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Hydrogel Eye Patch Combination of Tomato Extract and Astaxanthin as Anti-Aging

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ABSTRACT

Wrinkles are a signs of skin aging caused by intrinsic factors (dryness, thinning, wrinkles) and extrinsic factors like UV exposure, which increases Reactive Oxygen Species (ROS) and thereby triggering premature aging. Anti-aging efforts can be carried out through the use of cosmetic products, particularly topical agents containing antioxidants and cell regulators. This study aims to evaluate the physical and chemical characteristics, as well as the anti-aging effectiveness, of a combination of tomato extract and astaxanthin in the form of a hydrogel eye patch. The formulations were prepared in four variations, namely F0 as the base, F1 containing 1% tomato extract, F2 containing 1% astaxanthin, and F3 as a combination of both. Based on the test results, the best formula was F3, which contained a combination of tomato extract and astaxanthin. The evaluations conducted included organoleptic tests, weight and size uniformity, pH, swelling capacity, elasticity, and anti-aging effectiveness. The effectiveness test results showed that F3 provided the best result with a value of 61%. Statistical analysis using One-Way ANOVA showed a significance value of less than 0.05, indicating a significant difference between before and after the use of the hydrogel eye patch. Overall, the formulations F1, F2, and F3 met the applicable requirements and demonstrated that the combination of tomato extract and astaxanthin is effective for use in hydrogel eye patch formulations as an anti-aging agent, where as F0 did not meet the physical characteristics requirement, particularly in the pH evaluation, where the results exceeded the normal pH of human skin.

Keywords: antiaging, astaxanthin, tomato extract, hydrogel

Introduction

The skin area around the eyes is the most susceptible to premature aging due to its thinner epidermal thickness, lower lipid content, and higher exposure to oxidative stress from the environment (Kaur et al., 2021). The accumulation of free radicals causes collagen damage, decreased elasticity, the appearance of fine lines, and dark circles. This condition increases the need for innovative skincare products that are not only effective but also safe and based on sustainable natural ingredients (Lee &

Chen, 2020). To overcome this condition, cosmetic products are required that can reduce fine lines under the eyes. One of the eye preparations that is easy and comfortable to use is the hydrogel eye patch, which has the advantage of being simple and practical to apply. Basically, a hydrogel is a three-dimensional network structure formulated from certain natural and synthetic polymers, due to its ability to absorb and retain a considerable amount of water within its porous structure. Due to its high water absorption capacity, only very small molecules are able to pass through the hydrogel structure. This water retention property of hydrogels makes them an ideal candidate for use in controlled drug delivery systems (Ahsan et al., 2021)

Hydrogel eye patches absorb water, which causes them to swell and become highly flexible. Hydrogel eye patch preparations exhibit good elasticity, making them comfortable to use, and they function to cool, soothe, and moisturize the skin (Gery Umami et al., 2022). Hydrogel eye patches can moisturize dry skin, reduce wrinkles, dark circles, and puffiness under the eyes, as well as regenerate and tighten fatigued skin (Mask & Care, 2022). Two main groups of topical agents that can be used as components of anti-aging hydrogel eye patches are cell regulators and antioxidants. Lycopene and astaxanthin are included among compounds that exhibit both cell-regulating and antioxidant activities.

Tomatoes are one of the best sources of natural antioxidants. This fruit is rich in polyphenols and contains antioxidant compounds such as water-soluble vitamin C, as well as fat-soluble and hydrophobic compounds including vitamin E, β-carotene, and lycopene, along with flavonoids such as quercetin, glycosides, naringenin, chalcone, and chlorogenic acid, as well as potassium and folate, which are important for human health (Rao & Rao, 2017; Marti, Rosello, & Cornejo, 2016). These compounds can reduce oxidative stress, DNA mutations, malignancy, and other parameters of cellular damage (USDA, 2019). Hyaluronidase is an enzyme that can enhance absorption, dispersion, and drug delivery, increase tissue permeability, and reduce the viscosity of hyaluronic acid (Stern & Jedrezegas, 2019). Hyaluronic acid has a moisturizing effect on the skin by binding and retaining water molecules and contributes to the degradation of the extracellular matrix associated with wrinkle formation (Bukhari et al., 2018). Flavonoids play a role in the aging process because these compounds can scavenge Reactive Oxygen Species (ROS) and inhibit enzymes associated with aging (Panche et al., 2016).

Astaxanthin is a carotenoid pigment that occurs naturally in various marine organisms, particularly in the microalga Haematococcus pluvialis (Sitanggang, 2019). The antioxidant activity of astaxanthin has been demonstrated in several studies. Astaxanthin exhibits antioxidant activity that is up to 52 times stronger than that of vitamins and β-carotene. Astaxanthin possesses unique chemical properties due to its molecular structure. The presence of hydroxyl and carbonyl functional groups in keto-carotenoids makes astaxanthin a highly potent antioxidant (Liu et al., 2016). Astaxanthin inhibits the formation of Reactive Oxygen Species (ROS) and regulates the expression of enzymes that respond to oxidative stress, such as heme oxygenase-

1 (HO-1), which is a marker of oxidative stress and part of the regulatory mechanism involved in cellular adaptation to oxidative stress. Astaxanthin containing oleoresin and algal extract is used as an antioxidant agent in the formulation of hydrogels as anti-aging products (Davinelli et al., 2018).

Methodology

Materials and Instruments

The materials used in this study were tomato fruit extract, astaxanthin, xanthan gum, sodium alginate, propylene glycol, glycerin, sodium metabisulfite, DMDM hydantoin, rose fragrance, glucono delta-lactone, and deionized water. The instruments used in this study included laboratory glassware, a hotplate magnetic stirrer, a digital balance, an analytical balance, a pH meter, a texture analyzer, an overhead stirrer, and a Skin Moisture Analyzer SK-8.

Research Procedures

Sample Collection

The sample used was fresh tomato fruit (*Solanum lycopersicum* L.) that had reached maturity at 70–100 days and exhibited a red-colored skin surface. The samples were obtained from Bitingan Market, Kudus.

Preparation of Natural Deep Eutectic Solvent (NADES)

The NADES solvent prepared consisted of a combination of citric acid and sucrose with a predetermined molar ratio of 1:3 (M). Subsequently, 30% (v/v) deionized water was added to the NADES mixture, followed by mixing at a temperature of 80°C under stirring using a magnetic stirrer at 500 rpm until a stable solution was obtained, indicated by a clear mixture without precipitation, crystallization, or color change.

Extraction of Tomato Fruit (*Solanum lycopersicum* L.)

The extraction of tomato fruit (*Solanum lycopersicum* L.) was carried out using an ultrasonic method with NADES as the solvent. A total of 100 g of tomatoes were homogenized using a blender, then placed in an Erlenmeyer flask and dissolved in 500 mL of NADES solvent mixture. The extraction process was conducted using ultrasonication at 50°C for 30 minutes. After extraction, the resulting solution was filtered and stored in a dark container (Martinović et al., 2022).

Phytochemical Screening

Flavonoid Test

A total of 2 mL of extract was added with an adequate amount of hot water, then boiled for 5 minutes and filtered. A total of 5 mL of the filtrate was added with 0.05 mg of magnesium powder and 1 mL of concentrated HCl, then vigorously shaken. A positive result for flavonoid compounds of the flavonol group is indicated by the formation of red, yellow, or orange color (Aloanis et al., 2017).

Alkaloid Test

The sample extract was added with ammoniated chloroform, then shaken. The mixture was filtered and transferred into a test tube. Each filtrate was added with 0.5–1 mL of 2 N H_2SO_4, then shaken and allowed to stand. The upper layer of each filtrate was collected and transferred into three different test tubes. Each solution in the three test tubes was tested using Mayer, Wagner, and Dragendorff reagents. A positive result is indicated by the formation of a white precipitate indicate are potassium-mercury iodide complex (Mayer), brown precipitate indicate are potassium-iodine complex (Wagner), and orange precipitate indicate are potassium tetraiodobismuta complex (Dragendorff) (Endarini, 2016).

Tannin Test

The tomato extract was placed in a test tube, then added with 5% $FeCl_3$. The formation of a dark black solution indicates a positive result for for gallic tannins (Mawalia et al., 2022).

Saponin Test

The tomato extract was placed in a test tube, added with distilled water, and shaken for approximately 10 minutes. The formed foam was observed, then 2 N HCl was added and shaken again for ±10 minutes. The formation of stable foam with a height of 1–10 cm that does not disappear within approximately 10 minutes indicates the presence of saponins (Mawalia et al., 2022).

Phenolic Test

A total of 2 mL of tomato extract solution was added with 2 drops of $FeCl_3$. A positive result is indicated by the formation of green, red, purple, blue, or black color (Mawalia et al., 2022).

Procedure for the Preparation of Hydrogel Eye Patch

Table 1. Formulation of Hydrogel Eye Patch

No	Materials	Formula (% b/v)			
		F0	F1	F2	F3
1	Tomato Extract	-	1	-	1
2	Astaxanthin	-	-	1	1
3	Sodium Alginate	3	3	3	3
4	Xanthan Gum	0,50	0,50	0,50	0,50
5	Propylene Glycol	2,50	2,50	2,50	2,50
6	Glycerin	5,00	5,00	5,00	5,00
7	Sodium Metabisulfite	0,02	0,02	0,02	0,02
8	DMDM Hydantoin	0,10	0,10	0,10	0,10
9	Rose Fragrance	0,06	0,06	0,06	0,06
10	Aquadest ad	100	100	100	100

Note:
F0 = Hydrogel eye mask formula without extract (blank)
F1 = Hydrogel eye mask formula containing tomato extract
F2 = Hydrogel eye mask formula containing astaxanthin

F3 = Hydrogel eye mask formula containing a combination of tomato extract and astaxanthin

The preparation process of the hydrogel eye patch was carried out through the following steps. First, the weighed sodium alginate was added and stirred using a homogenizer for 10 minutes at a speed of 1800 rpm to form the gel base. Glycerin and xanthan gum were mixed and added into the gel base to form the hydrogel matrix. Stirring was continued at a constant speed. Subsequently, sodium metabisulfite was dissolved in 20 mL of deionized water, then mixed with tomato extract and astaxanthin. The solution was stirred until completely dissolved and homogeneous, then added into the gel base and stirred at a constant speed. Next, DMDM hydantoin was dissolved in propylene glycol and gradually added into a beaker containing the gel base until a semi-solid gel was formed. The semi-solid gel was then poured into molds and dried for 24 hours in an oven at a temperature of 40°C.

Evaluation

Organoleptic Observation

The formulation was observed for size, shape, color, and odor, as well as any changes in color and odor, using both black and white backgrounds.

Weight and Size of Hydrogel Eye Patch

The evaluation of weight and thickness of the hydrogel mask was conducted by taking five sheets of hydrogel masks and weighing them individually. The weight of each hydrogel mask was measured using a digital balance, while the length, width, and thickness were measured using a caliper.

Surface pH Test of Hydrogel Eye Patch

The hydrogel mask was allowed to swell for 2 hours in 100 mL of distilled water in a container, and the surface pH was measured using a pH meter.

Elasticity Test of Hydrogel Eye Mask

The hydrogel eye mask preparation was cut into a size of 6 cm in length and 2.5 cm in width, then manually stretched. A gentle pulling force was applied, and the time until the preparation broke or tore was recorded using a stopwatch. The tensile strength and elasticity level were calculated based on the measurement values using the following formula (Surini & Auliyya, 2017):

$$Elasticity = \frac{P1 - P2}{P2} x \ 100\%$$

Note:
P1 = Length before stretching

P2 = Length after stretching

Swelling Capacity of Hydrogel Eye Patch

Prepared hydrogel mask was cut into small pieces with dimensions of 1.2 cm × 1.2 cm × 0.04 cm (Lim et al., 2010). The pieces were then weighed and placed into a beaker containing 30 mL of distilled water. Water absorption was determined based on the following equation (Surini & Auliyya, 2017):

$$Swelling\ Capacity = \frac{W_n - W_o}{W_o} x\ 100\%$$

Note:
W_n = Weight of hydrated mask
W_o = Weight of dry mask before hydration

Anti-aging Effectiveness Test

The anti-aging effectiveness test, which had obtained ethical approval from the Research Ethics Committee of the Institut Teknologi Kesehatan Cendekia Utama Kudus, was conducted with inclusion criteria of 24 healthy female volunteers aged 20–35 years with aged skin conditions (dry skin, wrinkles, dullness, or hyperpigmentation), who were willing to participate as research subjects and to use the hydrogel eye patch. The test was conducted on the facial skin area. All volunteers were first assessed for baseline skin condition prior to treatment using the SK-8 device. The measured parameter was the percentage of moisture as an indicator of anti-aging effectiveness. The hydrogel eye patch was applied to the under-eye area of the volunteers and left in place for 20 minutes. After that, the hydrogel eye patch was removed and allowed to rest for 5 minutes to enable residual preparation to be absorbed. The facial skin condition was then re-evaluated after use using the SK-8 device (Mawalia et al., 2022).

Results and Discussion

Phytochemical Screening

Phytochemical screening was carried out to identify the content of secondary metabolites in natural ingredients. The secondary metabolites contained in tomato extract include saponins and flavonoids. Phytochemical screening is a preliminary stage that can provide an overview of the presence of certain compounds in natural materials. The results of phytochemical screening showed that the tomato extract gave positive results for flavonoids of the flavonol group. Flavonoids act as antioxidants by donating hydrogen atoms or through their ability to chelate metals, either in the form of glycosides (containing glucose side chains) or in free forms known as aglycones. The presence of flavonoid compounds, which exhibit high antioxidant activity comparable to vitamin C, contributes to anti-aging effects.

Flavonoids have been proven to provide benefits for skin health, including the potential to protect the skin from sunburn, as well as providing moisturizing and brightening effects, resulting in skin that is not only well-hydrated but also appears more radiant.

Table 2. Phytochemical Screening Results of NADES Extract of Tomato

No	Secondary Metabolites	Reagents	Observation	Result
1	Flavonoid	Mg powder + concentrated HCl	Deep red	+
2	Alkaloids	Mayer	No precipitate	–
		Dragendorff	No precipitate	–
		Bouchard	No precipitate	–
3	Tannin	Ferric chloride ($FeCl_3$) 5%	Orange	–
4	Saponin	Hot water + 2N HCl	Stable foam	+
5	Phenolic	$FeCl_3$	Orange color	–

Note: + = Positive result; – = Negative result

Evaluation

Organoleptic Test

Based on the results of the organoleptic test conducted on the physical appearance of the formulation, including aroma, color, texture, and shape, it was observed that all formulations had a rose fragrance, smooth texture, and a crescent-like shape. The crescent shape of the hydrogel corresponds to the contour of the under-eye area. Based on color observation, F0 (blank) exhibited a yellowish transparent color, while F1 showed a light orange color, F2 showed an orange color, and F3 showed a dark orange color. The brownish-orange coloration in F1, F2, and F3 was attributed to the natural dark orange color of tomato extract. Therefore, it can be concluded that increasing the concentration of the extract results in a darker color of the formulation, approaching the original color of the extract. This is supported by the study of Kadarul et al. (2023), which reported that higher extract concentrations produce darker and more intense coloration in the formulation.

Table 3. Evaluation Results of Hydrogel Eye Patch

Parameter	Average Results			
	F0	F1	F2	F3
Organoleptic				

a. Odor	Rose	Rose	Rose	Rose
b. Color	Yellowish clear	Orange	Light orange	Dark orange
c. Texture	Smooth	Smooth	Smooth	Smooth
d. Shape	Crescent	Crescent	Crescent	Crescent
Weight and Size				
a. Weight (g)	0.98	1.17	1.46	1.38
b. Size	6.3 × 2.3 cm	6.3 × 2.3 cm	6.3 × 2.3 cm	6.3 × 2.3 cm
c. Thickness	1.2 mm	1.2 mm	1.2 mm	1.2 mm
pH	8.13	5.7	6.3	5.9
Swelling Capacity	292	341	247	310
Elasticity	21%	18%	20%	20%

Note:
F0 = Hydrogel eye mask formula without extract (blank)
F1 = Hydrogel eye mask formula containing tomato extract
F2 = Hydrogel eye mask formula containing astaxanthin
F3 = Hydrogel eye mask formula containing a combination of tomato extract and astaxanthin

Weight and Size Results

The evaluation of the weight and size of the hydrogel was conducted to assess whether there were significant differences in the components of each formulation, as well as to determine the level of uniformity influenced by the dominance of the hydrophilic properties of the polymers used. During the preparation process, the tendency of water to be trapped within the patch material during drying may lead to an increase in the weight of the resulting patch. The thickness of the hydrogel eye patch also plays an important role in determining the ability of active substances to penetrate the skin. A thinner patch allows more effective penetration of active substances due to a more controlled diffusion process (Hermanto & Nurviana, 2019). Based on the data presented in Table 3, the evaluation of weight, size, and thickness of all four formulations indicates that the thickness falls within an acceptable range.

pH Test

The pH test was conducted to evaluate the pH of the hydrogel eye patch formulation to ensure its compatibility with the physiological pH of the skin, which generally ranges from 4.5 to 6.5 (Fatma Latifah, 2013). The skin under the eyes is known to be thinner and more sensitive compared to other skin areas; therefore, it is important to consider the pH value of the formulation, as it can influence the absorption of the preparation through the skin (Hasibuan et al., 2022). Surface pH measurements of the hydrogel were performed on four hydrogel eye mask samples, yielding average pH values of 8.13 for F0, 5.7 for F1, 6.3 for F2, and 5.9 for F3. Based on these results, the pH of hydrogels containing tomato extract, astaxanthin, and their combination falls within the acceptable skin pH range.

Swelling Capacity

The swelling capacity test was conducted to determine the percentage of the formulation's ability to swell. The increase in hydrogel mass represents the amount of water absorbed or the degree of hydration achieved. In a liquid medium, the hydrogel membrane undergoes swelling, indicating that the polymer is capable of absorbing the medium without dissolving. The results of the swelling capacity test are presented in Table 3. In this test, the hydrogel was immersed in water for 60 minutes to observe its swelling behavior. Based on Table 3, it was observed that up to 60 minutes, all formulations showed an increase in weight after hydration and did not exhibit syneresis, indicating that the hydrogel possesses good water retention capacity. The increase in weight of the formulation indicates that water was absorbed into the hydrogel during immersion in aquadest.

Elasticity

The elasticity test of the formulation was conducted to determine the percentage of elasticity possessed by the preparation. Elasticity represents the maximum ability of the formulation to be stretched before breaking. The required elasticity standard for skin preparations ranges from 30–115%. The results of the elasticity test are presented in Table 3. Based on the data in Table 3, it is known that the level of elasticity affects the flexibility of the formulation. The results showed that the hydrogel eye mask preparations tended to break or tear more easily, with elasticity values of 21% for F0, 18% for F1, 20% for F2, and 20% for F3. The obtained elasticity values indicate that the formulations did not meet the required standard for tensile strength. These results are closely related to the amount of plasticizer used. Plasticizers are excipients that function to improve the elasticity of the formulation. Increasing elasticity can be achieved by increasing the amount of plasticizers such as glycerol and propylene glycol (Indrawati, 2011). This is also supported by the study of Tamaela and Lewerissa (2007), which stated that the addition of plasticizers such as glycerol, sorbitol, and polyethylene glycol, which have low viscosity, can enhance the flexibility of the formulation.

Anti-aging Effectiveness Test

Moisture testing was conducted to evaluate how well the hydrogel eye patch can maintain skin hydration. Well-hydrated skin can prevent premature aging. Physiologically, the skin requires lipid and water content to maintain its function. The lipid layer on the skin surface and components within the stratum corneum are hygroscopic, enabling them to absorb water and form a system known as the natural moisturizing factor. The ability of the stratum corneum to bind water plays an important role in maintaining skin flexibility and elasticity (Tranggono & Latifah, 2007).

The highest increase in water content was observed in the group of volunteers who used the hydrogel eye patch containing a combination of tomato extract and astaxanthin. This indicates that the combination of tomato extract and astaxanthin in the hydrogel eye patch formulation enhances its ability to improve skin hydration.

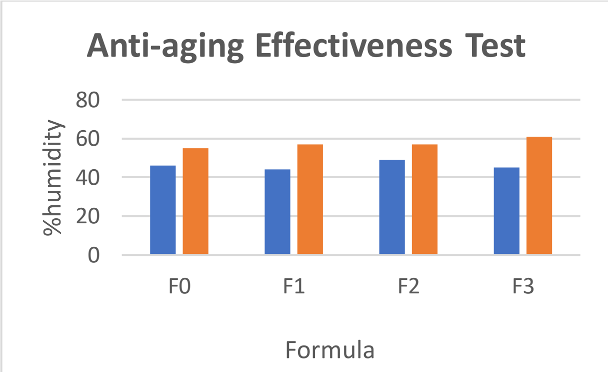

Figure 1. Percentage of Anti-aging Effectiveness

Based on the results of the anti-aging effectiveness test of the hydrogel eye patch formulations, it was observed that F0, F1, F2, and F3 showed differences among each formulation, which were attributed to the presence of different active substances in each formula. The average percentage of reduction showed that the best result was obtained in F3, namely the hydrogel eye patch formulation containing a combination of tomato extract and astaxanthin, with a value of 61%. This indicates the effect of topical agents, namely cell regulators and antioxidants. One of the compounds that acts as a cell regulator is flavonoids derived from tomato extract, while astaxanthin functions as an antioxidant component. The pharmacological activity of asiaticoside as a cell regulator includes increasing type I collagen synthesis produced by fibroblasts and improving tensile strength, which contributes to reducing wrinkles and strengthening skin tissue (Gancevicienе et al., 2012). Meanwhile, the pharmacological activity of astaxanthin as an antioxidant includes reducing collagen degradation by decreasing the concentration of free radicals (FR) (Ganceviciene et al., 2012).

Conclusion

The hydrogel eye patch formulations F1, F2, and F3 met the physical characteristics of a good hydrogel preparation, including organoleptic evaluation, weight, size, pH, swelling capacity, and elasticity. F3 produced the best formulation and demonstrated the highest anti-aging activity on the under-eye skin, with an anti-aging reduction percentage of 61%.

Declaration of Competing Interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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