THE INFLUENCE OF GLYCEROL ADDITION AND THERMAL TREATMENT DURATION ON THE CHARACTERISTICS OF EDIBLE FILM BASED ON KOLANG-KALING (Arenga pinnata)

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ABSTRACT

Research on the production of edible film from kolang-kaling with variations in glycerol addition and heating duration has been conducted with glycerol concentrations of 0; 0.5; 1; 1.5; and 2 mL, and heating times of 5, 10, 15, 20, and 25 minutes at a temperature of 70°C. This study aims to determine the effect of glycerol addition and heating duration on the characteristics of kolang-kaling edible film with the addition of Carboxymethyl Cellulose (CMC). The results showed that the best characteristics were obtained with the addition of 1 mL of glycerol with a heating time of 20 minutes, resulting in a film thickness of 0.053 mm, WVTR of 3.4632 g/m²/day, tensile strength of 14.316 MPa, biodegradability of 52.53%, and initial thermal degradation temperature of 257.66°C. Based on these results, the edible film from kolang-kaling has the potential to be used as an alternative eco-friendly food packaging to replace single-use plastic.

Keywords: CMC, Edible Film, Glycerol, Kolang-kaling, Heating

1. INTRODUCTION

1.1 Background

Plastic is one type of packaging material that is commonly used for food products. The use of plastic as packaging is quite popular because of its affordability and practicality. Indonesia ranks second in the world for plastic waste dumped into the oceans, after China, with about 187.2 million tons. The high usage of plastic is very concerning. As a result, plastic has become the type of waste that predominantly fills the oceans, accounting for up to 90% from the coastlines to the seabed (Suryono, 2019). Plastic is indeed practical for food packaging, but its use can pose health risks. Under hot conditions, acidic environments, or prolonged contact, plastic can degrade and release harmful compounds such as BPA and PCBs into food. Some types of plastic are more susceptible to this, especially when used for hot food. Therefore, safer and more environmentally friendly packaging alternatives are needed to maintain food quality and consumer health (Indraswasti, 2017).

One of the proposed solutions is edible film, which is a thin food packaging that can be eaten and easily decomposed. Edible film can protect products from physical and microbial damage, and is generally made from polysaccharides, proteins, or lipids. This material is in high demand because it is cheap, easily available, non-toxic, and biodegradable (Ismaya, 2020).

Kolang-kaling (Arenga pinnata) has the potential to be used as a raw material for edible film because it contains galactomannan that can form a gel. However, edible films made from natural materials are generally brittle and less elastic, so it is necessary to add additives such as Carboxymethyl Cellulose (CMC) to improve mechanical strength, and glycerol as a plasticizer to enhance the film's flexibility (Sitompul, 2017; Cengristitama, 2022).

In addition to the addition of materials, processing factors such as the duration of heating also affect the quality of edible films. Heating plays a role in the formation of polymer networks, reducing moisture content, and enhancing the mechanical properties of the film (Juliani et al., 2022).

Previous research by Arifin et al. (2021) on edible films made from corn stalk cellulose showed that variations in glycerol addition had a significant effect on tensile strength, but did not take into account the duration of heating. In fact, the combination of these two factors has the potential to produce edible films with more optimal physical and mechanical properties (Umar & Setiawan, 2022).

Based on this, this research was conducted to determine the effect of glycerol variation and heating duration on the characteristics of edible films made from kolang-kaling. This study is expected to produce edible films of good quality and has the potential to be an environmentally friendly alternative to plastic.

2. RESEARCH METHODS

2.1 Research Place

This research was conducted in the Oil and Gas Processing Laboratory, Department of Chemical Engineering, Lhokseumawe State Polytechnic.

2.1 Tools and Materials

2.2.1 Tools used

The tools used in this research include analytical balances, 50 mL graduated cylinders, 250 mL and 100 mL beakers, blenders, magnetic stirrers, hot plates, drop pipettes, petri dishes, stirrers, ovens, molds measuring 20×20 cm, desiccators, screw micrometers, tensile strength instruments, as well as Thermal Gravimetric Analysis (TGA).

2.2.2 Materials used

The ingredients used in this research include kolang-kaling fruit, glycerol, Carboxymethyl Cellulose (CMC), and aquadest.

2.3 Experimental Treatment Design

2.3.1 Fixed Variables

- Kolang-kaling porridge : 500 gr
- CMC : 2 gr
- Heating Temperature : 70℃

2.3.2 Independent Variables

- Heating time: (5, 10, 15, 20, and 25) minutes
- Glycerol volume: (0; 0.5; 1; 1.5 and 2) mL

2.3.3 Dependent Variable

1. Thickness Test
2. Water Vapor Transmission Rate (WVTR) Test
3. Tensile Strength Test
4. Biodegradability Test

2.4 Experimental and Testing Procedures

2.4.1 Making Kolang-kaling Fruit Puree

1. Prepare the kolang-kaling raw materials.
2. Wash the kolang-kaling thoroughly to remove dirt.
3. Cut the kolang-kaling meat into small pieces to facilitate the crushing process.
4. Place the kolang-kaling pieces into the blender, add water in a 1:1 ratio (weight/volume), and blend until smooth.
5. Strain the blended mixture using a sieve to obtain a smooth texture, resulting in fruit puree.

2.4.1 Preparation of Edible Film

1. Weigh 20 grams of kolang-kaling puree.
2. Place the weighed kolang-kaling puree into a 250 mL beaker, then add aquadest until the total volume reaches 100 mL.
3. Heat on a hot plate at 70°C while stirring with a magnetic stirrer for (5, 10, 15, 20, and 25) minutes.
4. Add 2 grams of CMC (Carboxymethyl Cellulose) into the solution, then stir again until homogeneous.
5. Next, add glycerol in amounts of (0; 0.5; 1; 1.5; and 2) mL into the

solution, stir again until the designated time is reached.

6. After reaching the heating time, turn off the hot plate.
7. Cool the solution until the temperature reaches 40°C.
8. Pour the cooled solution into a prepared mold with dimensions of 20x20 cm.
9. Dry the mixture for approximately 2-3 hours using an oven at 60°C until a film layer is formed.
10. Once dry, remove the edible film from the mold and it is ready for testing.

3. RESULTS AND DISCUSSION

3.1 Research Results

Table 3.1 Observation Data on Edible Film Products Based on Kolang-kaling

Heating Time (minutes)	Glycerol (mL)	Thickness (mm)	WVTR (g/m²/ day)	Tensile Strength (MPa)	Biodegradation (%)
5	0	0.086	10.1859	5.174	69.61
	0.5	0.072	6.7227	7.133	65.67
	1	0.057	4.6855	10.42	55.00
	1.5	0.050	8.1487	8.557	60.59
	2	0.048	9.1673	4.875	62.12
10	0	0.085	9.9822	6.053	69.27
	0.5	0.070	6.5189	7.743	65.35
	1	0.056	4.2781	10.882	54.04
	1.5	0.049	7.7413	10.086	58.79
	2	0.047	8.9636	5.840	61.00
15	0	0.082	9.9822	6.518	67.33
	0.5	0.069	6.1115	8.130	63.50
	1	0.054	3.8706	11.771	52.26
	1.5	0.047	7.5375	11.614	55.33
	2	0.045	8.7599	7.244	60.90
20	0	0.081	9.7784	7.315	67.82
	0.5	0.067	5.9078	9.328	64.04
	1	0.053	3.4632	14.316	52.53
	1.5	0.044	7.1301	13.409	57.29
	2	0.043	8.3524	13.320	60.70
25	0	0.081	9.5747	7.249	68.47
	0.5	0.066	5.0929	9.212	64.68
	1	0.051	3.2595	13.739	52.79
	1.5	0.044	6.7227	13.159	58.50
	2	0.043	8.3524	13.227	60.10

3.2 Discussion

Research on edible films based on kolang-kaling was conducted using the solvent casting method, where the materials are dissolved, heated, cast, and dried. Variations in heating time and glycerol volume were examined to observe their effects on the film characteristics through several test parameters including thickness, WVTR, tensile strength, biodegradability, and thermal stability.

3.2.1 Film Thickness Testing

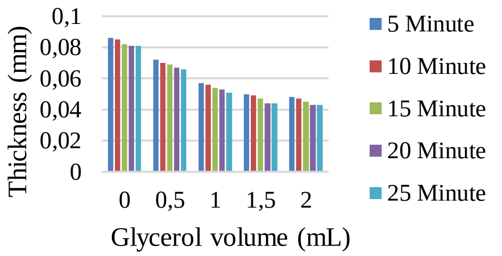

Figure 3.1 Thickness Graph (mm) Against Glycerol Volume Based on Heating Time

The thickness of the kolang-kaling film shows variations influenced by the duration of heating and the addition of glycerol as a plasticizer. Generally, the longer the heating time (5–25 minutes), the thickness of the film decreases, from a range of 0.048–0.086 mm to 0.043–0.081 mm. This decrease is due to increased water evaporation from the film solution, which makes the film structure denser.

At 5 minutes of heating, water evaporation is still limited, so the film has a high thickness, especially without glycerol. The addition of 2 mL of glycerol produces the thinnest film because glycerol reduces the viscosity of the galactomannan solution and accelerates leveling during printing. This trend is consistent up to 25 minutes of heating, where the film without glycerol remains the thickest and the film with glycerol is the thinnest.

Heating for 10 to 20 minutes shows a gradual decrease in thickness. This occurs because hydrophilic galactomannan absorbs water, but over time the water evaporates, and the film becomes denser. Glycerol continues to function to reduce the rigidity of the film by disrupting the interactions between galactomannan molecules and maintaining flexibility.

At 25 minutes of heating, the thickness of the film begins to stabilize. This indicates that water evaporation has nearly reached its maximum point, and the film structure has formed perfectly. Glycerol plays a crucial role in reducing surface tension, maintaining homogeneity, and producing a more flexible and uniform film.

Overall, galactomannan serves as the main structural component of the film, while glycerol acts as an effective plasticizer in reducing thickness, enhancing the spread of the solution, and improving the mechanical properties of the film.

3.2.2 Testing of Water Vapour Transmission Rate (WVTR)

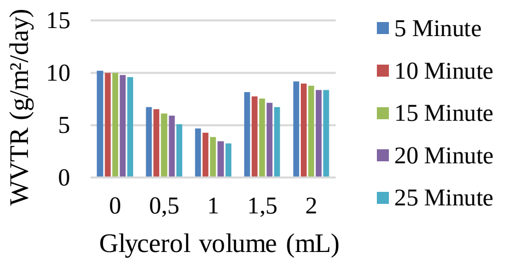

Figure 3.2 WVTR (g/m²/day) Graph Against Glycerol Volume Based on Heating Time

The Water Vapor Transmission Rate (WVTR) value of the kolang-kaling film shows a decrease as the heating time and glycerol volume increase. At 5 minutes of heating, the WVTR ranges from 10.1859 g/m²/day (without glycerol) to 9.1673 g/m²/day (with 2 mL of glycerol). This value is still high because the evaporation of water is not yet optimal, so the film structure is not dense.

With heating for 10 to 15 minutes, the WVTR decreases to 9.9822–8.7599 g/m²/day, indicating that the drying process begins to be effective and the film structure becomes tighter. Galactomanan starts to form a more orderly matrix network, while glycerol plays a role in maintaining flexibility without compromising the density of the film.

At 20 minutes, the WVTR continues to decrease to 9.7784–8.3524 g/m²/day. This indicates an increase in the density of the film structure due to more complete water evaporation. Glycerol continues to function as a plasticizer that supports the flexibility of the film without sacrificing its resistance to water vapor transmission.

Heating for 25 minutes resulted in the lowest WVTR, which is 9.5747–8.3524 g/m²/day, indicating that the film structure has formed perfectly and is physically stable. Galactomannan creates a dense network that effectively hinders water vapor permeability, while glycerol maintains a balance between the flexibility and compactness of the film structure.

Overall, WVTR decreases with increasing heating duration and glycerol volume. Glycerol contributes to the formation of flexible and homogeneous films, while adequate heating reinforces the internal structure of the film through the formation of intermolecular bonds in galactomannan. The combination of these two factors is crucial for producing films with good water vapor barrier properties that meet the standards for functional food packaging applications.

3.2.3 Tensile Strength Testing

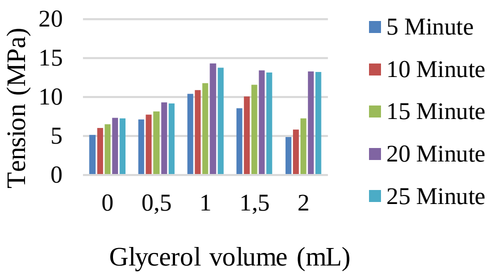

Figure. 3.3 Tension (MPa) Graph Against Glycerol Volume Based on Heating Time

The tensile strength of the kolang-kaling film is influenced by the combination of glycerol volume and heating duration. After 5 minutes of heating, the tensile strength ranges from 5.174 to 8.557 MPa. The addition of glycerol up to 1.5 mL increases tensile strength as it helps to reduce the rigidity of the film structure. However, at 2 mL of glycerol, tensile strength decreases, indicating that excess glycerol weakens the film structure.

Heating for 10 to 15 minutes shows an increase in tensile strength, reaching 11.771 MPa at 1 mL of glycerol at the 15th minute. This indicates that heating helps to strengthen the bonds between galactomannan molecules, while glycerol maintains the flexibility of the film.

At 20 minutes, the highest tensile strength is achieved, which is 14.316 MPa with the addition of 1 mL of glycerol. The film structure at this duration is denser due to maximum water evaporation, making the bonds between galactomannan molecules more stable. Glycerol continues to maintain the elasticity of the film without reducing its strength.

At 25 minutes, the tensile strength slightly decreases but remains high (7.993–13.739 MPa), indicating that the film structure has achieved stability. The addition of moderate amounts of glycerol (1–1.5 mL) still provides the best results, while excessive amounts can weaken the mechanical integrity of the film.

Overall, the combination of 20 minutes of heating and 1 mL of glycerol is the most optimal condition for producing films with the highest tensile strength and a balanced structure between strength and flexibility. Galactomannan as the main component forms a strong film network when heated, while glycerol helps maintain the film's flexibility to prevent it from cracking or breaking easily.

3.2.4 Biodegradation Testing

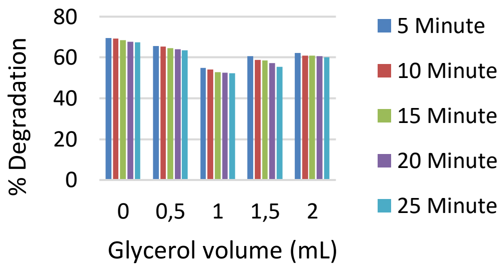

Figure. 3.4 Graph of % Degradation Against Glycerol Volume Based on Heating Time

The biodegradation level of kolang-kaling film is influenced by the volume of glycerol and heating time. At a heating time of 5 minutes, the percentage of biodegradation ranges from 69.61% (without glycerol) to 62.12% (2 mL of glycerol). The addition of glycerol reduces the biodegradation rate because it strengthens and tightens the film structure, thereby slowing down the decomposition process by microorganisms. However, since the heating duration is still short, the film structure has not formed a solid structure, making the film without glycerol more brittle and easier to decompose.

As the heating time increases to 10–15 minutes, the level of biodegradation continues to decrease, indicating that the film structure becomes increasingly dense and organized. Glycerol still influences the reduction of degradation, but the entire film remains classified as biodegradable, with a value above 60%. Galactomannan in the coconut jelly forms a gel network that becomes more stable due to heating, and glycerol enhances the flexibility of the film, although at the cost of the degradation rate.

After 20 minutes of heating, the film shows the best balance between strong structure and degradability. The biodegradation value ranges from 67.82% to 60.7%, depending on the glycerol volume. The film with 1 mL of glycerol demonstrates optimal characteristics: sufficiently strong and flexible, yet still capable of being degraded by environmental microorganisms. Heating for 25 minutes results in a completely stable film structure, with a biodegradation value ranging from 68.47% to 60.1%. There is no significant decrease compared to the previous time, indicating that the structure has reached maximum stability. Although the addition of glycerol still reduces the degradation rate, all films remain biodegradable, making them safe for the environment.

Overall, the addition of glycerol lowers the biodegradation rate as it increases the strength and density of the film network. On the other hand, longer heating times strengthen the galactomannan bonds through the process of water evaporation, forming a denser and more stable film structure. The combination of 20 minutes of heating and the addition of 1 mL of glycerol is the optimal condition to produce films that balance mechanical strength, flexibility, and degradability in the environment. Therefore, adjusting these two parameters is crucial to designing biodegradable films suitable for eco-friendly packaging applications.

3.2.5 Thermal Stability Testing

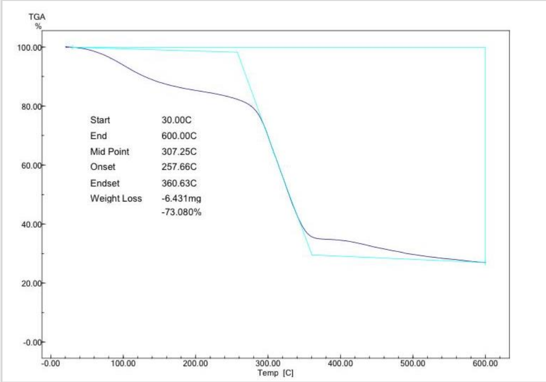

Figure. 3.5 Thermal Analysis Graph (Temperature (°C) Versus Remaining Sample Mass (%))

The results of the thermal analysis show that significant thermal degradation begins to occur in the temperature range of 257.66°C (onset) to 360.63°C (endset), with the midpoint of degradation at a temperature of 307.25°C. Below 257.66°C, the sample shows no drastic mass loss, indicating that the film has good thermal stability at low to medium temperatures. The recorded mass loss of 6.431 mg or 73.08% of the initial mass indicates that the main component of the edible film is organic material that is easily decomposed at high temperatures. The remaining mass of about 26.92% at the final temperature (600°C) may consist of carbon residue or organic matter that has not thermally degraded. Overall, the edible film with a glycerol volume of 1 mL and heating time of 20 minutes demonstrates adequate thermal performance, particularly for applications involving the heating of food materials that do not involve exposure to high temperatures above 257.66°C.

4. CONCLUSION

4.1 Conclusion

Based on the results of the research that has been carried out, the following conclusions can be drawn:

1. The heating time affects the physical, mechanical, and biodegradation properties of the edible film. The optimal duration of

15 to 20 minutes produces a film with a thickness of 0.043mm to 0.053mm, with the highest tensile strength of 14.316 MPa at 20 minutes, as well as WVTR showing good water vapor resistance. All treatments showed biodegradation >50% within 3 days. Galactomannan from kolang-kaling plays a role in forming a dense and stable film matrix during the heating process.

2. The addition of glycerol affects the flexibility, strength, and barrier properties of the film. The best treatment is the addition of 1 mL of glycerol and a heating time of 20 minutes, resulting in a film with a thickness of 0.053 mm, tensile strength of 14.316 MPa, WVTR of 3.4632 g/m²/day, and is also biodegradable (>50%), all conforming to JIS standards. The treatment of 1 mL of glycerol and a heating time of 20 minutes shows good thermal stability with an onset degradation temperature of 257.66°C and a remaining mass of 26.92% at 600°C. Galactomannan in the water chestnut supports good interaction with glycerol, maintaining the flexibility while ensuring the stability of the film structure.

4.2 Suggestions

Further research regarding the shelf life and stability of edible films is needed, especially regarding the effects of temperature and environmental humidity. This is important because glycerol-based films tend to shrink over storage time, resulting in increased thickness and potentially affecting their physical and functional properties. Periodic evaluation through testing of physical and functional stability is necessary to ensure that the films remain stable and suitable for use in food industry applications.

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