Formulation and Characteristics of Hydrogel Patch Containing Pineapple Peel (*Ananas comosus* L.) Ethanol Extract

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Abstract

Pineapple peel (*Ananas comosus* L.) contains bioactive compounds such as flavonoids and the enzyme bromelain, which possess antioxidant, anti-inflammatory, antibacterial, and anticancer properties, and the ability to accelerate wound healing. Hydrogel patches are effective in wound healing due to their hydrophilic properties that maintain moisture and prevent bacterial infection in open wounds. This study aims to develop and test the characteristics of hydrogel patch formulations containing ethanol extracts of pineapple peel with varying concentrations of 10%, 20%, and 30%, compared to a control (hydrogel patch without pineapple peel extract). A series of evaluation tests were conducted to assess the patch characteristics, including organoleptic tests, pH, absorbency, weight uniformity, swelling ratio, patch thickness, and folding endurance. The results showed that the concentration of pineapple peel extract affects the hydrogel patch characteristics. The higher the extract concentration, the darker the patch color, but the pH, absorbency, and swelling ratio decrease. Patches with higher extract concentrations also showed an increase in weight. Absorbency tests indicated that none of the formulas met the acceptance criteria (<10%), with absorbency results of 22.97%, 11.60%, and 21.95% for 10%, 20%, and 30% extract concentrations, respectively, and 23.43% for the control. Swelling ratio and thickness tests showed the best results for the control, followed by the 10%, 20%, and 30% extract concentrations. The folding endurance test showed that the control and 10% extract formula had good results (>300 folds), while higher extract concentrations reduced the folding endurance of the hydrogel patch

Keywords: extract, pineapple peel, hydrogel patch, formulation, patch characteristics

1. INTRODUCTION

Badan Pusat Statistik (BPS) states that Lampung Province is the largest pineapple producer in Indonesia, with production reaching 861,706 tons in 2022. However, despite this, the people of Lampung primarily consume only the flesh of the pineapple, while the core and peel are still considered waste. Research has shown that pineapple peel contains pharmacological potential for wound healing (Varilla et al., 2021).

Pineapple peel, the outer part of the fruit *(Ananas comosus* L.*)*, has a rough texture and small spines. Phytochemical screening reveals the presence of alkaloids, flavonoids, saponins, quinones, and phenols (Reiza et al., 2019). Flavonoids in pineapple peel function as antioxidants, anti-inflammatories, and antibacterials (Panche et al., 2016). Pineapple peel also contains bromelain, an enzyme with various benefits such as anti-inflammatory, anticancer, and antibiotic properties, which can accelerate wound healing (Varilla et al., 2021).

Using natural materials as antibacterials can be an alternative in wound treatment. Research has proven that pineapple peel extract has pharmacological potential as an effective antibacterial against both gram-positive and gram-negative bacteria, such as *Escherichia coli, Staphylococcus aureus, Vibrio cholerae, Klebsiella pneumoniae, and Pseudomonas aeruginosa* (Omorotionmwan et al., 2019).

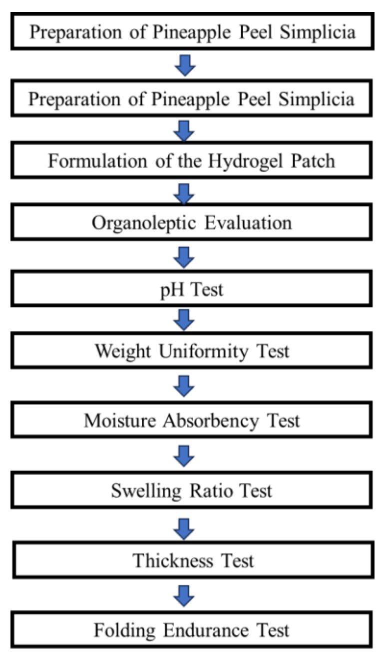
Hydrogel is a type of hydrophilic polymer macromolecule with an interconnected network structure. Its hydrophilic nature and network structure offer advantages in various applications, such as moisture retention and water content enhancement (Ilkhawati et al., 2023). The macromolecular nature provides flexibility and the ability for hydrogel to expand when exposed to water, with high water diffusion rates (Harliantika & Noval, 2021). Hydrogel patch formulations have been widely used in the wound healing process (Edy et al., 2016). The hydrogel layer in patch form can absorb and retain a volume of water when in contact with a wet wound, maintaining moisture, preventing infection, and facilitating skin regeneration (Hanistya et al., 2021).

Therefore, this study aims to develop and evaluate the characteristics of hydrogel patch formulations with the addition of ethanol extract of pineapple peel. This research is expected to contribute to the development of pharmaceutical preparations and the utilization of waste into innovative and beneficial health products.

2. METHODS

This research was conducted at the Pharmaceutics Laboratory and Microbiology Laboratory of the Faculty of Medicine, University of Lampung, from May to June 2024.

The research process begins with preparing pineapple peel simplicia, which is then extracted using the maceration method. The concentrated ethanol extract is obtained through evaporation with a rotary evaporator. The pineapple peel extract is then formulated into hydrogel patches, and their characteristics are evaluated, including organoleptic tests, pH, weight uniformity, absorbency, swelling ratio, patch thickness, and folding endurance. pH testing was carried out on days 1, 7 and 14.



Picture 1. Research Workflow

Materials and Tools

The materials used in this research are pineapple peel simplicia, filter paper, distilled water, 70% ethanol, 96% ethanol, ether, dimethyl sulfoxide (DMSO), Polyvinyl Alcohol (PVA), Polyethylene Glycol (PEG 400), Hydroxypropyl Methyl Cellulose (HPMC), aluminum foil, and non-woven plaster. The tools used in this research includes a rotary evaporator, water bath, oven, desiccator, calipers, petri dishes, beaker glasses, magnetic stirrer, hot plate, and pH meter.

Preparation of Pineapple Peel Simplicia

Pineapple peel (*Ananas comosus* L.) for this study was obtained from Bambu Kuning Market, Bandar Lampung City. The collected pineapple peels underwent a wet sorting process to remove dirt and other foreign materials, followed by sun drying for 3 days to obtain dry simplicia. The dried pineapple peel simplicia was then ground into a fine powder using a blender, ready for the extraction process (Ramadhan, et al., 2024).

Pineapple peel extraction was carried out using the maceration method. The powder was placed in a closed glass jar, then mixed with 96% ethanol at a ratio of 1:4. The jar was sealed and left to stand for 3 x 24 hours, with thorough agitation every 24 hours. The macerated mixture was then filtered through filter paper, and the filtrate was evaporated using a rotary evaporator at 40–50°C until a concentrated extract was obtained. The remaining residue was re-macerated with 96% ethanol at a 1:4 ratio for an additional 3 x 24 hours (Ramdhan, et.al., 2024).

Formulation of the Hydrogel Patch

The formulation of the pineapple peel hydrogel patch used a combination of PVA and HPMC as the base. This combination was chosen to prevent the formation of a hard film due to the high PVA content, and the inclusion of HPMC produced a more elastic gel. The optimal formula for the transdermal patch was found to have 6.127% HPMC and 2.373% PVA (Ilkhawati et al., 2023).

Table 1. Pineapple Peel Extract Hydrogel Patch Formulation

Material	Function	Control	F1	F2	F3
Pineapple Peel Extract	Active ingredient	-	10 %	20%	30%
PVA	Backing	2,5%	2,5%	2,5%	2,5%
PEG 400	Plasticizer	10%	10%	10%	10%
HPMC	Gel base	5%	5%	5%	5%
DMSO	Enhancer	3%	3%	3%	3%
Aquadest (ad)	Solvent	100 g	100 g	100 g	100 g

Description: control = formula without pineapple peel extract;
F1 = formula with 10% pineapple peel extract;
F2 = formula with 20% pineapple peel extract;
F3 = formula with 30% pineapple peel extract.

The formulation process begins with weighing the materials. PVA is dissolved in hot distilled water, and HPMC is developed in hot distilled water. The dissolved PVA is then mixed with the HPMC base. Pineapple peel extract is dissolved in 96% ethanol, and once dissolved, it is added to the hot water-dissolved HPMC and PVA mixture. PEG 400, comprising 10% of the hydrogel composition, is added, and the mixture is stirred for 20 minutes using a magnetic stirrer and hot plate. DMSO is then added, and mixing continues for an additional 10 minutes before pouring the formula into a mold. Each formula is labeled and the mold is placed in an oven to dry at 40°C for 24 hours. The formed layer is then removed and cut into 1 x 1 cm² pieces. These pieces are adhered to the adhesive side of non-woven plaster and stored in a dry, airtight container away from sunlight.

Characteristics Testing

After formulation, the hydrogel patches containing pineapple peel extract undergo a series of characteristic tests: organoleptic evaluation, pH test, weight uniformity test, moisture absorbency test, swelling ratio test, thickness test, and folding endurance test.

a. Organoleptic Evaluation

directly observing the shape, color, and odor of the hydrogel patch preparation that had been made (Harliantika & Noval, 2021).

b. pH Test

The pH test is performed on a 1 x 1 cm² hydrogel patch sample dissolved in 10 ml of hot distilled water and measured with a pH meter at a temperature range of 24-25°C. Transdermal preparations (including patches) with a pH of 4.5 to 7 are safe for skin use (Patel & Jani, 2016).

c. Weight Uniformity Test

Weight uniformity is tested by weighing 5 hydrogel patches from each formula using an analytical balance, then calculating the average weight and standard deviation. Good weight uniformity is indicated by a standard deviation ≤0.05 and deviation <5% (Fuziyanti et al., 2022).

d. Moisture Absorbency Test

The moisture absorbency test involves storing the hydrogel patches at room temperature in a desiccator for 24 hours, then heating them at 40°C in an oven for 24 hours, followed by reweighing. Good moisture absorbency is indicated by values not exceeding 10% (Fuziyanti et al., 2022).

e. Swelling Ratio Test

The swelling ratio is determined by comparing the mass of the hydrogel patch before (Wd) and after (Ws) testing at specific times. The test involves applying 8 mL of distilled water to a 1 x 1 cm² patch and weighing at various intervals (5, 15, 25, 35, 45, 55, and 60 minutes) (Rahayuningdyah, 2020). The swelling ratio is calculated using the formula:

$$Swelling\ \ ratio = \frac{Ws-Wd}{Wd} \times 100\%$$

$$\frac{Ws-Wd}{Wd} \times 100\%$$

(Rahayuningdyah *et al*., 2020).

f. Thickness Test

Patch thickness is measured with a micrometer accurate to 0.01 mm. Thickness is measured at three points on each patch, and the average thickness is calculated. An acceptable thickness is ≤1 mm (Fuziyanti et al., 2022).

g. Folding Endurance Test

Folding endurance is tested by folding the hydrogel patch sample repeatedly at the same point until it tears. The number of folds required to cause tearing is recorded. A patch is considered of good quality if it withstands more than 300 folds (Baharudin & Maesaroh, 2020)

3. RESULT AND DISCUSSION

After evaluating the hydrogel patches, including organoleptic tests, pH tests, weight uniformity tests, moisture absorbency tests, swelling ratio tests, thickness tests, and folding endurance tests:

a. Organoleptic Test

The organoleptic evaluation involves direct observation of the patch's form, color, and odor. The results show that the control formula is white and odorless, as it does not contain pineapple peel extract. The control patch is square, 1 x 1 cm in size, with a smooth and solid surface. Formula I has a light brown color, a characteristic pineapple odor, and a texture similar to the control. Formula 2 is dark brown, has a pineapple smell, and a slightly soft texture. Formula 3 is dark brown with a smooth surface but has a soft and brittle texture due to the high concentration of extract. The results of the organoleptic evaluation are shown in Table 2.

Table 2. Organoleptic Test Results

Formula	Color	Smell	Form and Characteristics	Documentation
Control	White	Odorless	Measuring 1 cm x 1 cm, smooth and dense texture	
F1	Light brown	The distinctive smell of pineapple	Measuring 1 cm x 1 cm, smooth and dense texture	
F2	Dark brown	The distinctive smell of pineapple	Measuring 1 cm x 1 cm, smooth textured, slightly soft	
F3	Dark brown to black	The distinctive smell of pineapple	Measuring 1 cm x 1 cm, smooth textured, slightly soft, brittle	

b. pH Test

The pH test is conducted to ensure that the pH of the hydrogel patch is compatible with the skin's pH. The pH of the hydrogel patch should fall within the range of 4.5-6.5, which matches the skin's pH, to avoid potential skin irritation. The pH ranges from day 1, 7, and 14 for the control formula to formula 3 are as follows: 7.87-8, 6.15-7, 3.92-5.09, and 3.72-4.35, respectively. The ideal pH range for topical preparations is 4.5-7. Therefore, the pH of formula 1 from day 1 to day 14 meets the ideal pH range for topical preparations.

Table 3. pH Test Results for Hydrogel Patch Preparations

Formula	pH		
	Day-1	Day-7	Day-14
Control	7.87	7.88	8
F1	6.15	6.90	7
F2	3.92	4.57	5.09
F3	3.72	4.30	4.35

Formulations with a pH range up to pH 4.5 - 7 are safe for use on the skin (Patel & Jani, 2016). As the concentration of pineapple peel extract increases, the pH of the formulation decreases (becoming more acidic), as shown in Table 2. This is due to the acidic nature of the pineapple peel extract. pH testing was conducted weekly over three weeks. The results indicate that the control formula, Formula 1 (F1), and Formula 2 (F2) have pH ranges that are close to the normal skin pH. Additionally, all formulas showed an increase in pH over time.

c. Weight Uniformity Test

The weight uniformity test aims to assess the differences in weight between each formulation, which can be influenced by the high hydrophilic nature of the polymer components. During the manufacturing process, the water content in the patch can increase its weight (Hermanto & Nurviana, 2019).

Table 4 shows that as the concentration of pineapple peel extract in the formulation increases, the weight of the formulation also increases. This is due to the non-evaporative nature of the pineapple peel extract compared to the solvent during the drying process. In this test, the control formula has a weight range of 85.2 - 100.5 mg with an average of 94.22 mg, F1 has a weight range of 201.3 - 217.5 mg with an average of 208.96 mg, F2 has a weight range of 245.1 - 255.1 mg with an average of 250.04 mg, and F3 has a weight range of 269.3 - 283.6 mg with an average of 278.18 mg.

Table 4. Weight Uniformity Test Results

Formula	Weight (mm)					Mean ± SD
	R1	R2	R3	R4	R5	
Control	93,1	100,5	85,2	94,0	98,3	94,22 ± 5,889
F1	217,5	210,2	213,6	202,2	201,3	208,96 ± 7,077
F2	254,3	255,1	250,3	245,1	245,4	250,04 ± 4,736
F3	281,8	283,6	281,5	274,7	269,3	278,18 ± 6,009

Note: R = Replication, SD = Standard Deviation

Good weight uniformity is achieved when the standard deviation is ≤0.05 and the deviation is <5% (Fuziyanti et al., 2022). However, the standard deviation for all formulas does not yet meet the requirements. The lowest standard deviation was found in Formula 2, indicating that the average weight of Formula 2 is more consistent compared to the other formulas. The

high standard deviation is influenced by the inconsistency in the size of the hydrogel patches. Weight uniformity is affected by the polymer components, which tend to absorb water. During the manufacturing process, water can easily be retained in the hydrogel patches during drying, leading to an increase in the weight of the produced hydrogel patches (Fuziyanti et al., 2022)

d. Moisture Absorption Test

The ability of the hydrogel to absorb moisture is an important parameter for assessing the effectiveness of the hydrogel patch. A lower percentage of moisture absorption indicates that the product is more stable and protected from microbial contamination. Table 5 shows the percentage of moisture absorption for each formula as follows: control formula 23.43%, Formula 1 22.97%, Formula 2 11.60%, and Formula 3 21.95%. A good moisture absorption value should not exceed 10% (Fuziyanti et al., 2022).

e. Swelling Ratio Test

The results of the moisture absorption test are shown in the following table 5. Table 5 indicates that none of the formulas meet this requirement, but Formula 2 comes closest with a moisture absorption percentage of 11.60%. High moisture absorption percentages can be influenced by the hygroscopic nature of the extracts used (Wardani & Saryanti, 2021).

Hydration or the increased ability to absorb water is reflected by an increase in the mass of the hydrogel patch. The ability of the hydrogel patch to absorb water is related to the formation of bonds during the cross-linking process. To monitor the swelling profile of the hydrogel patch, samples were allowed to swell for 60 minutes. The results can be seen in table 6

Table 5. Results of Absorption Test

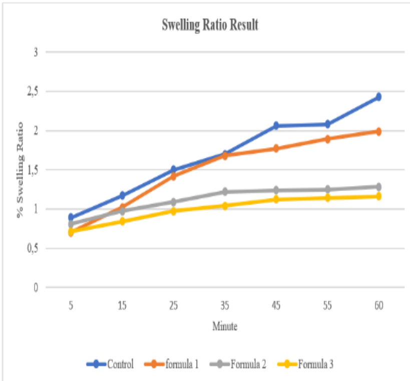
Formula	% Moisture Absorption Test
Control	23.43
F1	22.97
F2	11.60
F3	21.95
Mean ± SD	0,89 ± 0,126

Note : SD = Standard Deviation

Table 6. Swelling Ratio Test Results

Formula	% Swelling Ratio Minutes						Mean ± SD
	5’	15’	25’	35’	45’	55’	
Control	0.89	1.17	1.5	1.7	2.06	2.08	1,57 ± 0,436
F1	0.70	1.02	1.42	1.68	1.77	1.89	1,41 ± 0,462
F2	0.81	0.97	1.09	1.22	1.24	1.25	1,09 ± 0,162
F3	0.71	0.84	0.97	1.04	1.12	1.14	0,97 ± 0,198

Note : SD = Standard Deviation



Picture 2. Graph of Swelling Ratio Test Results

The observation results displayed in the graph show that the control formula has the best ability to absorb liquid, followed by Formula 1, Formula 2, and Formula 3. The data indicates that as the concentration of extract in the hydrogel patch increases, the patch's ability to absorb liquid decreases

f. Thickness Test

The ability of active ingredients to penetrate the skin can be influenced by the thickness of the hydrogel patch. A thinner patch is more effective in penetrating the skin because the transfer of active ingredients becomes more controlled (Hermanto & Nurviana, 2019).

Based on the measurements, the thickness of the hydrogel patches from each formulation meets the established standard of less than 1 (Fuziyanti et al., 2022). Thinner hydrogel patches are generally easier to use and more acceptable to users. If the hydrogel patch is too thick, the release of active ingredients becomes less effective. Factors that can influence the thickness of hydrogel patches include the size of the mold, the volume of the solution, and the total amount of solids in the solution.

Table 7. Thickness Test Results

Formula	Thickness (mm)			Mean ± SD
	R1	R2	R3	
Control	0,88	0,87	0,77	0,840 ± 0,06
F1	0,90	0,88	0,97	0,916 ± 0,05
F2	0,91	0,92	0,98	0,926 ± 0,04
F3	0,98	0,95	0,95	0,960 ± 0,05

Note: R = Replication, SD = Standard Deviation

g. Folding Endurance Test

The folding endurance test assesses the durability of the hydrogel patch against repeated folding. A patch that demonstrates good folding endurance is expected to be elastic and not easily torn during use. This test involves repeatedly folding the patch at the same point. A hydrogel patch is considered to have good quality if it can withstand more than 300 folds (Baharudin & Maesaroh, 2020). The results of the folding endurance test are presented in 8.

Table 8. Folding Power Test Result

Formula	Folding Power			Regulations	Interpretation of Results
	R1	R2	R3		
Control	>200	>200	>300	Good patch folding power is >200 folds (Galaktomanan et al., 2020)	Qualify
F1	>200	>200	>300		Qualify
F2	<200	<200	<300		Not Qualify
F3	<200	<200	<300		Not Qualify

The test results show that the folding resistance of the hydrogel patch from formulas 0 and 1 is considered good, as they can withstand more than 200 folds without tearing or becoming brittle. However, despite not being damaged, formula 1 shows clear fold marks after being tested 300 times. This occurs because formula 1 is thicker compared to formula 0. The use of a plasticizer in the hydrogel patch formulation can affect the elasticity and fold resistance of the hydrogel. In this formula, propylene glycol acts as the plasticizer.

4. CONCLUSION

Based on the testing results of hydrogel patches containing pineapple peel extract (*Ananas comosus* L.) it can be concluded that the concentration of pineapple peel extract as an active ingredient affects the organoleptic properties, pH of the formulation, absorption capacity, thickness of the formulation, and the absorption of the formulation. In this study, the hydrogel patch formulations with pineapple peel extract are divided into four types: control formula, formula 1, formula 2, and formula 3, with pineapple peel extract concentrations of 0%, 10%, 20%, and 30%, respectively. Based on the tests conducted, formula 1 with 10% extract content is the best compared to formulas 2 and 3. Therefore, the use of pineapple peel extract in hydrogel patch formulations can affect various characteristics of the hydrogel patch, and adding pineapple peel extract should be considered in hydrogel patch formulations.

Further evaluation of the stability of hydrogel patch formulations during storage and optimization of the formulation is needed to determine the product's shelf life, prevent degradation of active ingredients, and improve the efficiency of the hydrogel patch formulation.

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