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Effect of Using Pedada Fruit *(Sonneratia caseolaris)* Pectin With Glycerol as Edible Coating

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A B S T R A C T

Pectin, a natural polysaccharide, is widely utilized in the food industry, particularly as a base material for edible coatings due to its film-forming ability. Despite its potential, Pedada fruit (Sonneratia caseolaris), a mangrove species rich in pectin, remains an underutilized resource. This study aims to explore the application of pectin extracted from pedada fruit as a component of edible coatings, adding glycerol as a plasticizer to enhance flexibility and reduce brittleness commonly observed in pure pectin films. A completely randomized design (CRD) with a factorial pattern was employed, consisting of two factors: pectin concentration (1%, 2%, and 3%) and glycerol concentration (1%, 2%, and 3%), each replicated three times. The data were analyzed using Analysis of Variance (ANOVA) at a 5% significance level, followed by Duncan's Multiple Range Test (DMRT) for treatments showing significant differences. Results indicated that increasing concentrations of pectin and glycerol significantly affected the edible coating's water vapor transmission rate, film thickness, and viscosity. The optimal formulation was achieved with 3% pectin and 2% glycerol, yielding a water vapor transmission rate of 4.083 g/m²/day, film thickness of 0.128 mm, and viscosity of 1022.23 mPa·s. These findings highlight the potential of pedada-based pectin as an eco-friendly alternative for sustainable food packaging solutions.

Contribution to Sustainable Development Goals (SDGs):
SDG 3: Good Health and Well-being
SDG 9: Industry, Innovation, and Infrastructure
SDG 12: Responsible Consumption and Production
SDG 13: Climate Action
SDG 15: Life on Land

1. INTRODUCTION

1.1. Research Background

Edible coating is a thin layer that can be eaten and serves as an artificial barrier to water vapor, oxygen, and carbon dioxide, and can reduce water activity on the material's surface to slow down damage [1]. The components that make up edible films and coatings are grouped into hydrocolloids, lipids, and composites. The polysaccharide group is the most widely used group in the manufacture of edible coatings [2]. Polysaccharides used for making edible films or coatings are pectin, chitin, chitosan, and starch [3].

One source of natural pectin that has not been widely utilized is pedada fruit (Sonneratia caseolaris). Pedada fruit (Sonneratia caseolaris) is one of the natural preparations that has the potential as a raw material for making edible coatings because it contains pectin as a gelling agent. It has been reported that pedada fruit contains 11.98% pectin [4]. Based on the pectin content of pedada fruit, it is quite potential to be developed as a source of pectin.

Good quality pectin refers to the International Pectin Proceducers Association (IPPA) quality standards. Research on pedada fruit pectin extraction has been conducted, but has not been widely utilized. The potential of pedada fruit as a source of pectin is very large, given its physical and chemical properties that allow it to be extracted and developed as a raw material for making environmentally friendly edible coatings. However, edibles made from pure polymers tend to be brittle and crack easily [3], so adding plasticizers such as glycerol is needed to increase the flexibility and elasticity of the coating.

Glycerol is a water-soluble plasticizer that forms hydrophilic films such as pectin, starch, and protein [5]. The addition of glycerol can reduce intermolecular forces between polymer chains, thus making edible coatings more flexible, transparent, and not easily cracked [6]. Research by [7] proved that the application of edible coating with a concentration of 2% apple pectin with the addition of 1% glycerol plasticizer has the best edible properties with edible characteristics that meet Japanese Industrial Standards with a film thickness of 0.06 mm, tensile strength of 17.10 MPa and water vapor transmission rate of 5.955 g/m2/hour. Research by [8] also showed that edible coating treatment with 3% pectin concentration and 2.5% glycerol can maintain the quality of mustard fruit better than mustard fruit without coating. Considering these things, it is necessary to research the utilization of pectin from pedada fruit and glycerol as a base material for edible coatings.

1.2. Literature Review

Pedada fruit is one of the few mangrove species that thrive in Indonesia. Pectin is a natural substance found in most food plants. The level of fruit maturity also affects the pectin content produced because the composition of protopectin, pectin and pectic acid content in the fruit varies greatly and depends on the degree of fruit maturity [9]. [10] reported that pedada fruit contains 11.98% pectin content so that pedada fruit can be used as an alternative source of pectin. Pectin is widely used as a functional component in the food industry because it can form a gel.

Extraction is a process of separation from solid or liquid materials with the help of solvents. The solvent used must extract the desired substance without dissolving other materials [11]. Extractant solutions (solvents) that can be used in the process of extracting pectin from fruit are water, alcohol, acid solutions, and polyphosphates [12]. According to Ref. [13], changes in pectin compounds are caused by protopectin hydrolysis in the extraction of pectin. The process causes protopectin to turn into pectinate (pectin) by heating in acid at a certain temperature and extraction time.

Microwave-assisted extraction (MAE) is an extraction technique that combines microwave energy and conventional extraction techniques with solvents [14]. MAE uses the principle of dielectric heating involving microwave [15]. Microwave is able to provide more even heat so that it can produce more pectin yield with low energy consumption in a relatively short time [16]

Edible film coatings should have good elasticity and flexibility, low brittleness, high toughness to prevent cracking during handling and storage. Therefore, plasticizers with small molecular weight (non-volatile) are usually added to the formation of hydrocolloid films to modify the flexibility of edible films such as starch, pectin, gel, and protein. One type of plasticizer that is widely used so far is glycerol. Glycerol is one of the plasticizers that functions to reduce the brittleness of biodegradable films. Its use can increase the plastic properties of biodegradable films, and reduce intermolecular forces along the polymer chain, making the film flexible and plastic [17]. The use of glycerol as a plasticizer will produce an attractive, clear, and shiny appearance. [6].

Table 1. Pectin quality standards based on International Pectin Producers Association (IPPA) grades

No	Quality Factor	Content
1	Gel strength, min grade	150
2	Methoxyl Content	>7, 12
	• High methoxyl pectin, %	2,5 – 7,12
	• Low methoxyl pectin, %	
3	Moisture content, %max.	12
4	Ash content, %max.	10

Edible coating is a thin layer of material that can be eaten or used as a wrapping product that can provide selective resistance to gas and water vapor transmission and mechanical damage [18]. The selected coating material must meet several criteria as an edible coating, namely being able to withstand oxygen and water vapor, colorless, tasteless, does not cause changes in food properties and must be safe for consumption.

According to Ref. [2], polysaccharide is the most widely used group in manufacturing edible coatings. The nature of this hydrocolloid film is generally water soluble, so it is beneficial for its use. The mechanism of polysaccharide-based edible formation is by breaking the polymer part to re-form the polymer chain into a film or gel matrix. The quality of edible film is seen from its physical properties, including optical properties in the form of transparent color so that the coated product remains visible, water vapor transmission rate, barrier properties against gas and water vapor, and mechanical properties such as tensile strength, thickness, elasticity (young modulus) [19].

Table 2. Edible quality standard values based on Japanese Industrial standard (JIS)

No	Quality Factor	Content
1	Thickness	Maximum 0,25 mm
2	Water Vapor	Maximum 7 $g/m^2/day$
3	Transmission Rate	Maximum 10 $g/m^2/hour$

2. MATERIALS AND METHODS

The materials used are ripe pedada (Sonneratia caseolaris) fruit with a soft texture obtained from mangrove farmers in Surabaya City; the materials used in the analysis are HCI 0.05 N, ethanol 96%, distilled water, glycerol, $CaCl_2$, NaCl, NaOH 0.25 N, NaOH 0.1 N, PP (phenolphthalein) indicator.

The tools used are basin, crock pot, sieve, spoon, measuring cup, 80 mesh sieve, stove, baking sheet, cabinet dryer, microwave, analytical balance, blender, erlenmeyer, beaker, stirrer, funnel, dropper pipette, cup, oven, desiccator, burette, volumetric flask, penetrometer, viscometer.

This study used a completely randomized design (CRD) factorial pattern with two factors with three replications. The data obtained were analyzed using Analysis of Variance (ANOVA) at the 5% level. If there are significant differences between treatments, further tests with Duncan's Multiple Range Test (DMRT) at the 5% level are used. From the combination of the two treatment factors, 9 samples were obtained as follows:

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Table 3. Combination of Treatments of this Research

Code	Pedada Pectin (%)	Glycerol (%)
A1B1	1	1
A1B2	1	2
A1B3	1	3
A2B1	2	1
A2B2	2	2
A2B3	2	3
A3B1	3	1
A3B2	3	2
A3B3	3	3

2.1. Methods of Making Pedada Fruit Flour

The process of making pedada flour includes the preparation of raw materials, namely pedada fruit (Sonneratia caseolaris), peeling and washing, blanching at 80°C for 15 minutes, softening the fruit, filtering, drying in a cabinet at 60°C for 18 hours, grinding and sieving [10].

2.2. Pectin Extraction of Pedada Fruit Flour

The pedada fruit pectin extraction process was carried out using 0.05N HCL solvent using the microwave assisted extraction (MAE) method with a heating time of 6 minutes and 450 Watt power. Pectin obtained from this extraction was analyzed including yield, water content, and methoxyl content.

2.3. Preparation of Edible Coating

The process of making edible coating is done by weighing pectin flour 1 gram, 2 grams, and 3 grams, then dissolving it with 100 ml distilled water, after mixing, glycerol is added as much as 1ml, 2ml, 3ml until the solution is homogeneous. Furthermore, the solution was heated at 40˚C and stirred for 15 minutes. Then, the solution was cooled at room temperature. Then the edible coating solution was analyzed including thickness, solution viscosity, and water vapor transmission rate (WVTR).

3. RESULT AND DISCUSSION

3.1. Raw Material Analysis

The results of pectin analysis of pedada fruit that will be used as edible coating can be seen in Table 4.

Table 4. Pectin analysis results of pedada fruit

Components	Pedada fruit pectin	Literature	
		Pedada fruit pectin [20]	Pedada fruit pectin [10]
Yield	14,45	13,06	14,92
Water Content	5,18	5,55	5,24
Methoxyl Content	5,69	9,44	5,68

Based on the results of the analysis in Table 3, the yield, water content, and methoxyl content of pectin are not much different from the literature of [20] but different from the literature of [10].This is because in this study and the research conducted by [20] the pectin extraction method used was the microwave assisted extraction (MAE) method, while in the research of [10] using the conventional pectin extraction method. Extraction using the MAE method is thought to be more effective and efficient than conventional extraction methods because in traditional extraction, heat is transferred from the heating medium (container) to the inside of the sample, while in MAE heat is generated from the friction of cell molecules in the sample. In conventional extraction methods, heat transfer from outside to inside makes the extraction process less efficient because the heat source takes time to reach the sample cell molecules [21]. So theoretically, this heat energy affects the reaction rate. The more radiation energy absorbed, the greater the heat energy received by the material, so the reaction rate is faster and the product formed as a yield is higher [22].

The water content results in the three studies are not much different, in this study and [20] used a drying time of 8 hours. Meanwhile, [10] reported using a longer drying time of 18-20 hours. This shows that the MAE method and conventional methods have different heating mechanisms. The MAE method using microwaves can produce rapid and even heating from within the material, so as to evaporate more water in the material quickly. This will facilitate drying and result in lower pectin moisture [23].

Methoxyl levels in this study when compared with the results of research by [10] the methoxyl pectin levels they obtained reached 9.44%, or classified as high methoxyl pectin (HMP). The difference in results obtained is thought to be due to differences in extraction methods, harvest age, fruit varieties, and climate in the area of origin of mangrove fruit, which is different from previous studies. However, the results of the methoxyl content in this study are not very different from the results reported by [20], who also used the MAE method. This similarity indicates that the use of the same extraction method, coupled with a similar drying process and extraction conditions, contributed to the consistent methoxyl content results. Conventional extraction methods tend to involve longer heating times, which allows re-esterification reactions to occur, thus increasing the methoxyl content readings. On the other hand, the MAE method is faster and more efficient, minimizing component degradation and keeping the pectin structure stable without significantly increasing the methoxyl content.

In terms of application, the low methoxyl content obtained in this study supports the formation of an effective edible coating layer, because LMP is able to produce a more stable and semipermeable film. This is in line with the opinion of [24] who stated that LMP has the ability to form a more rigid gel and is suitable for fruit preservation applications.

3.2. Edible Coating Analysis

3.2.1. *Water Vapor Transmission Rate*

Based on the analysis of variance, there was no significant interaction ($p \geq 0.05$) between the treatment of pedada fruit concentration and glycerol on the water vapor transmission rate of edible coating, but each treatment had a significant effect ($p \leq 0.05$) on the water vapor transmission rate of edible coating. The average value of water vapor transmission rate of edible coating obtained in the treatment of pectin concentration of pedada fruit ranged from 1.39-4.78 g/m2/day. Edible with the lowest water vapor transmission rate in this study was found in the treatment of 1% pedada fruit pectin concentration with the addition of 1% glycerol, which amounted to 1.39 g/m2/day. While the edible with the highest water vapor transmission rate in this study was found in the edible treatment with 3%

concentration of pedada fruit pectin with the addition of 3% glycerol, which amounted to 4.78 g/m2/day.

Table 5. Analysis result of edible coating

Pedada Pectin (%)	Glycerol (%)	Water Vapor Transmission Rate ($g/m^2/day$)	Thickness (mm)	Viscosity (mPa.s)
1	1	1.39±0.077	0.02 ± 0.008	693.62 ± 0.701[a]
1	2	1.53±0.064	0.04 ± 0.009	719.63 ± 0.558[b]
1	3	2.13±0.365	0.05 ± 0.001	767.10 ± 0.654[c]
2	1	2.74±0.269	0.08 ± 0.009	782.32 ± 0.828[d]
2	2	3.04±0.303	0.09 ± 0.007	806.48 ± 0.679[e]
2	3	3.21±0.312	0.11 ± 0.007	903.72 ± 0.852[f]
3	1	3.70±0.338	0.12 ± 0.010	931.22 ± 0.651[g]
3	2	4.08±0.076	0.13 ± 0.012	1022.23± 0.701[h]
3	3	4.78±0.277	0.14 ± 0.006	1107.55 ± 0.823[i]

Based on the table 5, the higher the concentration of pedada fruit pectin, the higher the water vapor transmission rate of the edible coating produced. The increase in the water vapor transmission rate (WVTR) value of the edible coating formed is due to pectin's hydrophilic nature, which means it is easy to attract water molecules. Edible coatings that are hydrophilic have weak bonds due to the constituent components of the film matrix, and the edible pores that form tend to be wider. This causes the resulting edible coating to absorb water easily and makes it easier for water vapor to penetrate, increasing WVTR value. Following Ref. [25], water vapor migration occurs in the hydrophilic part of the film. The greater the hydrophilicity of the edible film, the higher the water vapor transmission rate of the film.

Table 4 shows that the higher the concentration of glycerol added, the higher the water vapor transmission rate of the edible coating produced. The addition of glycerol as a plasticizer in pectin-based edible coating formulations can increase the flexibility of the product formed but also has the potential to increase the water vapor transmission rate (WVTR) because to increase the flexibility of the resulting film, glycerol will increase the amount of bound water and reduce molecular density by lowering the internal forces between pectin polymer chains and creating free space in the film matrix so as to form more gaps that can be passed by water molecules, and result in an increased water vapor transmission rate value. Following the statement of [26], Increasing glycerol concentration increases the water vapor transmission rate of edible film. Glycerol is a hydrophilic plasticizer that can reduce the density of the edible film constituent matrix and increase the gap for molecules to occupy. The hydrophilic nature of glycerol decreases the hydrophobic properties of the film so that it facilitates the absorption of water vapor and increases the value of the water vapor transmission rate in edible film.

The water vapor transmission rate (WVTR) value in this study is different from the value of water vapor transmission rate of [27] of 0.044-0.081 $g/m^2/day$. This difference may be due to Pradana's research, besides using a combination of pectin and glycerol, there are also other materials used, namely starch. Starch strengthens the film layer's structure and reduces the gap between molecules, thus reducing the permeability to water vapor. Without starch, pectin films tend to be more open to water vapor due to a less dense structure, allowing higher water vapor transmission. Although the WVTR value in this study is not as good as the results reported by [27], the value obtained is still within the eligibility limits as edible based on the [28] is a maximum of 7 $g/m^2/day$. Thus, the developed edible coating still meets the criteria for a functional food coating.

3.2.2. *Thickness*

Based on the analysis of variance, there was no significant interaction ($p \geq 0.05$) between the treatments of pedada fruit pectin concentration and glycerol concentration on the thickness of edible coating. Each treatment had a significant effect ($p \leq 0.05$). The average edible coating thickness value obtained in the treatment of pedada fruit pectin concentration ranged from 0.02-0.14 mm. Edible with the lowest thickness in this study was found in the treatment of 1% concentration of pedada fruit pectin with the addition of 1% glycerol which amounted to 0.02mm. While the edible with the highest thickness in this study was found in the edible treatment with 3% concentration of pedada fruit pectin with the addition of 3% glycerol, which amounted to 0.14mm.

Table 4 shows that the higher the concentration of pectin from pedada fruit added, the higher the thickness value of the edible coating produced. In this study, increasing the concentration of pectin from pedada fruit (Sonneratia caseolaris) proved to cause the formation of a thicker film. This is closely related to pectin's natural properties, which contains many hydroxyl groups that form a gel network during the drying process. The increase in pectin concentration of pedada fruit is in line with the increase in total soluble solids in the coating solution, which means that the higher the concentration of pectin added, the greater the amount of solids in the edible coating solution that will form a film structure during the drying process, resulting in a denser, tighter, and thicker layer. This is in accordance with [29] research that increasing pectin concentration from 1% to 2% caused an increase in edible film thickness from 123.5 μm to 189.6 μm. This was due to the increase in total soluble solids in the coating solution, which contributed to the formation of a thicker film.

Table 4. shows that the higher the concentration of glycerol added, the higher the thickness value of the edible coating produced. The higher concentration of glycerol added can increase the thickness of the edible coating. Glycerol works by entering the gaps between the pectin polymer chains, thus expanding the distance between polymer chains and causing the

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film matrix's development and increasing the film's volume formed. Glycerol also attracts water and slows down the drying rate. Thus, the edible film takes longer to form a thicker layer during drying. This is in accordance with [30] who showed that the addition of glycerol in edible film based on cassava starch and apple pectin increased the film thickness. The thickness increased from 0.12 mm (1% glycerol) to 0.15 mm (1.5% glycerol). This increase was due to glycerol's hygroscopic nature, which retained water longer during the drying process, resulting in a thicker film.

The edible thickness value in this study is different from the thickness of [31] of 0.14-0.22 mm. The result of the thickness value in this study is lower. This is most likely due to the difference in ingredients in the formulation. Pradana used a combination of pectin, cassava starch, and gelatin in the form of edible film, while this study only used pectin as the main formulator for the edible coating. The addition of starch in the research of [31] serves as a structural reinforcement and enhancer of total film-forming solids so as to produce thicker films. The absence of starch in the formulation in this study causes the film layer formed to tend to be thinner because it only relies on pectin as the main forming agent. Nevertheless, the lowest to highest edible thickness results obtained in this study are still acceptable and support the coating function because they have met the standard as edible based on the [28] which is edible thickness of no more than 0.25mm.

3.2.3. *Viscosity*

Based on the analysis of variance shows that there is a real interaction (p≤05) between the treatment of pedada fruit extract concentration and glycerol concentration on the viscosity of edible coating, and each treatment has a real effect ($p \leq 0.05$) on the viscosity of edible coating. Table shows that the higher concentration of pectin of pedada fruit added can significantly increase the viscosity of edible coating ($p \leq 0.05$). The average value of edible coating viscosity obtained in treating pedada fruit pectin concentration ranged from 693.62-1107.55 mPa.s. Edible with the lowest viscosity in this study was found in the treatment of 1% pedada fruit pectin concentration with the addition of 1% glycerol, which amounted to 693.62 mPa.s. At the same time, the edible with the highest viscosity in this study was found in the treatment of edible with 3% concentration of pedada fruit pectin with the addition of 3% glycerol, which amounted to 1107.55 mPa.s.

The addition of pedada fruit pectin concentration and glycerol concentration can increase the viscosity of the edible coating solution. The pectin used in this formulation comes from pedada fruit (Sonneratia caseolaris), which is known to have a high methoxyl content of 5.69% and is classified as Low Metoxyl Pectin (LMP) which has a large number of free carboxylic groups (-COO-) due to the low level of methoxylation. These groups allow for intermolecular interactions through hydrogen bonding and electrostatic forces, forming a tight network of molecules in solution. When added as a plasticizer, glycerol interacts with the pectin chain by forming hydrogen bonds between the hydroxyl (-OH) groups of glycerol and the polar groups of pectin. The interaction causes the formation of a denser three-dimensional structure and attracts some of the free water in the system, thus increasing the viscosity of the solution. This is in line with research by [29], which showed that viscosity increased as pectin concentration increased, which also affected the thickness and strength of the resulting film. According to [32], water will bond through hydrogen bonds with hydroxyl groups on hydrocolloids to form a double helix conformation and a three-dimensional structure. So that the state of the solution is more stable and there is an increase in viscosity. [33] which states that increasing the glycerol concentration increases the viscosity value of pectin-based edible coating solutions. [34] stated that the addition of plasticizers such as glycerol increases the viscosity of the edible film solution, which in turn increases the thickness of the resulting film. This increase in viscosity is due to the interaction between glycerol and the main polymer in the solution, which strengthens the film structure.

[35] state that the ideal film solution viscosity value for coating applications ranges from 700 to 10,000 mPa-s (cP), depending on the application method such as dipping, spraying, or painting. A viscosity value of about 1000 mPa.s (cP) is considered sufficient to ensure uniform and effective film formation in coating the surface of food products. So in this study, the viscosity of pectin that is considered qualified is in the edible coating solution with the addition of 3% pectin concentration and 2% glycerol, which is 1022.23 mPa.s (cP), and the treatment of adding 3% pectin concentration and 3% glycerol, which is 1107.55 mPa.s (cP).

4. CONCLUSION

There was a significant interaction ($p \leq 0.05$) between the treatment of pedada fruit pectin concentration and glycerol concentration on the viscosity of edible coating solution. Still, there was no significant interaction ($p \geq 0.05$) on water vapor transmission rate and edible thickness. Each treatment had a significant effect ($p \leq 0.05$) on the water vapor transmission rate, thickness, and viscosity of edible coating. The best treatment was obtained in the treatment of 3% pedada fruit extract concentration and the addition of 2% glycerol concentration with edible characteristics including water vapor transmission rate of 4.083 g/m^2/day, thickness of 0.128 mm; viscosity of 1022.23 mPa.s (cP).

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