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Optimization of peel-off gel mask formula containing Binahong (*Anredera cordifolia*) leaf extract based PVA-CMC- alginate combination

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ABSTRACT: Facial masks are often used for the prevention of skin damage, such as skin aging due to free radical activity. The peel-off gel mask is convenient because it can be easily removed after drying without rinsing. Free radical activity can be inhibited by using antioxidants. One of the antioxidants can be derived from natural materials such as binahong. This study aimed to optimize the peel-off gel mask formula containing binahong leaf extract and evaluate the antioxidant activity of the gel mask formula during the storage period. Peel-off gel masks were prepared by combining PVA, CMC-Na, and sodium alginate as gelling agents. A simplex lattice design (SLD) method was used to optimize the peel-off gel mask formula. The optimum formulation was obtained using a combination of 3.5 g PVA, 1.5 g sodium alginate, 5 g propylene glycol, and 0.1 g potassium sorbate. The optimum formulation has an average spreading capacity of 9.2 ± 0.21 cm, adhesion capacity of 1.09 ± 0.33 seconds, viscosity level of 1491.67 ± 10.78 cP, pH of 7.21 ± 0.02, a drying time of 68 ± 6.24 min, tensile strength of 1.792 ± 0.25 MPa, elongation of 68.077% ± 1.14, and antioxidant capacity with inhibition percentage of 55.087% ± 2.87. The peel-off gel mask containing binahong leaf extract meets the good criteria as the peel-off gel mask. Moreover, the characteristics of the optimal formula peel-off gel mask did not change significantly for 4 weeks of storage at 40^{o}C ± 2^{o}C/75%RH ± 5%RH.

KEYWORDS: Peel-off gel mask; binahong; PVA; alginate; CMC.

1. INTRODUCTION

Facial skin is a very sensitive area that requires special and intensive care. Facial treatments aim to prevent skin disorders or damage such as pimples, dark spots, and fine wrinkles as part of premature aging. The main factor that induces the premature aging of skin cells is exposure to free radicals, which can induce the formation of matrix metalloproteinases (MMPs) and the degradation of elastin and collagen. As a result, fine wrinkles, hyperpigmentation, roughness, and indentations may appear on the skin [1-4].

Facial skin care can be done from inside or outside the body. Facial treatments from outside the body can be approached by using facial mask dosage forms. Facial masks are topical preparations available in various base forms such as creams, papers, powders, and gels. At present, many cosmetic products use the gel as the base of the mask, which forms a film that can be easily removed and is called a peel-off mask [5].

Peel-off masks have unique characteristics because they can form a thin film after the applied gel dries and have adhesive properties, and the film layer can bind dirt or even dead skin on the face quite strongly without leaving any mask residue on the face [5]. Moreover, the tight and adhesive film causes the skin to be cleansed and can increase the skin's moisture, thus helping the active ingredients in the mask to work on the epithelial cells of the skin [5-6].

Binahong (*Anredera cordifolia*) is one of the natural ingredients that have been used by the Indonesian people for a long time for their health and beauty. Binahong leaves contain phenolic group molecules that can act as an antioxidant and prevent premature aging of the skin. Therefore, binahong leaf extract was formulated into a peel-off gel mask based on a combination of PVA, CMC, and alginate. To optimize the peel-off gel mask formulation, the simplex lattice design (SLD) method was used to obtain variations in the ratio of PVA, CMC-Na, and alginate. The goal of this study was to develop an optimal peel-off gel mask

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formulation that forms a film and can be peeled off without residue after complete drying [7], has a spreading capacity of approximately 5-7 cm [8], and has good storage stability.

2. RESULTS and DISCUSSION

2.1 Determination of Total Phenolic and Antioxidant Activity of Binahong Extract

According to the obtained linear regression equation (Figure 1), y = 0.0095x + 0.1092, the phenolic content in binahong leaf extract (5% w/v) can be calculated. The total phenolic content was 23.207 ± 0.061 mg gallic acid equivalent (GAE) per 1 g sample of binahong leaf extract.

The evaluation of the antioxidant activity of binahong leaf extract aimed to determine the ability of binahong extract to inhibit free radicals. According to a linear regression equation (Figure 2) that was obtained, y = 83.074x + 4.1198, the IC50 value of the antioxidant activity can be calculated by substituting y = 50. Based on the calculation results, the IC50 value of binahong leaf extract was 552.3 µg/mL, which means that 552.3 µg/mL of binahong leaf extract (5% w/v) is required to scavenge 50% of DPPH free radicals.

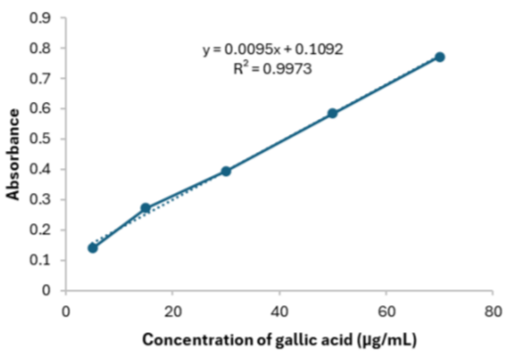

Figure 1. Calibration curve of gallic acid

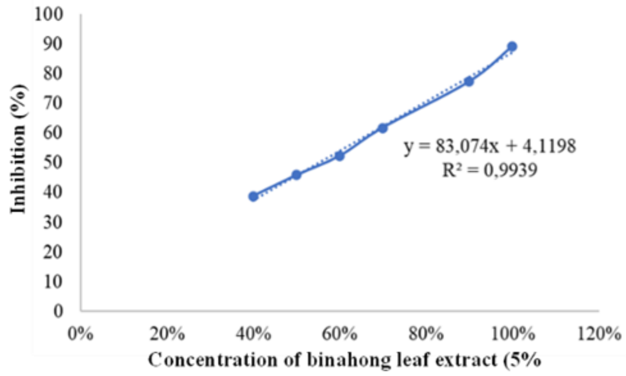

Figure 2. Calibration curve of inhibition capacity of binahong leaf extract

2.2 Characterization of Peel-Off Gel Mask Containing Binahong Extract

In this study, a simplex lattice design (SLD) was used to obtain the optimal formulation of a peel-off gel mask containing binahong. The SLD is a helpful technique to determine the optimum concentrations of components in the formula and has been successfully applied by several researchers [9,10].

The physical property characterization of the peel-off gel mask containing binahong extract was performed on 14 runs of the predicted formula from the simplex lattice design (SLD) method and after 24 hours. Firstly, the spreading capacity was evaluated to ensure that the gel could spread properly without high pressure during application and to avoid uncomfortable feelings. Regarding the results of the spreading capacity of the peel-off gel mask (Figure 3a), it was shown that run 7 had the highest spreading capacity (9.2 ± 0.21 cm), and run 8 had the lowest spreading capacity (7.1 ± 0.09 cm).

According to the SLD equation of the effect of PVA, CMC-Na, and sodium alginate on the spreading capacity, the three gelling agents gave a positive response, indicating that each additional amount of PVA, CMC-Na, and sodium alginate could increase the spreading capacity of the peel-off gel mask. The SLD method determined the effect of the three gelling agents on the spreading capacity, which can be seen in the equation below.

$$Y = 9.57A + 5.51B + 8.4C \qquad (1)$$

Y: spreading capacity response; A: PVA (g); B: CMC-Na (g); C: Na-alginate (g)

The most influential gelling agent on the spreading capacity was PVA because it has the highest positive response value according to equation (4) and the red color of the contour plot in Figure 4a. According to data material of polymers (section 4.1. material), PVA has the lowest viscosity. The viscosity level of the polymer fluid affects the flow resistance of the fluid, while the shear rate or spreading capacity will increase as the viscosity decreases due to molecular alignment and disentanglement of the polymer chains [11].

2.2.1 Adhesive capacity

The adhesive capacity was evaluated to determine the ability of the gel to adhere to the application site. The results of the evaluation for 14 run formulas (Figure 3b) showed that run 13 had the longest adhesion (3.27 ± 2.86 seconds) and the shortest was run 1 (0.87 ± 0.13 seconds). The SLD method determined the effect of the three gelling agents on the bond strength as shown in the equation below.

$$Y = -0.59A + 3.79B + 1.69C \qquad (2)$$

Y: adhesiveness capacity response; A: PVA (g); B: CMC-Na (g); C: Na-alginate (g)

CMC-Na and sodium alginate gave a positive response indicating that each additional amount of CMC-Na and sodium alginate increased the adhesiveness capacity of the peel-off gel mask. The gelling agent that had the most influence on the adhesive capacity response was CMC-Na. Otherwise, PVA gave a negative response indicating that each additional amount of PVA could decrease the adhesiveness capacity of the peel-off gel mask referring to equation (2) and the darker blue area indicates the lowest adhesiveness capacity response in Figure 4b. CMC had the highest adhesiveness than alginate and PVA. This phenomenon indicated that the interfacial tension between the glass surface and the gel CMC-Na was small enough to achieve strong adhesion [12].

2.2.2 The viscosity of the peel-off gel mask

Fig. 3c showed that the highest viscosity value was run 10 (5943.67 ± 63.25 cP) and run 7 had the lowest viscosity value (1491.67 ± 10.78 cP). Regarding the simplex lattice design result on the viscosity response, equation (3) showed that CMC-Na had the most influence on the viscosity of the peel-off gel mask. Moreover, the contour plot of the viscosity response (Fig.4c) showed that the addition of CMC-Na (yellow area) affected the viscosity response. Because CMC-Na can release Na+ ions which can be replaced by hydrogen ions to become HCMC in the water, the hydrogen bonds will form cross-linked bonds which can increase the viscosity of the gel [8].

$$Y = 3045.77A + 6844.63B + 1056.48C \qquad (3)$$

Y: viscosity value response; A: PVA (g); B: CMC-Na (g); C: Na-alginate (g)

2.2.3 pH value of the peel-off gel mask

The evaluation of pH gel aims to determine the degree of acidity of the product. The pH value of topical products should be close to the pH value of the skin to prevent skin irritation. Evaluation of the pH value for the 14 runs showed that run 4 had the highest pH (7.52 ± 0.13) and run 6 had the lowest pH (7.15 ± 0.05). There was not much difference (Figure 3d) because each gelling agent has a similar pH when they are dissolved in the water, PVA has a pH of 5.0-8.0, CMC-Na has a pH of 6.5-8.5, and sodium alginate has a pH of 7.2 [12]. Thus, SLD produced an equation for the pH response with a similar positive number for each component of gelling agents.

$$Y = 7.11A + 7.28B + 7.38C \qquad (4)$$

Y: pH value response; A: PVA (g); B: CMC-Na (g); C: Na-alginate (g)

The effect of the gelling agent combination on pH value can also be seen in Figure 4d, the green area indicates a high pH response followed by a blue area indicating a low pH response. The highest pH response was produced by the sodium alginate area, while the lowest pH response was produced by the PVA area.

2.2.4 Drying time

The drying time evaluation of the gel after spreading on the surface of the glass plate obtained results for 14 runs of more than 30 min (Figure 3e and Figure S1). This might be because the drying test method was not relevant to the real conditions. The author conducted a trial using masks to ensure the required time for the drying process of the gel mask, it was obtained in less than 30 min (data not shown). Therefore, it is necessary to modify the in vitro method to evaluate the drying time of the gel. Regarding the contour plot of the dry time response (Fig4e), the yellow area indicates the highest dry time response, followed by the green area and the blue area which indicates the lowest dry time response.

The SLD approach to determine the effect of the gelling agent component on the drying time response produced the equation below.

$$Y = 50.77A + 68.77B - 0.41C + 9.94AB + 169.36AC + 81.36BC \qquad (5)$$

Y: drying time response; A: PVA (g); B: CMC-Na (g); C: Na-alginate (g)

Based on equation (5), PVA and CMC-Na gave a positive response indicating that both could increase the drying time of the mask. Otherwise, sodium alginate gave a negative response indicating that sodium alginate could reduce drying time. The gelling agent that had the most effect on the drying time of the peel-off gel mask was CMC-Na because it can hold water relatively strong [13, 14] and minimize the loss of moisture in the matrix film through hydrogen bonds from the hydroxyl group [15,16]. However, the negative coefficient of alginate meant that alginate could reduce drying time because it required ionic crosslinking to enhance water-holding by the polymer chain [17]. Furthermore, the combination of PVA-CMC-Na, PVA-sodium alginate, and CMC-Na - sodium alginate also gave a positive response indicating that the interaction between the two polymers could increase the drying time of the peel-off gel mask [18].

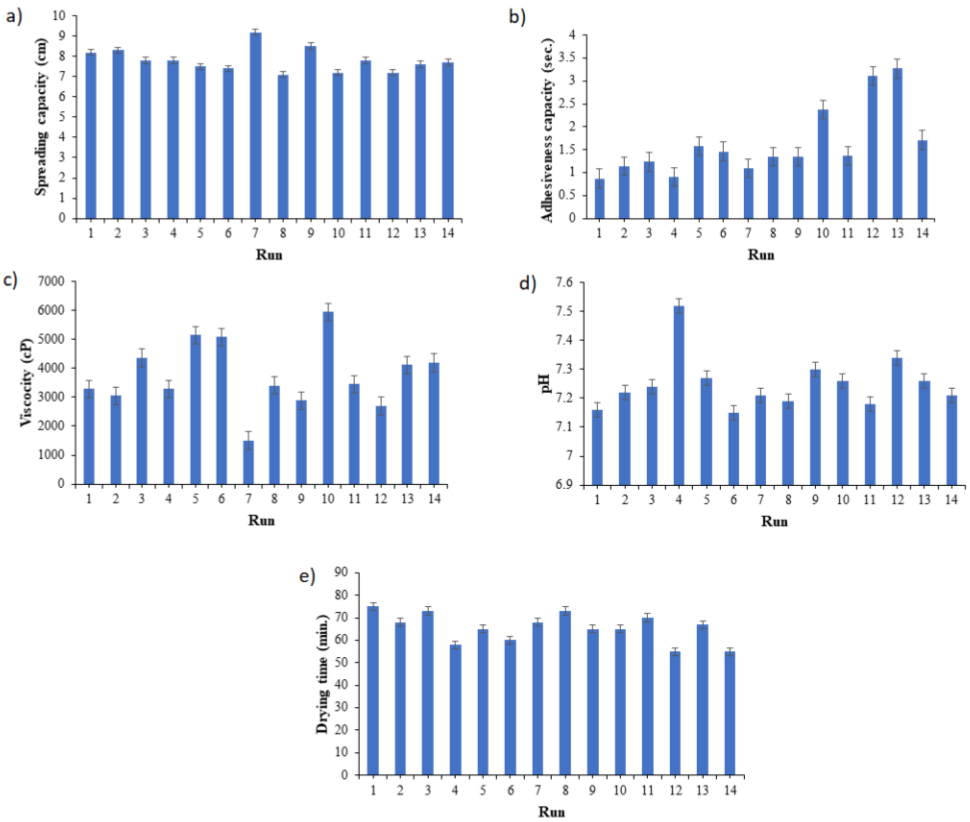

Figure 3. Physical characteristics of gel peel-off masks containing binahong extract: a) spreading capacity, b) adhesiveness capacity, c) viscosity, d) pH level, e) drying time

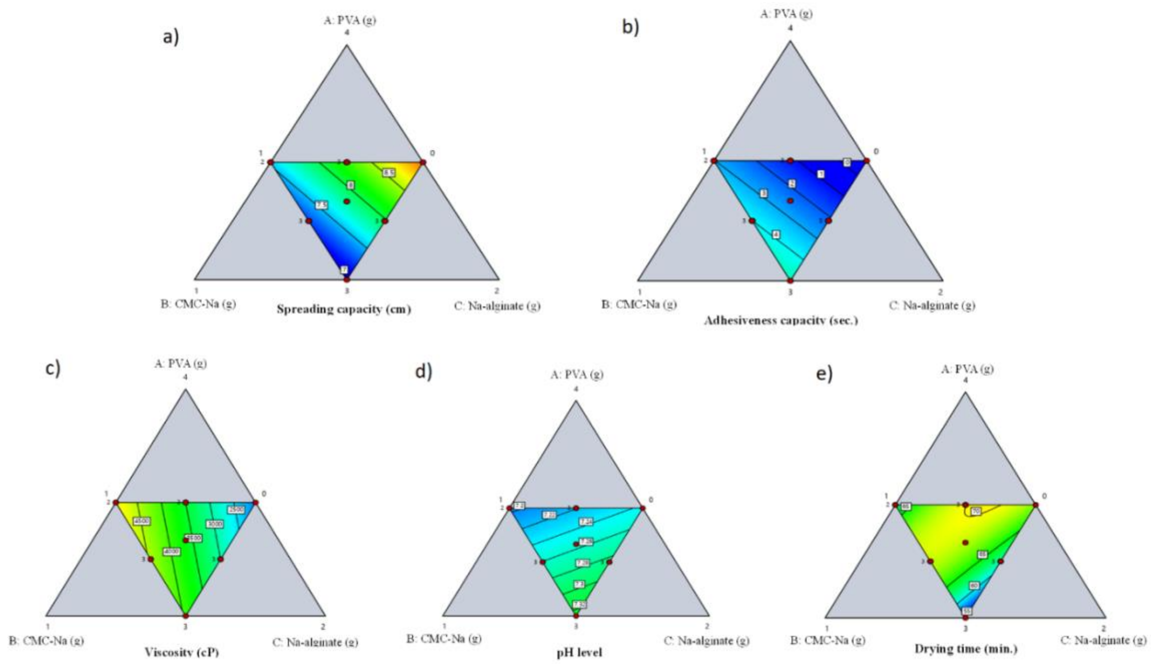

Figure 4. Contour plot the response of A: PVA, B: CMC-Na, and C: Na-alginate on (a) spreading capacity, (b) adhesiveness capacity, (c) viscosity, (d) pH level, and (e) drying time parameters.

2.3 Optimum Formula of Peel-Off Gel Mask Containing Binahong Leaf Extract

Determination of the optimum peel-off gel mask formula was determined using the SLD method. The selected response characteristics for determining the optimum formula are in Table 1. The optimum formula was determined by a desirability value which has a range of 0-1, where the greater desirability value indicates the response parameter used in the optimization formula can reach the optimum point according to the desired target. In this study, the optimum formula of a peel-off gel mask containing binahong leaf extract had a desirability value of 0.899 (Figure 5a). The optimum formula was chosen to contain 3.5 g PVA, 0 g CMC-Na, and 1.5 g sodium alginate. Moreover, the predicted physical parameter of the optimum formula will have a pH value of 7.24, a viscosity value of 2051.49 cP, a drying time of 67.52 min., and a spreading capacity of 8.98 cm (Figure 5b).

The predicted optimum formula was prepared and characterized to compare the experimental results to the predicted parameters of SLD. Regarding Table 2, experimental results were not significantly different from the predicted result of the SLD method.

Table 1. Independent Variable and Dependent Variable of Peel-Off Gel Mask Formula

Independent Variable	***Limit***		
	Lower	***Upper***	***Target***
PVA	3 g	3.5 g	*In range*
CMC-Na	0 g	0.5 g	*In range*
Sodium alginate	1 g	1.5 g	*In range*
Dependent Variable	***Lower***	***Upper***	***Target***
pH	7.15	7.52	*In range*
Viscosity	1491.67 cP	5943.67 cP	*In range*
Drying time	55 min	75 min	*In range*
Spreading capacity	7.1 cm	9.2 cm	*Maximize*

Moreover, the optimum formula's tensile strength and elongation capacity were also evaluated. According to the measurement results, the optimum formula peel-off gel mask has an average tensile strength and elongation of 1.79 ± 0.25 MPa (equivalent to 18.27 kgf/cm2) and 68.07 ± 1.14 %, respectively. The result indicates that the film layer of the peel-off gel mask containing binahong leaf extract has good elasticity and does not break easily when peeled off.

Table 2. Verification of optimum formula

Response	Prediction	Experiment	p-value	Significance
pH	7.24	7.18	0.45	none
Viscosity	2051.49	1755.67	0.31	none
Drying time	67.52	69.44	0.58	none
Spreading capacity	8.98	9.27	0.36	none

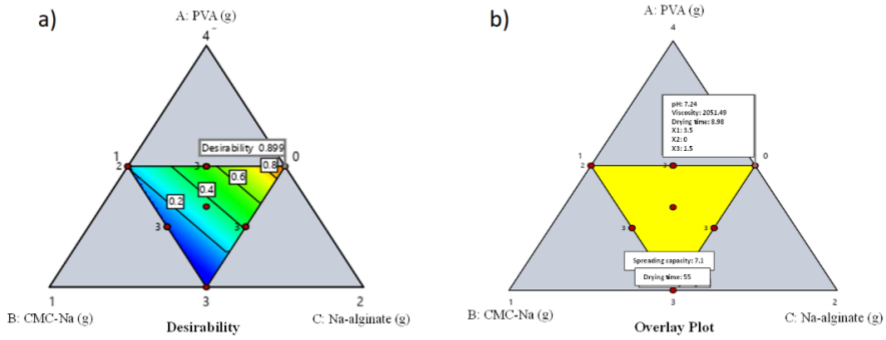

Figure 5. (a) Contour plot of desirability value and (b) superimposed contour plot on physical response parameters.

2.4 Stability Study of Gel Peel-Off Mask Containing Binahong Leaf Extract

The optimum formula peel-off gel mask had no odor, color, or homogeneity change during the stability study. Regarding Post Hoc and t-test calculations, it showed that there were no significant differences in the pH value, spreading capacity, adhesiveness capacity, drying time, tensile strength, and elongation parameters of the peel-off gel mask after 4 weeks of storage at 40°C ± 2°C/75% RH ± 5% RH (Table 3). However, the viscosity value of the peel-off gel mask containing binahong leaf extract decreased massively after one week of storage and could not be measured due to the torque being too low. The reduction of gel viscosity was influenced by the extract component in the formula because the viscosity of the peel-off gel mask without extract (Table S1) did not show a significant difference from the initial condition. Even though the viscosity of the optimum formula decreased significantly, the formula was still able to form a good elastic film layer which had tensile strength and elongation of 0.84 ± 0.15 MPa and 54.49 ± 16.41%, respectively.

Table 3. Physical characteristics of the peel-off gel mask containing binahong leaf extract before and after the stability study

Parameter	Initial condition	After 4 weeks
Spreading capacity (cm)	9.32 ± 0.64	11.53 ± 0.10
Adhesiveness capacity (sec.)	1.37 ± 0.39	0.761 ± 0.03
pH value	7.61 ± 0.28	7.83 ± 0.24
Drying time (min)	63.89 ± 1.57	65 ± 0.00
Viscosity value (cP)	1116.55 ± 2 1.56	-
Tensile strength (MPa)	1.79 ± 0.25	0.84 ± 0.15
Elongation (%)	68.08 ± 1.14	54.49 ± 16.41
Antioxidant activity - Inhibition (%)	60.89 ± 17.62	55.08 ± 2.87

3. CONCLUSION

We established the optimum formula for the peel-off gel mask containing binahong extract, which has good properties and stability using a combination of PVA and sodium alginate as basic gelling agents. Even though the viscosity value of the mask formula containing binahong extract decreased after 1 week of storage at 40°C ± 2°C/75% RH ± 5% RH, the optimum mask formula without extract was still stable. It means that the optimum formula of the peel-off gel mask can still be used as an alternative formula for other active compounds or extracts that are more compatible with PVA and alginate.

4. MATERIALS AND METHODS

4.1 Materials

Binahong leaves were obtained from Yogyakarta, Indonesia. PVA (hydrolyzed, 88%, viscosity 4%=45 mPa.s) was purchased from Poval (Japan). CMC FH5000 (viscosity 1% = 5500-6000 mPa.s) was purchased from Changshu wealthy science and technology (China). Sodium alginate (viscosity 1% = 100-200 mPa.s, mol. wt. ~ 75-100 kDa) was purchased from Kimica International. Propylene glycol was purchased from Dow Chemical Pacific. Potassium sorbate was purchased from Jiangbei Additive (China). Ethanol and methanol were purchased from Merck. 2,2-diphenyl-1-picrylhydrazyl (DPPH) was purchased from TCI Chemicals (Japan). Gallic acid, Folin-Ciocalteu, and NaOH were purchased from Sigma-Aldrich.

4.2 Determination of binahong leaves

Determination was carried out to ensure the correctness of the binahong plant (Anredera cordifolia) regarding the literature by observing morphological characteristics. The selected binahong leaves come from one tree, are picked in the morning, are not torn, and not eaten by insects, and are the same size.

4.3 Extraction Process

Fresh binahong leaves (10 g) were weighed and washed, then binahong leaves were soaked in 200 mL of water at 90°C for ±5 min. Extract binahong were cooled at room temperature and ready to be used in preparing the masks process.

4.4 Determination of Total Phenolic

4.4.1 Standard curve of total phenolic content

Gallic acid (10 mg) was dissolved in methanol to a final concentration of 1000 µg/mL. Standard solutions with concentrations of 5, 15, 30, 50, 70 µg/mL were prepared. Standard solutions (1 mL) were added with 5 mL Folin-Ciocalteu reagent (5% in distilled water) and incubated for 8 min. Then 4 mL NaOH (1% in distilled water) was added and incubated for 1 hour. The solutions were measured with a UV-Vis spectrophotometer at a maximum wavelength of 687 nm.

4.4.2 Sample preparation

Binahong extract (1 mL) was added with 5 mL Folin-Ciocalteu reagent (5% in distilled water) and incubated for 8 minutes. Then, 4 mL NaOH (1% in distilled water) was added to the sample and incubated for 1 hour. The solutions were measured with a UV-Vis spectrophotometer at a maximum wavelength of 687 nm.

4.5 Determination of the Antioxidant activity of Binahong Extract

Binahong extract (50 mL) was added with 100 mL ethanol to a final concentration of 50% v/v. Sample solutions were prepared in different concentrations of 5%, 10%, 15%, and 20% v/v. 3 mL of DPPH solution (100 µg/mL) was added to the sample solution (2 mL), then homogenized and incubated for 30 min. The solutions were measured with a UV-Vis spectrophotometer at a maximum wavelength of 516 nm. The percentage of oxidation inhibition was calculated using the following equation:

$$inhibition\ (\%) = \frac{Absorbance\ (standard) - Absorbance(sample)}{Absorbace\ (standard)} \times 100\% \qquad (6)$$

The IC50 antioxidant activity of binahong extract was calculated using the linear regression equation by plotting the sample concentration on the x-axis and % inhibition on the y-axis.

4.6 Formulation of Peel-Off Gel Mask Containing Binahong Extract

The formulation of the gel peel-off mask was optimized by varying the combination of gelling agents (PVA, CMC, and alginate). The amounts of PVA, CMC Na, and sodium alginate were 3-3.5 g, 0-0.5 g, and 1-1.5 g, respectively. The ratio of gelling agents was generated using the simplex lattice design (SLD) method to obtain an optimal formula. The concentration of each component in the formula is shown in Table 4.

Table 4. The concentrations of each compound of peel-off gel mask containing binahong extract.

	Run													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Binahong extract	90	90	90	90	90	90	90	90	90	90	90	90	90	90
PVA	3.5	3.5	3.33	3.25	3.5	3.5	3.5	3.25	3.5	3.25	3.25	3	3.25	3.25
CMC-Na	0.25	0.25	0.33	0.25	0.5	0.5	0	0.5	0.25	0.5	0.25	0.5	0.5	0.25
Potassium alginate	1.25	1.25	1.33	1.5	1	1	1.5	1.25	1.25	1.25	1.5	1.5	1.25	1.5
Propylene glycol	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Potassium sorbate	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

PVA was dissolved in 40 mL of Binahong extract, CMC-Na was dissolved in 20 mL of Binahong extract, and sodium alginate was dissolved in 30 mL of hot Binahong extract, then each gelling agent was homogenized by stirring at 200-250 rpm to form a gel mass. The PVA, CMC-Na, and sodium alginate gel mass were mixed until a homogeneous gel was obtained. Potassium sorbate solution in propylene glycol was added to the gel mass, then the mass was stirred until a homogeneous gel mass was obtained.

4.7 Characterization of Gel Peel-Off Mask Containing Binahong Extract

4.7.1 Spreading capacity

The spreading test was performed by placing 0.5 g of the peel-off gel mask in the center of the spreading tester. The top cover glass was weighed and placed on the peel-off gel mask mass and held for 1 minute, then the diameter of the gel mass was measured. Continuously, weights ranging from 50-250 g were placed on the sample and the diameter of the gel mass was measured after 1 minute of standing. The requirement for good spreading of a peel-off gel mask is 5-7 cm [19].

4.7.2 Adhesive Capacity

Peel-off gel (0.1 g) was placed between the object-glass on the test equipment, and then 50 g weight was suspended on the left side of the object glass. Continuously, 1 kg weight was placed on the object glass for 5 minutes, then the weight was removed and the time when the two sides of the object glass could be separated was recorded [20].

4.7.3 Measurement of gel Viscosity

The viscosity of the gel mass was evaluated using a Brookfield LV Viscometer, spindle number RV 6, at 100 rpm for 1 minute [21]. The viscosity was observed until it reached stability and the results were recorded.

4.7.4 Evaluation of pH gel

Peel-off gel mask (1 g) was diluted in 9 mL of distilled water, then the sample was analyzed using a pH meter (Ohaus).

4.7.5 Drying time

Peel-off gel mask (0.5 g) was placed on a glass plate (2.54 × 7.62 cm) and then spread to form a 1 mm thick layer. The glass plate was continuously dried in an oven at 37 ± 1°C. The drying time was recorded when the dried film formed and could be removed from the glass plate.

4.7.6 Antioxidant activity of the peel-off gel mask containing binahong leaf extract

Peel-off gel mask (0.05 g) was diluted in 100 mL of distilled water to obtain a concentration of 500 µg/mL. The sample solution was prepared in a series of concentrations of 50, 100, 150, and 200 µg/mL. 1 mL of DPPH (100 µg/mL) was added to 2 mL of sample solution. The mixed solution was homogenized and incubated at room temperature in the dark. Then the solutions were measured at a maximum wavelength of 516 nm using a UV-Vis spectrophotometer.

4.7.7 Tensile strength & elongation test

The film of the peel-off gel mask containing binahong leaf extract was cut into an "I" shape with a length of 5 cm and a width of 5 mm in the middle. Then, the "I" shaped film was clamped at both ends and pulled slowly using a Zwick/z.05 Tensile Strength and Elongation Tester [22]. Tensile strength and elongation were calculated according to the following equations:

$$\text{Tensile strength} = \frac{Force\ (kgf)}{Area\ (cm^2)} \qquad (7)$$

$$\text{Elongationate (\%)} = \frac{Final\ length\ (cm) - Initial\ length\ (cm)}{Initial\ length\ (cm)} \times 100\% \qquad (8)$$

4.8 Stability Study of Gel Peel-Off Mask Containing Binahong Extract

A stability study of the optimized peel-off gel mask formula was conducted according to ICH guidelines and ASEAN harmonization. The peel-off gel mask products were stored in the climate chamber at 40°C ± 2°C/75% RH ± 5% RH. The physical characterization and antioxidant activity of the peel-off gel masks were evaluated in weeks 1, 2, 3, and 4.

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Conflict of interest statement: The authors declared no conflict of interest in the manuscript.

Supporting information Additional supporting information can be found online in the Supporting Information section at the end of this article.

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