Engineering and Technology Journal e-ISSN: 2456-3358

Volume 09 Issue 12 December-2024, Page No.- 5666-5672

DOI: 10.47191/etj/v9i12.16, I.F. – 8.227

Making Edible Film from Cassava Peel Starch and Dragon Fruit Peel

Andi Artiningsih[1], Waode Uwi Anafsia[2], Alvina Dwiyanty[3], A. Suryanto[4]

[1,2,3,4] Department of Chemical Engineering, Faculty of Industrial Technology, Universitas Muslim Indonesia, 90231, Makassar, Indonesia

ABSTRACT: The need for plastic increases every year as a food packaging material. The purpose of this study was to determine the effect of the ratio of cassava peel starch and dragon fruit peel in making edible films and to determine the level of durability and stability of edible films on food safety and quality. The method used to make edible films from cassava peel starch and dragon fruit peel with the maceration method followed by evaporation using a rotary evaporator to produce dragon fruit skin color. This study was conducted with 4 ratios, namely without extract and with the addition of dragon fruit peel extract at concentrations of 2 ml, 4 ml and 6 ml. The results of the study showed that edible films with the addition of extracts were able to increase water content by 13.95% - 20.95%, film absorption by 25.95% - 59.00%, edible film thickness by 0.06-0.13 mm and weight loss by 8.83 -11.37. grams. The tensile strength of the film after the addition of dragon fruit peel extract decreased from 3.27-1.50 Mpa.

KEYWORDS: Biodegrable; Cassava Peel Starch; Dragon Fruit Peel; Edible Film; Packaging

I. INTRODUCTION

Indonesia is the second largest producer of plastic waste in the world after China. The need for plastic increases every year. The problem of waste is a classic problem faced by society, where based on data from the Central Statistics Agency (BPS), plastic waste in Indonesia reaches 64 million tons per year. The use of plastic has become an important thing for human life because of its practical, lightweight, durable nature and its affordable price for various types of people. Plastic is generally widely used as a container, packaging and wrapping for various products [1]. The use of plastic as a material in food or food packaging is considered less environmentally friendly because the amount of environmental pollution caused can cause damage. Therefore, to overcome this problem, it can be done by developing packaging used to package food products. One of the packaging materials that is widely used is edible film. Edible film is a packaging material made from environmentally friendly materials because it is renewable and environmentally friendly. The material that is widely used to make edible film is a type of tuber that contains starch [2].

Starch is a type of polysaccharide that is abundantly available and is easily decomposed by nature (biodegradable), easy to obtain and quite affordable. The properties of starch are also suitable for edible film materials, including reducing water activity on the surface of the material, improving the surface structure of the material, reducing oxygen contact with the material [3].

Cassava skin is still underutilized by the community so that it often becomes waste. The inner part of cassava skin contains protein, crude fiber, crude fat, calcium and phosphorus and has a fairly high percentage of starch content that can be used as a basic material for edible films. The starch content in cassava skin is higher when compared to the starch content with several types in other tubers. High cassava starch production, easy and cheap planting make cassava starch have great potential to be used as a basic material for making edible films. film. In addition, cassava skin starch has an amylopectin content of 87% and an amylose content of 17%. The amylopectin content in cassava skin starch is quite high, allowing the edible film produced to be strong and flexible. Starch-based edible films are non-isotropic, meaning they are odorless, tasteless and transparent, so that cassava skin starch is very safe to use in making edible films [4].

This study also uses color pigments derived from fresh dragon fruit skin. Dragon fruit skin is rich in betacyanin pigments, which provide attractive and striking colors. In addition to its beautiful color, red dragon fruit skin also has many other important components, namely polyphenols, which are known to have strong antioxidant properties. Therefore, dragon fruit skin not only has aesthetic value, but also significant nutritional value.

The utilization of characteristics in dragon fruit skin in this study aims to explore the potential of dragon fruit skin as a source of nutrients and antioxidants in the manufacture of beneficial edible films. This approach opens up opportunities to utilize dragon fruit skin in the manufacture of edible films, which can function not only as a protector but also provide health benefits. Thus, dragon fruit skin can be a valuable alternative in the development of products in the field of food ingredients or foods that are more nutritious and safe for consumption.

Some of the previous research results show relevance in the development of polymer materials used for making edible films. One significant study is on edible films based on pectin derived from robusta coffee skin and glucomannan. This edible film shows very good characteristics. The main difference between these studies lies in the type of raw materials used. Research on coffee skin pectin focuses on the utilization of coffee waste, while this study uses a combination of cassava skin starch and dragon fruit skin extract in improving the characteristics of the edible film produced. By considering the results of previous studies, there is potential to renew research involving dragon fruit skin pectin. This can be done by optimizing the ratio between pectin and starch used, as well as conducting further research on additives that can improve the physical and mechanical quality of edible films [5]. Furthermore, other studies have explored pectin from dragon fruit peel and its application in making edible films. The difference in this study lies in the extraction method used to produce color pigments. Previous studies used the Microwave Assisted Extraction (MAE) method with variations in material weight and extraction time. This study showed that the use of extraction with 72% oxalic acid solvent produced a higher pectin yield when compared to conventional extraction methods, in addition there were significant differences in the variation of raw materials used. Previous studies only used dragon fruit peel pectin as the main ingredient. Meanwhile, in this study, there is a more complex approach by combining starch produced from cassava peel with dragon fruit peel extract which is rich in pectin. This approach not only enriches the composition of raw materials but also has the potential to improve the physical and organoleptic characteristics of the resulting edible film [6]. Another study on the characteristics of edible film from cassava skin waste with the addition of various combinations of plasticizers and their application to pineapple fruit has been conducted. This edible film shows good characteristics when using a combination of plasticizers, namely glycerol and propylene glycol.

The difference in this study lies in the type of plasticizer used in the previous study combining glycerol and propylene glycol, while this study only utilizes glycerol and dragon fruit skin extract [7]. Based on the findings of previous studies, this study aims to integrate various existing approaches to develop optimal edible films as environmentally friendly food packaging. The main focus of this study is to achieve the desired properties of edible films, including the percentage of film water content, absorption value, film thickness size, weight loss value, tensile strength, and optimal elasticity as an alternative to plastic as packaging for food materials by considering the maceration extraction method and the right material composition.

II. EXPERIMENTAL

2.1 Materials and chemicals

The raw materials used in this study include cassava peel waste, dragon fruit peel waste, 96% food grade ethanol, glycerol, carboxyl methyl cellulose, filter paper, and aluminum foil.

2.2 Methods

2.2.1 Preparation stage of research raw materials

Preparation of raw materials begins with collecting cassava skin from snack production, then cleaning dirt from cassava skin and cutting and peeling.

2.2.2 Cassava peel starch separation stage

The cleaned cassava peel is then cut into sample sizes of ±1 cm then soaked in water for 24 hours and the water is replaced every 8 hours after which it is drained. Furthermore, it is mashed using a blender to produce cassava peel porridge. Then the cassava peel porridge is filtered and precipitated for 24 hours. The water is discarded to obtain cassava peel starch. Cassava peel starch is dried in an oven at a temperature of 60°C for 13 hours. After drying, the starch is mashed with a blender and then filtered again.

2.2.3 Dragon fruit skin extract making stage

The dragon fruit skin that has been washed clean is sliced into small pieces and then air-dried for 3 days. Furthermore, the dried dragon fruit skin is ground with a blender and sieved to produce fine dragon fruit skin powder. Furthermore, the dragon fruit skin powder is extracted by maceration using 96% ethanol solvent for 24 hours. After that, filtering is carried out using filter paper until the filtrate is obtained and then the solvent is evaporated at a temperature of 50°C with a rotary evaporator

2.2.4 Edible film making stage

The film solution was made with 3 ratios between cassava peel starch extract and dragon fruit peel. In this study, a mixture of 5 g of cassava peel starch and 2 mL of glycerol and 2 mL of dragon fruit peel extract with 100 mL of distilled water in 4 beakers. The solution was then heated and stirred using a magnetic stirrer for 45 minutes until it reached the gelatinization temperature. The gelatinization temperature of cassava starch is 60-70°C. Then 0.25 grams of CMC or carboxyl methyl cellulose powder was added. Then the solution was kept heated while stirring for 10 minutes. The suspension in the beaker was cooled to room temperature.

Then stirred again on the hot plate stirrer. 30 mL of suspension was printed on a glass plate. Drying was carried out at a temperature of 45°C for 15 hours. Then the edible film was cooled at room temperature (25°C) for 30 minutes. This procedure was repeated with a ratio of 4 mL and 6 mL of dragon fruit peel extract.

Table 1. Table 1. Composition of the mixture of materials for making edible film

Sample	Material				
	Starch (gr)	Glycerol nl)	CMC (gr)	Aquadest (ml)	Dragon Fruit Peel Extract (ml)
1	5	2	0,25	100	0
2	5	2	0,25	100	2
3	5	2	0,25	100	4
4	5	2	0,25	100	6

2.2.5 Analysis of Results with Chemical Tests

The characteristics of edible film products from cassava peel starch and dragon fruit peel can be done by gravimetric analysis consisting of water content testing, absorption testing, thickness testing, weight loss quality testing and tensile strength testing.

III. RESULTS AND DISCUSSION

3.1 Preparation of edible film raw materials

The process of making edible film through a heating process at a temperature of 70-80°C for 45 minutes for the gelatinization process. The addition of distilled water in the edible film solution will cause a bond in amylose and amylopectin to break so that hydrogen bonds are formed between water molecules with amylose and amylopectin [8]. Thus, this process causes the size of the granules to increase and swelling until the granules break so that amylose and amylopectin diffuse out and a gelatinization reaction occurs.

The process of making edible films from cassava starch is also added with glycerol which functions as a plasticizer, which has a significant impact on the physical and mechanical properties of the film. Films containing glycerol have better resistance to tension and tensile force, and are better able to withstand deformation without cracking. This is very important in practical applications, where the film must be flexible enough to be coated or wrapped safely around food products without cracking and also able to maintain moisture and avoid excessive drying, which can cause the film to become brittle and break. This is very important in maintaining the quality and freshness of food products wrapped in edible film to extend the shelf life of a food ingredient [9]. The manufacture of edible films in this study also used Carboxy Methyl Cellulose (CMC) as a gelation that acts as a thickener, stabilizer, binder and smooth texture former with the aim of improving mechanical characteristics through the heating process and will form a very good film, this is because CMC has biodegradable, non-toxic and water-soluble properties so that it can be an alternative for making edible films [10].

The addition of dragon fruit skin extract in this study plays an important role. This is because dragon fruit skin contains very good bioactive compounds such as antioxidants, flavonoids and natural color pigments such as betacyanin which plays a role in providing a purplish red color. Betacyanin is one of the dyes that can be used as a natural dye for food and as an alternative to synthetic dyes because it has an attractive color, is easily soluble in water, and has high antioxidant activity so it is safe for consumption [11].

The color change of betacyanin pigment in dragon fruit skin (Hylocereus polyrhizus) from red or purple to orange or yellow during the research process can be influenced by the sensitivity of the betacyanin pigment. This is in accordance with the opinion of [12], which states that betacyanin is a very sensitive pigment that can experience rapid degradation when exposed to alkaline pH conditions and high temperatures.

Edible film quality research includes edible film characteristic tests consisting of water content, absorption analysis, thickness test, weight loss quality test, tensile strength test, which can be seen in Table 2 below:

Table 2. Edible Film Characteristics Test Results

Sample	Parameter				
	Water Content (%)	Absorption Capacity (%)	Thicknes (mm)	Weight Shrinkage (gr)	nsile trength Nm^2)
1	13,95	25,95	0,06	8,83	3,27
2	14,22	28,89	0,08	9,96	2,45
3	14,50	46,78	0,01	9,37	1,96
4	20,95	59,00	0,13	11,37	1,5

3.1 Edible Film Water Content

Edible film water content testing aims to measure the amount of water contained in the edible film. In this test, the results of water content from various dragon fruit skin extract ratio variations are presented in Figure 1 below.

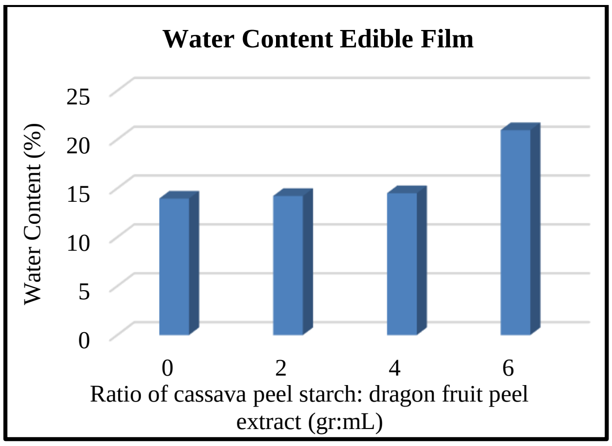

Figure 1. Results of Analysis of Water Content of Edible Starch Film Cassava Peel and Dragon Fruit Peel.

The water content of edible film plays an important role in the stability of the product it coats and can determine the freshness and durability of food ingredients. Therefore, edible film is expected to have a low water content so that in its application as primary packaging it does not contribute water to the product which will have an impact on product damage and reduced shelf life [13].

Edible film quality requirements according to SNI standard Number 06-3735-1995 edible film has a maximum water content of 16%. The water content value of the edible film obtained was for the highest value in the treatment of adding 6 ml of dragon fruit peel extract, namely with a value of 20.96%, while the lowest value of the edible film water content in the treatment without dragon fruit peel extract was 13.95%. The percentage value of water is increasing along with the increasing concentration of dragon fruit skin extract. This is because dragon fruit skin contains active compounds that have hydrophilic properties, such as polysaccharides, flavonoids, betacyanin pigments. The compound components in dragon fruit skin are hydrophilic, tend to have the ability to bind water through carboxyl groups that attract water molecules through hydrogen bonds so that they will contribute to increasing the absorption of water content in edible films [14].

The higher the concentration of an extract, the more hydrophilic compounds are available to bind water content from the environment. At a concentration of 6 ml of dragon fruit peel extract, the amount of these hydrophilic compounds increased significantly, which increased the ability of the edible film to absorb and retain water. In this case, the hydrophilic properties of dragon fruit peel can increase the water content of the film.

The increase in water content is also influenced by the interaction between dragon fruit peel extract and the polymer matrix used in the edible film making material, in this case, cassava peel starch which has hydrophilic properties. When this dragon fruit peel extract is mixed with cassava peel starch, which consists of amylose and amylopectin, an interaction occurs between these components. Starch, especially amylopectin content which has a branched structure, absorbs more water because of the many hydroxyl groups that form hydrogen bonds with water molecules. Cassava peel starch, especially amylopectin, can absorb water content during the gelatinization process where the gelatinization temperature of cassava starch is 70-80°C [15].

3.2 Edible film Water Absorption

The water absorption test shows the amount of water that can be absorbed by the edible film sample. The water absorption of various compositions of dragon fruit skin extract can be seen in Figure 2 below.

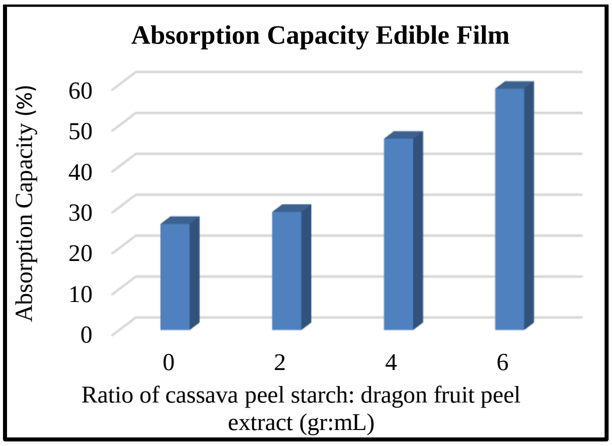

Figure 2. Results of Edible Starch Film Absorption Analysis Cassava Peel and Dragon Fruit Peel

Based on Figure 2, it is known that the water absorption value of various composition variations of dragon fruit skin extract ranges from 29.95% to 59%. The water absorption value increases, this is in accordance with the opinion of [16], where dragon fruit skin containing OH- and COOH groups will tend to cause edible films to absorb more water. The OH- group forms hydrogen bonds with water, so the greater the percentage of OH- content, the higher the water absorption capacity of the film. Likewise, the COOH group can attract water through interactions between acids and bases with increasing extract concentration, the water absorption capacity of the film will generally increase because both groups of functional groups increase the film's ability to absorb moisture from the surrounding environment.

The increase in the overall film absorption capacity based on the concentration of dragon fruit peel extract of 2, 4, and 6 ml occurred due to the high polar compounds, especially betacyanin, phenolic compounds, flavonoids, and polysaccharides, which play a role in strengthening the hydrophilic properties of the film. Each additional concentration of dragon fruit peel extract will increase the polar interaction with water molecules, so that the film absorption value also increases continuously along with the addition of dragon fruit peel extract [6].

3.4 Edible film thickness

The film thickness indicates the ability of edible film as a packaging for food products where the thickness value is obtained from measurements using a screw micrometer. The thickness value of edible film from various variations of dragon fruit skin extract composition can be seen in Figure 3 below.

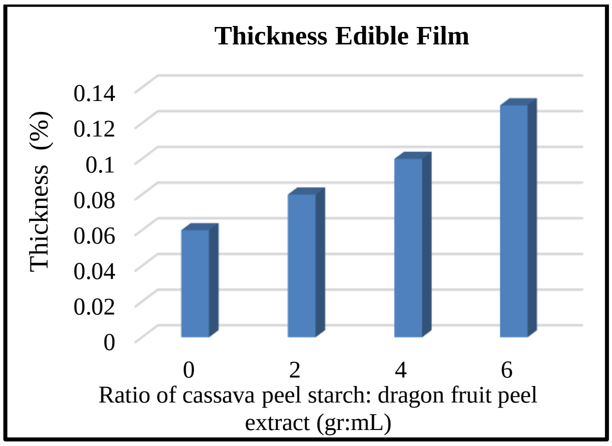

Figure 3. Results of Thickness Analysis of Edible Starch Film Cassava Peel and Dragon Fruit Peel.

Based on Figure 3, it is known that the thickness value for various extract composition variations ranges from 0.06 mm to 0.13 mm. The thickness value of this edible film is classified as good because it is still below the maximum standard for the thickness of edible film issued by the Japanese Industrial Standard (JIS), which is ≤0.25 [15]

The thickness of the edible film increases with the increasing concentration of dragon fruit peel extract added. The increase in the thickness of the edible film in this study was influenced by the content of dragon fruit peel extract containing active compounds, including betacyanin, fiber and other bioactive compounds that have the potential to interact with starch molecules. When the extract concentration increases, the total amount of solid material in the mixture also increases, causing an increase in the viscosity of the film-forming solution. This can affect the distribution of molecules in the film matrix, the layer formed becomes thicker.

Bioactive compounds from dragon fruit skin extract can act as agents in forming bonds, strengthening the starch molecular network, which will be able to increase the thickness of the edible film. This interaction produces a denser and more compact structure, due to the increase in dissolved solids content which plays a role in increasing mass and volume.

Thickness affects the barrier properties of water vapor and the shelf life of a product. The higher the thickness value of the edible film, the better the edible film is in protecting the packaged product from external influences. The addition of plasticizer in this study, namely glycerol, also affects the thickness of the film because it increases the total solids in the solution so that the precipitate as an edible film will be thicker in the edible film printing process [17].

3.5 Edible film weight loss

Weight loss measurements were carried out to determine the effect of using edible film from cassava skin starch and dragon fruit skin on the length of storage time for weight loss. The weight loss of various composition variations of dragon fruit skin extract can be seen in Figure 4 below.

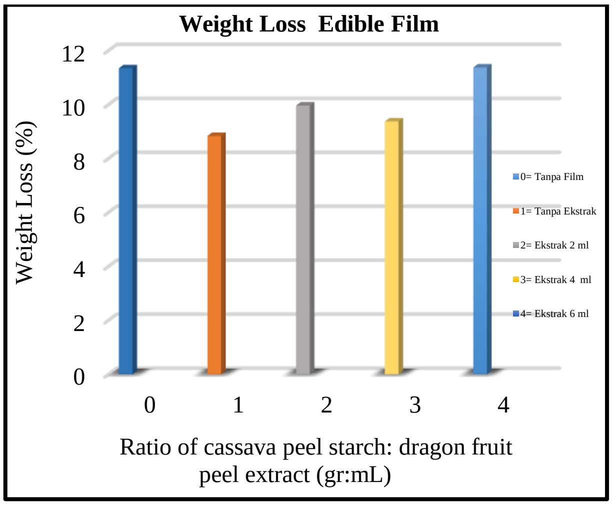

Figure 4. Results of Weight Loss Analysis of Edible Cassava Peel and Dragon Fruit Peel Starch Films

Based on Figure 4 above, it is known that the level of weight loss increases with the addition of dragon fruit skin extract. In this study, the sample without dragon fruit skin extract had the lowest weight loss value, namely 8.83%. Meanwhile, the sample with 6 ml of dragon fruit skin extract experienced the highest weight loss, namely 11.37%.

The increase in weight loss in this study was due to the dragon fruit skin containing bioactive compounds that can contribute to the barrier properties of the film. However, excessive increases in the levels of dragon fruit skin extract can also affect the physicochemical properties of the film, when the extract concentration increases, the quality of the tissue in cassava starch can be disrupted, which will cause loss of film integrity and increase porosity. The increase in weight loss in pear samples was also caused by the respiration and transpiration processes which were influenced by environmental factors such as temperature and humidity around the test sample.

Transpiration can occur when the humidity around the film is lower than the humidity in the film itself. When water evaporates, the weight of the film decreases, increasing the weight loss value. In addition, respiration is a process in which organic matter in edible films, such as food ingredients, can convert glucose into energy and will produce by-products such as water and carbon dioxide. During respiration, especially if the film contains organic components, water can be lost as a result of metabolism. This process can also contribute to film weight loss, especially if the film is stored in improper conditions will affect shrinkage [18].

Increasing the concentration of fruit extracts can cause an increase in film moisture, which leads to a decrease in film quality in terms of moisture resistance. This is in line with previous studies which state that the addition of additional materials such as fruit extracts in edible films often shows an increase in their barrier and functional properties. However, the addition of excessive extracts will affect the final quality of the edible film [3].

3.6 Edible Film Tensile Strength

The tensile strength of edible film is one of the important parameters that indicates the ability of the film to withstand tensile force without being damaged. High tensile strength is usually the result of selecting the right raw materials and an optimal manufacturing process. The use of raw materials such as cassava peel waste combined with plasticizers such as glycerol can increase the flexibility and strength of edible film. Natural plant-based materials can provide a solution to reduce dependence on conventional plastics that are difficult to decompose. The tensile strength of various compositions of dragon fruit peel extract can be seen in Figure 5.

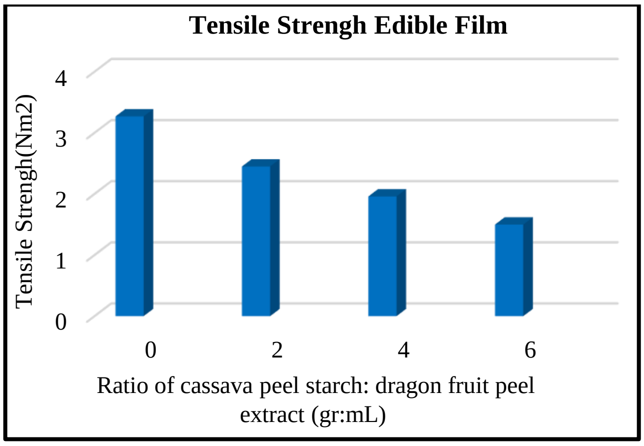

Figure 5. Results of Tensile Strength Analysis of Edible Cassava Peel and Dragon Fruit Peel Starch Films

Based on Figure 5 above, it can be seen that the higher the addition of dragon fruit skin extract, the more the edible film with tensile strength tends to decrease along with the increase in dragon fruit skin extract. This is because dragon fruit skin extract contains dissolved components that enter the film matrix network so that it will interfere and also weaken the bond between polymers and the formation of the film becomes less than optimal. The research that has been conducted shows that the characteristics of the edible film with the addition of a concentration of 0% (without the addition of dragon fruit skin extract) produces a tensile strength value of 3.27 MPa. After adding 2 ml of extract, the tensile strength value drops to 2.45 MPa, then adding 4 ml of extract the tensile strength value continues to decrease to 1.96 MPa.

The tensile strength value continues to decrease along with the addition of dragon fruit skin extract until the addition of 6 ml with a tensile strength reaching 1.50 MPa. These results are influenced by the content of active compounds, namely citric acid found in the fruit skin. This is in accordance with previous research which states that the citric acid content in fruit extract is one of the crosslinking agents because it has three carboxyl groups, which can bind to hydroxyl groups so that they can form hydrogen bonds between molecules that can improve mechanical characteristics and resistance to water and affect the pH of the film system, which has the potential to change the starch structure. Antioxidant compounds in dragon fruit skin, such as flavonoids and pectin, can contribute to a decrease in the tensile strength of edible films by disrupting the tissue structure, making it more fragile. Water-soluble flavonoids and high water content in the extract increase humidity, causing the film to be more elastic and fade and less mechanically stable, so that its strength to withstand a pulling force is reduced, thus affecting the tensile strength value of the film [19] [20].

The percentage of tensile strength value in this edible film decreased with the addition of dragon fruit skin extract, but the resulting tensile strength value was still above the minimum standard of 3,923 MPa according to the Japanese International Standard. Thus, this study shows that edible films still have improved tensile strength properties that comply with JIS standards as packaging.

CONCLUSIONS

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

Making Edible film from the ratio between cassava peel starch (Manihot Esculenta) and Dragon fruit peel extract (Hylocereus Polyrhizus) produces thin sheets of yellow and brownish white (without the addition of dragon fruit peel extract). The characteristics of edible film from cassava peel starch (Manihot Esculenta) with variations of dragon fruit peel extract (Hylocereus Polyrhizus) are able to increase the percentage of water content, namely 13.95% - 20.95%, the percentage of film absorption from 25.95% - 59.00%, the percentage of edible film thickness from 0.06 mm - 0.13 mm and weight loss from 8.83 grams -11.37 grams. The tensile strength value of edible film after the addition of dragon fruit peel extract decreased from 3.27 Mpa to 1.50 Mpa and the percentage of elongation value started from 101.33% - 102%.

ACKNOWLEDGMENT

The author would like to thank the Chemical Engineering Department, Faculty of Industrial Technology Muslim University of Indonesia for helping to provide facilities for the use of the laboratory and LP2S-UMI as support for the faculty's superior Research Grant Funds in 2024.

REFERENCES

1. F. Rosmi, D. A. Sari, and S. Imawati, "Efforts to increase knowledge in utilizing plastic waste through flower crafts from plastic bags on Rt 001," J. Pengabdi. Masy., pp. 1–10, 2020.

2. B. L. Iverson and P. B. Dervan, "Making Edible Film from Cassava Starch as Food Packaging," pp. 7823–7830, 2023.
3. S. Apriyani, A. Prasetya, and S. Mujiharjo, "Application of Cassava Peel Starch as Raw Material for Edible Coating with the Addition of Chitosan to Extend the Shelf Life of Rimau Gerga Lebong (Rgl) Oranges in Bengkulu Application of Cassava Peel Starch as a Raw Material for Edible Coating with the Addition of Chit," Agro Ind., p. 21–32, 2020.
4. S. R. Dewi and A. Widyasanti, "The Effect of Cassava Starch Concentration on the Characteristics of Edible Films Made from Cassava Starch with the Addition of Starfruit Leaf Extract," J. Keteknikan Pertan. Trop. and Biosist., Vol. 11, No. 2, pp. 158–167, 2023.
5. F. I. Dea, I. S. M. Purbowati, and C. Wibowo, "Characteristics of Edible Films Produced with Robusta Coffee Fruit Peel Pectin and Glucomannan as Basic Materials," Agrointek J. Teknol. Ind. Pertan., vol. 16, no. 3, pp. 446–456, 2022.
6. Megawati, "Dragon Fruit Peel Pectin Extraction and Its Application as Edible Film," J. Renewable Natural Materials, Vol. 4, No. 1, pp. 14–20, 2020.
7. R. A. Mudaffar, "Characteristics of Edible Film from Cassava Peel Waste with the Addition of Plasticizer Combination and Its Application on Minimally Processed Pineapple Fruit," J. Tabaro Agric. Sci., Vol. 4, No. 2, pp. 473, 2020.
8. I. Nafilah and E. Sedyadi, "The Effect of Sorbitol and Glycerol Addition on the Degradation of Cassava Starch Bioplastic in Soil and Compost Media," J. Kridatama Science and Technology., Vol. 1, No. 1, pp. 38–46, 2019.
9. A. Fatnasari, K. A. Nocianitri, and I. P. Suparthana, "The Effect of Glycerol Concentration on the Characteristics of Edible Film of Sweet Potato Starch (Ipomoea Batatas L.)," Sci. J. Food Technol., Vol. 5, No. 1, p. 27–35, 2019.
10. R. D. A. Putri, D. Sulistyowati, and T. Ardhiani, "Analysis of Carboxymethyl Cellulose Addition to Edible Film of Garut Tubers Starch as Strawberry Fruit Packaging," Jrst (Jurnal Ris. Sains Dan Teknol., Vol. 3, No. 2, P. 77, 2019,.
11. E. B. P. Agne, R. Hastuti, and Khabibi, "Extraction And Stability Assay On Betacyanin Colorant From Dragon Fruit (Hylocereus Polyrhizus) Peel And Its Application As Natural Food Colorant," J. Kim. Sains dan Apl., Vol. 13, No. 2, P. 51–56, 2021.
12. Sucianti, Nurhaeni, and J. Hardi, "Microencapsulation of Super Red Dragon Fruit Peel Extract (Hylocereus Costaricensis) on Various Maltodextrin Masses and Its Application as an Antioxidant," Kovalen J. Ris. Kim., Vol. 6, No. 3, pp. 191–197, 2020.
13. A. Alfian Et Al., "Making Edible Film from Cassava Peel Starch Using Sorbitol Plasticizer with Citric Acid as Crosslinking Agent (Variation of Carrageenan Addition and Citric Acid Addition)," J. Inov. Process, Vol. 5, No. 2, pp. 46–56, 2020.
14. A. Nizori, N. Sihombing, and Surhaini, "Characteristics of Red Dragon Fruit Peel Extract (Hylocereus Polyrhizus) with the Addition of Various Concentrations of Citric Acid as Natural Food Coloring," J. Teknol. Ind. Pertan., Vol. 30, No. 2, pp. 228–233, 2020,.
15. H. N. Rusman, "Potential of Fruit Peel Waste as Raw Material in Making Edible Film," J. Researcher. and Developer. Agrocomplex, Vol. 2, No. 1, pp. 92–98, 2019.
16. N. Arlofa, I. Suwandi, R. Haitami, and ..., "Determination of Adsorption Capacity of Red Dragon Fruit Peel (Hylocereus Polyhizus) as Adsorbent of Heavy Metal Pb," … Nas. Researcher. Lppm …, pp. 1–7, 2023,.
17. M. M. Permata, "Systematic Review: Effect of Starch Type and Plasticizer on Edible Film Characteristics," 2020.
18. M. D. Syaputra, E. Sedyadi, I. Fajriati, and Sudarlin, "Application of Cassava Starch Edible Film with the Addition of Aloe Vera Extract on Cayenne Pepper (Capisum Frutascens L.)," Integr. Lab J., Vol. 01, No. 01, pp. 1–16, 2020.
19. H. Kristianto, A. Jennifer, A. K. Sugih, and S. Prasetyo, "Potential of Polysaccharides from Fruit Waste as Natural Coagulants in Water and Wastewater Treatment: A Review," J. Process Engineering, Vol. 14, No. 2, pp. 108, 2020,.
20. F. M. Tarmidzi, I. K. Maharsih, and T. R. Jannah, "Synthesis of Pectin-Gelatin Hydrogel with the Addition of Dragon Fruit Peel Extract as a Candidate for Burn Wound Dressing," Vol. 4, No. September 2019, pp. 53–60, 2020.
21. J. N. W. K. Warkoyo, Budi Rahardjo, Djagal Wiseso Marseno, "Physical, Mechanical and Barrier Properties of Edible Film Based on Incorporated Kimpul Tuber Starch (Xanthosoma Sagittifolium)," Vol. 34, No. 1, p. 72–81, 2021.
22. N. Pitaloka, D. Aryo, B. Wibisono, and K. N. Wahyusi, "Characterization of Edible Film from Various Rice Seeds Starch with Addition of Chitosan," Vol. 16, No. 1, 2021.