gel Mask

The results of combining contour plots, often referred to as superimposed contour plots, are presented below. This includes the superimposed contour plot results for the Snail Mucus Peel-off Gel Mask. The superimposed contour plot result is presented in Figure 5.

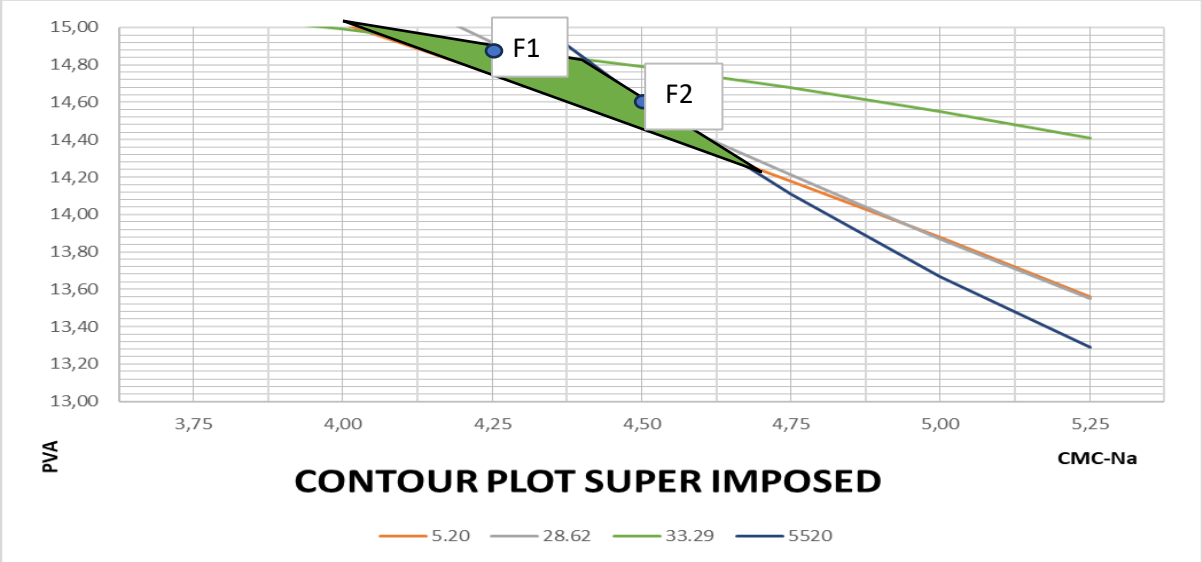


Figure 5. Contour Plot Super Imposed of Snail Mucus Peel-off Gel Mask

The superimposed contour plot represents the area encompassing all intersections of the physical properties' tests. The defined optimal region represents the intersection of formulation constraints derived from individual response requirements, including acceptable spread ability, adhesiveness, drying time, and viscosity. These response ranges were selected based on literature-supported performance criteria and practical usability considerations for peel-off gel masks. It should be emphasized that the identified optimal region reflects formulation optimization parameters rather than absolute clinical performance thresholds. From this area, two formulation points are selected, which are considered optimal for the Snail Mucus Peel-Off Gel Mask. The selected formula from contour plot superimposed are presented in Table 4.

Table 4. Selected Formula from Contour Plot Superimposed

Materials	Formula		Function
	F1	F2	
Snail Mucus	9%	9%	Active substance
CMC-Na	4.25%	4.5%	Basis, thickening agent
PVA	14.89%	14.61%	Basis, peeling agent
Methyl paraben	0.2%	0.2%	Preservatives
Propyl paraben	01%	0.1%	Preservatives
Propylene glycol	12%	12%	Humectant
Aquadest add	100	100	Solvent

Information:
F1: low CMC-Na concentration – high PVA concentration
F2: high CMC-Na concentration – low PVA concentration

The formula was taken because it was thought to be the optimum formula for the snail mucus peel-off gel mask. The formula is a point that is in the super imposed contour plot area above. From the two formulas, a snail mucus peel-off gel mask was then made according to the base composition above.

3.5. Characterization of Snail Mucus Peel-off Gel Mask

The evaluation of peel-off snail slime gel masks includes organoleptic observations, which assess the consistency, color, odor, and homogeneity of the gel. Subsequently, a series of physical characterization tests are conducted, including assessments of spreading power, drying

speed, viscosity, pH levels, adhesion. These comprehensive tests aim to determine the value of each physical characterization of the snail mucus peel-off gel mask.

The organoleptic test is conducted through visual observation, allowing for direct assessment of the gel's shape, color, and aroma. Typically, the gel appears clear and has a semi-solid consistency (Allen, L. V. and Ansel, 2014). The evaluation of selected formula of snail mucus peel-off gel is presented in Table 5.

Table 5. Evaluation of Snail Mucus Peel-off Gel

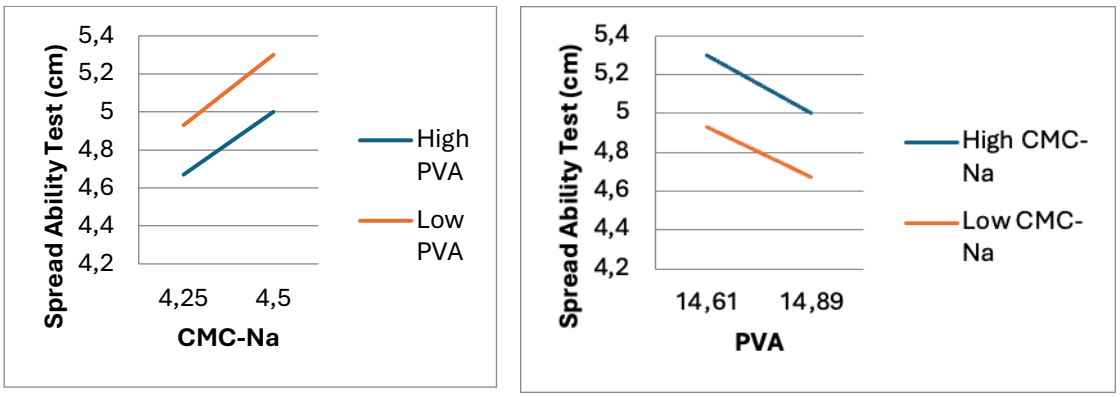
No	Characteristic	Formula	
		F1	F2
1.	Color	Clear	Clear
2.	Odor	Odourless	Odourless
3.	Homogeneity	Homogen	Homogen
4.	Consistency	Soft viscous	Soft viscous
5.	pH	4.63	4.63
6.	Viscosity (cPas)	34016,67	3892
7.	Drying Speed (menit)	36.23	34.26
8.	Spread Ability Test (cm)	4.67	5.30
9.	Adhesiveness (detik)	27.38	28.21

Description: Data is presented by replication 3 times
Information:
F1: low CMC-Na concentration – high PVA concentration
F2: high CMC-Na concentration – low PVA concentration

This optimization utilizes a factorial design method, which is particularly suited for evaluating multiple factors simultaneously. A formula is considered optimal when it exhibits the desired characteristics and properties associated with a high-quality peel-off gel mask preparation. The optimization focused on key physical properties, including viscosity, drying speed, spread ability test, and adhesiveness.

3.5.1. Spread Ability Test

Analysis of average results from physical properties tests reveals that the baseline value of the mask's spreading power for peel-off gel is significantly influenced by the data collected. Increasing the concentration of CMC-Na enhances the spread ability of the gel mask, particularly at high levels of PVA concentration. However, while there is some improvement at lower PVA concentrations, it is not as pronounced. Conversely, as the concentration of PVA increases, the ability to spread the mask decreases at both high and low levels of CMC-Na concentration (Figure b). The effects of CMC-Na and PVA concentrations on the spreadibility of the peel-off gel mask are illustrated in Figure 6, while the corresponding main effect and interaction effect are summarized in Table 6.



(a) (b)

Figure 6. The relationship between CMC-Na concentration and gel spread ability test (a); The relationship between PVA concentration and gel spread ability test (b).

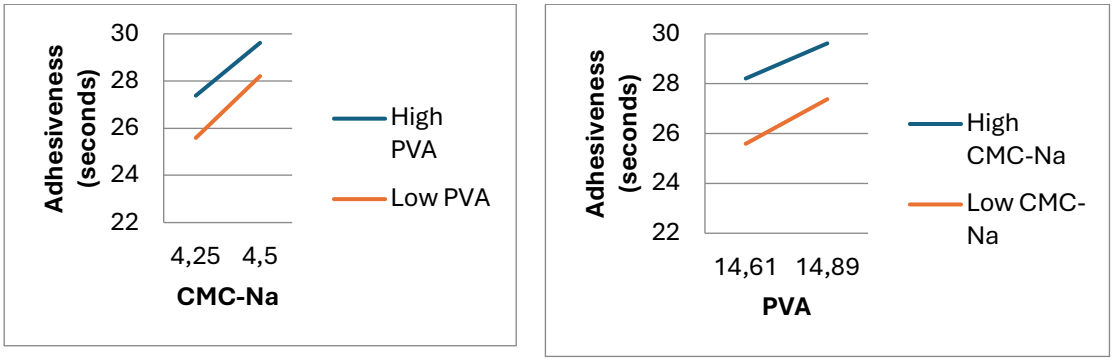
Table 6. CMC-Na effect, PVA effect and interaction effect in determining the spread ability of gel masks.

Effect	Value Effect of Spread Ability
CMC – Na	0.35
PVA	|-0.28|
Interaction	|-0.02|

The calculations of the effect values yield the results presented in the table above. Among the tested materials, single CMC-Na plays a more dominant role in influencing changes in dispersion power compared to single PVA and the interaction between CMC-Na and PVA. Conversely, single PVA contributes to a decrease in gel spread ability, as indicated by its negative effect value. Similarly, the interaction between PVA and CMC-Na also reduces gel spread ability, reflected in its negative effect value.

3.5.2. Adhesiveness

The effects of CMC-Na and PVA concentrations on the adhesiveness of the peel-off gel mask are illustrated in Figure 7, while the corresponding main effects and interaction effect are summarized in Table 7.



(a) (b)

Figure 7. The relationship between CMC-Na concentration and gel adhesiveness test (a); The relationship between PVA concentration and gel adhesiveness test (b).

Increasing the concentration of CMC-Na enhances the adhesion of the gel mask at low levels of PVA concentration, while also resulting in a modest increase at higher PVA concentrations (Figure 7a). Conversely, higher concentrations of PVA further improve the adhesion of the mask at low levels of CMC-Na, though the increase is less pronounced at higher CMC-Na concentrations (Figure 7b).

Table 7. CMC-Na effect, PVA effect and interaction effect in determining the adhesiveness of gel masks.

Effect	Value Effect of adhesiveness test
CMC – Na	2,43

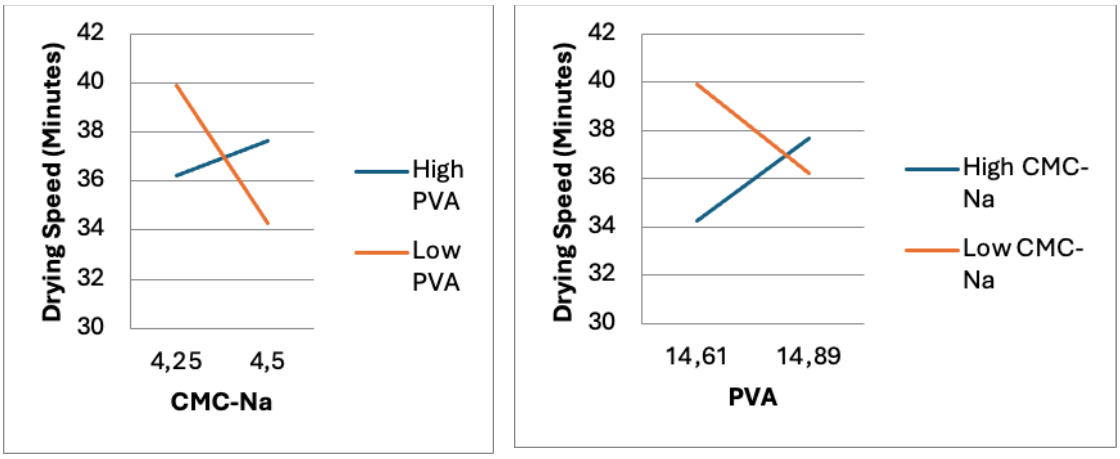
PVA	1,6
Interaction	|-0,19|

The calculated effect values presented in the table above indicate that single CMC-Na is more influential in altering adhesive properties compared to single PVA and the interaction between CMC-Na and PVA. While single PVA contributes to enhancing gel adhesion, its effect is relatively modest. In contrast, the interaction between PVA and CMC-Na results in a decrease in gel adhesion, as evidenced by the negative effect value associated with this combination.

This research demonstrates that both CMC-Na and PVA positively impact gel adhesion, but the influence of CMC-Na is significantly stronger. This can be attributed to the hydrophilic nature of both substances, which allows them to retain moisture during preparation, thereby enhancing the gel's ability to adhere to the skin. Notably, the adhesion strength of the two gels aligns with existing literature, indicating a duration of adhesion exceeding 4 seconds.

3.5.3. Drying Speed

As the concentration of CMC-Na increases, the drying speed decreases at low levels of PVA concentration, while it increases at high levels of PVA concentration (Figure 8a). Conversely, higher concentrations of PVA enhance the drying speed at elevated CMC-Na concentrations, but reduce it at lower CMC-Na levels (Figure 8b). The effects of CMC-Na and PVA concentrations on the drying speed of the peel-off gel mask are illustrated in Figure 8, while the corresponding main effects and interaction effect are summarized in Table 8.



(a) (b)

Figure 8. The relationship between CMC-Na concentration and gel drying speed test (a); The relationship between PVA concentration and gel drying speed test (b).

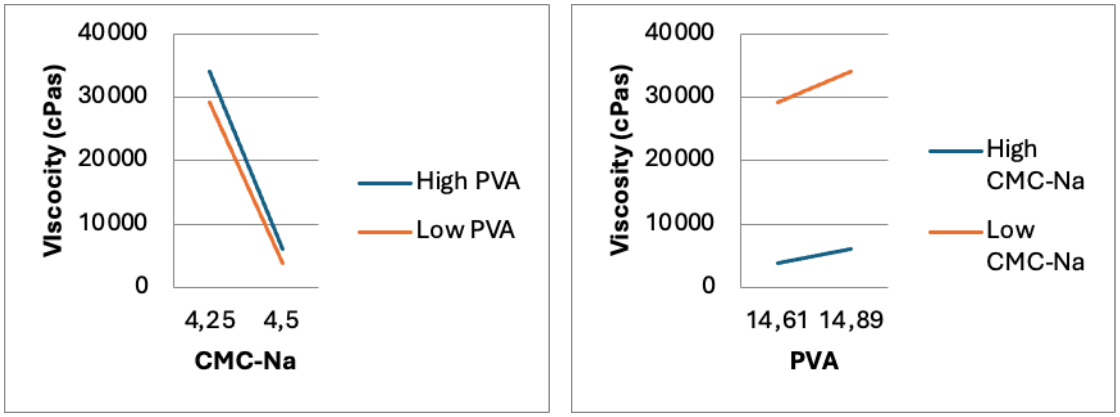
Table 8. CMC-Na effect, PVA effect and interaction effect in determining the drying speed of gel masks.

Effect	Value Effect of Drying Speed Test
CMC – Na	|-2,1|
PVA	|-0,13|
Interaction	3,52

The calculations of the effect values are presented in the table above. CMC-Na alone has a more significant impact on reducing drying speed compared to PVA alone. Both CMC-Na and PVA exhibit negative effect values, indicating that each independently contributes to a decrease in gel drying speed. However, the interaction between PVA and CMC-Na is positive, suggesting that their combined effect enhances the drying speed of the gel. This revision enhances clarity, coherence, and readability while preserving the original meaning.

3.5.4. Viscosity

As the concentration of CMC-Na increases, the viscosity of the mask decreases at low levels of PVA concentration, while only a slight increase is observed at higher PVA concentrations (Figure 9a). Conversely, higher PVA concentrations lead to a significant increase in the viscosity of the mask at elevated CMC-Na levels, with a drastic rise noted at lower CMC-Na concentrations (Figure 9b). The effects of CMC-Na and PVA concentrations on the viscosity of the peel-off gel mask are illustrated in Figure 9, while the corresponding main effects and interaction effect are summarized in Table 9.



(a) (b)

Figure 9. The relationship between CMC-Na concentration and gel viscosity test (a); The relationship between PVA concentration and gel viscosity test (b).

Table 9. CMC-Na effect, PVA effect and interaction effect in determining the viscosity of gel masks.

Effect	Value Effect of Viscosity
CMC – Na	|-26605,33|
PVA	3519,33
Interaction	|-1347,33|

The calculations of the effect values, as presented in the table above, indicate that single PVA has a more dominant influence on viscosity changes compared to CMC-Na alone and their interactions. The effect of CMC-Na on reducing gel viscosity is characterized by a negative effect value. Similarly, the interaction between PVA and CMC-Na also contributes to a decrease in gel viscosity, as evidenced by its negative effect value.

The reproducibility of viscosity measurements was evaluated using the coefficient of variation (CV%). The CV values ranged from 0.46% to 5.13%, indicating good experimental consistency across replicates. Despite the large differences in viscosity between formulations, the low CV values confirm that the measurements were reproducible and that the observed variation is attributable to formulation composition rather than experimental error.

In gel manufacturing, key components that significantly influence the physical quality of gel preparation are the gelling agent and humectant. Gelling agents play a crucial role by forming a network structure within the gel system. The structural framework created by polyvinyl alcohol (PVA) and sodium carboxymethyl cellulose (CMC-Na) is primarily due to hydrogen bond interactions, which occur between the hydroxyl groups and water, as well as other ingredients. The greater the number of hydrogen bonds formed, the stronger the resulting bonds leading to increased viscosity. This study highlights that PVA has a substantial impact on enhancing gel viscosity, as its concentration is more dominant than that of CMC-Na. PVA readily expands when interacting with water due to its active hydroxyl (-OH) groups. The resume of CMC-Na and PVA effect on physical properties are presented in Table 10.

Table 10. Resume of Effect of CMC-Na and PVA with Physical Properties of Gel

Evaluation Test	**Description**

Viscosity	Single PVA is dominant in determining the increase in gel viscosity.
Drying Speed	The interaction of PVA and CMC-Na plays a role in increasing the drying speed of the gel.
Spread Ability Test	Single CMC-Na is dominant in determining the increase in gel spread ability test.
Adhesiveness	A single CMC-Na is dominant in determining the increase in gel adhesion.

This study was limited to a 2^2 factorial design evaluating only two formulation factors (CMC-Na and PVA), while other excipients were kept constant. The analysis focused solely on physicochemical characterization, and long-term stability testing was not performed. Further studies incorporating expanded experimental designs and stability evaluation are recommended to strengthen formulation robustness and applicability.

4. CONCLUSION

In this study, a superimposed contour plot was constructed to identify feasible formulation regions, resulting in two candidate optimal formulations: F1 (CMC-Na 4.25% and PVA 14.89%) and F2 (CMC-Na 4.5% and PVA 14.61%). Rather than representing a single absolute optimum, these formulations reflect different performance advantages within the defined optimization constraints. F1 demonstrated higher viscosity, suggesting stronger film-forming potential and structural integrity, whereas F2 exhibited superior spread ability, indicating improved ease of application. Therefore, the selection of the most suitable formulation may depend on the desired balance between film robustness and application characteristics. Factorial analysis revealed that PVA was the dominant factor influencing viscosity, while CMC-Na predominantly affected spread ability and adhesiveness. Drying speed was influenced by the interaction between both polymers. Overall, the factorial design approach successfully identified a feasible formulation space for snail mucus peel-off gel masks, providing a rational basis for further product refinement and application-specific optimization.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

All authors declared that there was no conflict of interest.

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