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OPTIMIZATION OF THE ADDITION OF POLIVINIL ALCOHOL (PVA) AS A PLASTICIZER IN BIOFILM WITH TAPIOCA-CHITOSAN FLOUR MATERIAL

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Abstract

The addition of a plasticizer, namely polyvinyl alcohol (PVA) as a plasticizer, will increase flexibility and prevent the polymer from cracking. The purpose of this study was to compare the mechanical properties of biofilms from tapioca-chitosan flour with or without the addition of polyvinyl alcohol (PVA) and determine the mass of polyvinyl alcohol (PVA) which can provide optimum mechanical properties of biofilms, test the biodegradability of biofilms and polypropylene plastics and to analyze biofilms using FT-IR. The making of biofilm from 4% tapioca flour and 2% chitosan was carried out by adding variations of polyvinyl alcohol as much as 0, 1, 2, 3, 4 and 5 grams to each tapioca-chitosan flour solution. The effect of adding polyvinyl alcohol (PVA) can be seen from the results of the tensile strength test, the breaking length test, the water resistance test and the biodegradability test. The resulting biofilm functional group analysis was performed by FT-IR. The results showed that the addition of PVA could increase the tensile strength and breaking length, but decreased the water resistance of the biofilm. The optimum mechanical properties of tapioca-chitosan flour biofilm resulted from the addition of 3 grams of PVA with a tensile strength of 2.163 kgf / cm^2, the breaking length of 13.64% and 12.46% of absorbed water. Biofilms can be degraded by the fungus *Aspergilus niger*. The results of biofilm analysis using FTIR indicate the presence of functional groups (CH, NH_2, NH, OH, CO and CN) which are the functional groups of the biofilm constituent materials. The optimum mechanical properties of tapioca-chitosan flour biofilm resulted from the addition of 3 grams of PVA with a tensile strength of 2.163 kgf / cm^2, the breaking length of 13.64% and 12.46% of absorbed water. Biofilms can be degraded by the fungus *Aspergilus niger*. The results of biofilm analysis using FT-IR indicate the presence of functional groups (CH, NH_2, NH, OH, CO and CN) which are the functional groups of the biofilm constituent materials.

Keywords: biofilm; chitosan; plasticizer; polyvinyl alcohol; tapioca flour.

1. INTRODUCTION

Plastic is one of the most influential pollutants and is one type of solid waste that cannot be degraded naturally which will become a global environmental problem. According to authors in Ref. [1]. Plastics that can not be degraded by microorganisms in the environment can cause pollution and environmental damage because they are carcinogenic which are harmful to health. In terms of these problems, it is necessary to develop the use of alternative materials to make degradable polymer materials, namely biofilms. Biofilms can be used as a bioplastic material (biodegradable plastic) which has advantages over plastics derived from petroleum, namely its biodegradable nature and comes from natural materials that are abundant in this world. Biofilms from pure starch have mechanical properties, namely tensile strength and break length which are still lacking, the use of pure starch as a biofilm forming material must be modified first [2]. Due to this deficiency, additional materials are needed to improve the mechanical properties of the plastic with other biopolymers such as chitosan which is non-toxic and has the nature of dissolving in an organic acid solution, namely acetic acid. The best chitosan is in a 2% acetic acid solution [3]. The use of chitosan as an additive in the manufacture of biodegradable plastics will reduce water absorption speed, improve properties mechanics, and reduce the moisture properties of the film [4]. To overcome the stiff nature of the biofilm, polyvinyl alcohol (PVA) is used as a plasticizer so that the resulting plastic is more elastic. PVA is a synthetic polymer that is soluble in water and non-toxic, and can be degraded naturally or biodegradable [5]. The results of research by authors in Ref. [6] showed that the mechanical properties of the biofilm (2% starch + 4% chitosan + 2 g lauric acid) had a tensile strength of 0.2632 kN / mm2 and a breaking length of 14.67%. The results obtained from the measurement of polypropylene plastic which is used as a standard are tensile strength of 2.116 kgf / cm^2 and break lengths between 10-500%. This research will examine the

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optimization of the addition of polyvinyl alcohol (PVA) plasticizer to biofilms made from tapioca-chitosan flour which can produce good biofilms.

2. METHODS

The materials used in this study were tapioca flour, chitosan obtained from the IPB fishery faculty, Japanese kuraray polyvinyl alcohol (PVA), PDA (Potato Dextrose Agar) media, Aspergilus niger mushroom, 100% CH_3COOH and distilled water.

The tools used in this study were the Gotech AL-7000M tensile strength test, Thermo Fisher FT-IR brand, incubator, hot plate and stirrer, measuring cup, measuring flask, glass cup, stirrer, oven, thermometer 100 ° C. , plastic molds, digital scales, desiccators, petri dishes, rulers, tweezers, pipettes, watch glasses, calipers and tweezers

The research method begins with the process of making 6 pieces of tapioca solution with a concentration of 4%. Be marked with codes (solutions 0, 1, 2, 3, 4 and 5) with each tapioca solution made duplicate with the code (solutions A and B). Each code of tapioca solution will be added with 2% chitosan solution and polyvinyl alcohol varying from 0, 1, 2, 3, 4 and 5 grams. All the mixture was stirred for 30 minutes using a magnetic stirrer and heated on a hot plate at a temperature of 70-80 ° C until homogeneous. After that the mixture will be poured into a biofilm mold (tray) that has been sterilized beforehand, let stand for 24 hours, then dried in an oven at 60 ° C for 12 hours. Biofilm is released from the mold. The biofilm was then tested for tensile strength and breaking length (ASTM D638), water resistance testing [5], biodegradability testing (ASTM G-21-70), and testing of biofilm functional groups using FT-IR.

3. RESULTS AND DISCUSSION

The resulting biofilm from tapioca-chitosan flour with variations of PVA was produced in the form of clear, yellow, transparent and stiff sheets due to the homogeneity of the biofilm mixture. The results of the biofilm with a variation of 0 grams of PVA were very stiff and easy to crack. The increasing mass of PVA, the more elastic the biofilm produced, so it is not easy to crack.

The results of the biofilm thickness in Figure 2 show that the increasing mass of PVA, the thicker the biofilm produced. This is due to the increasing mass of the biofilm at each additional weight of the use of PVA

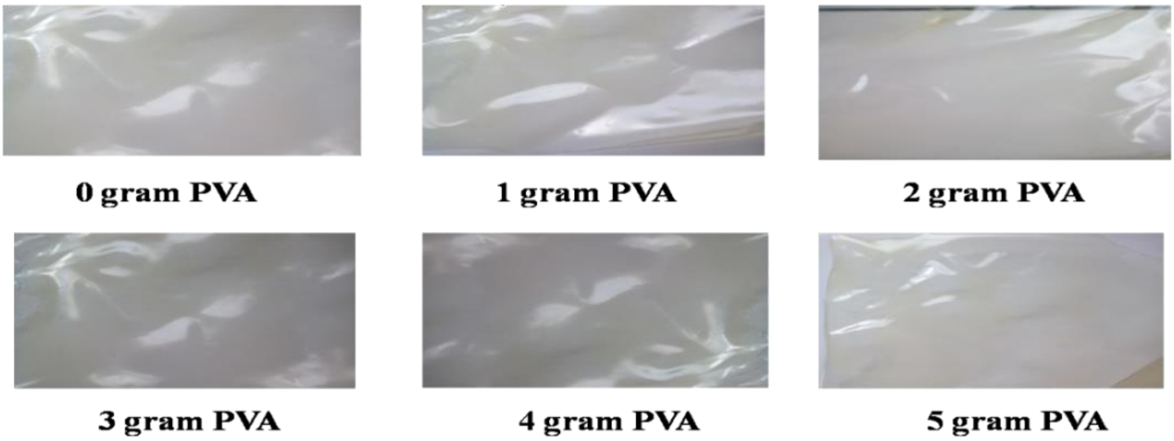

Figure 1. Tapioca-chitosan flour biofilm with variation of PVA

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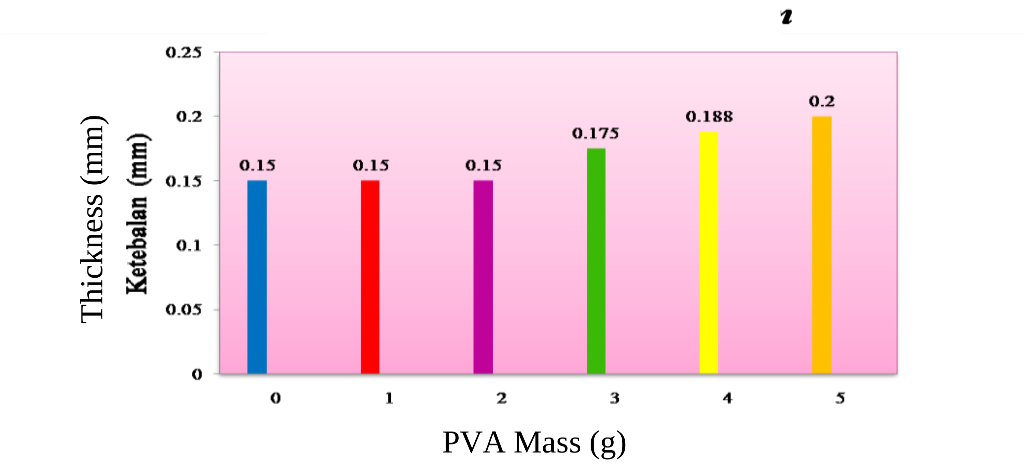

Figure 2. Thickness of tapioca-chitosan flour biofilm with variation of PVA

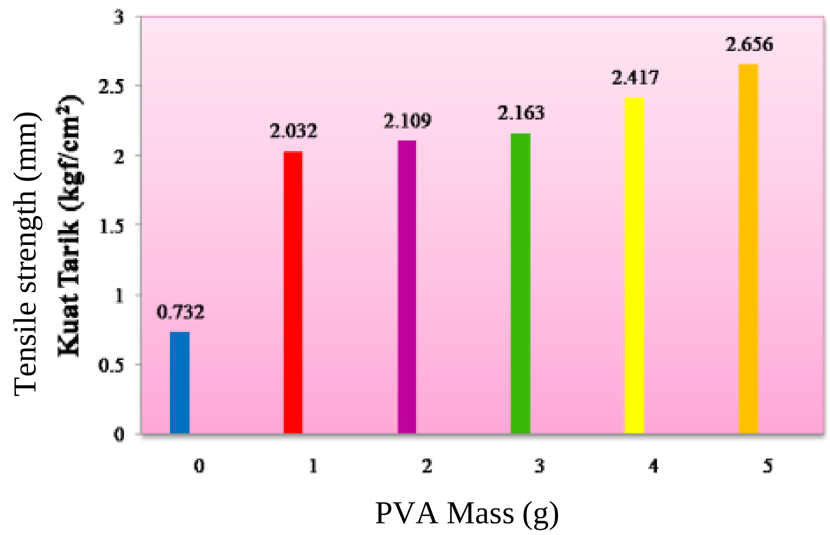

Figure 3. Effect of PVA mass on tensile strength of tapioca-chitosan flour biofilm

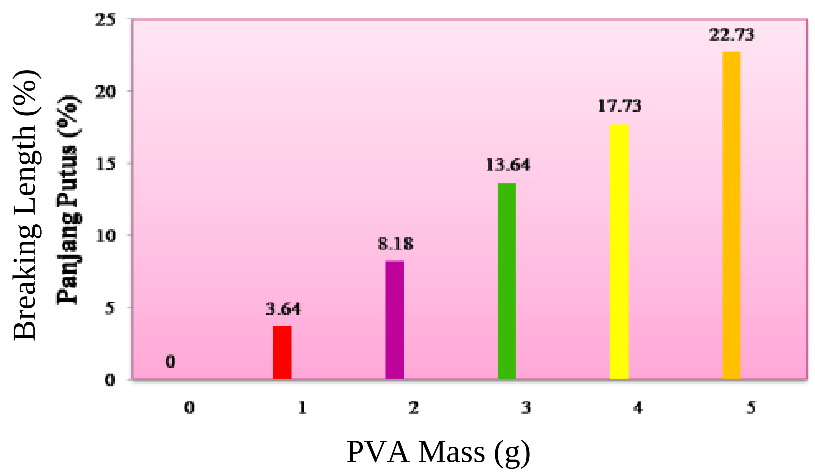

Figure 4. Effect of PVA mass on breaking length of tapioca-chitosan flour biofilm

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3.1 Mechanical Properties of Biofilms

Based on Figure 3, the tensile strength of biofilms from various compositions of polyvinyl alcohol (PVA) ranges from 0.732-2.656 kgf / cm^2. Biofilms with the addition of 0 grams of PVA have very low tensile strength, namely 0.732 kgf /cm^2 compared to biofilms with the addition of variations of PVA. Biofilm with 0 grams of PVA easily breaks when pulled by means of tensile strength. Biofilm with the addition of PVA, when pulled by means of tensile strength produces a much greater tensile strength and is not easily broken. The presence of PVA mass plays a role in increasing the tensile strength value. The number of carbon atoms in the chain and the number of hydroxyl groups present in the plasticizer molecule will affect the mechanical properties of the biofilm. The lowest tensile strength value is 0.732 kgf / cm^2 in the composition of 4% tapioca flour: 2% chitosan and 0 gram PVA. This is due to the weak hydrogen bonds between the starch and chitosan molecules so they are easily broken. The highest tensile strength value is 2.656 kgf / cm2 in the composition of 4% tapioca flour: 2% chitosan: 5 grams of PVA, this is influenced by the higher inter-molecular hydrogen bonds, so that the value of biofilm tensile strength is high because the biofilm at break requires large energy, as research conducted by authors in Ref. [1] suggests that the more hydrogen bonds contained in the biofilm, the more chemical bonds will be getting stronger and harder to break because it requires a lot of energy to break the bond.

From Figure 4, the results of the breaking length test were obtained from biofilms made from starch-tapioca chitosan with variations in PVA ranging from 0.00-22.73%. In the biofilm with 0 grams of PVA, the breaking length was 0.00% because when it was pulled with a tensile strength device, the biofilm broke immediately without any elongation. In contrast to the biofilm with added PVA, when pulled by a tensile strength device, the biofilm elongated, although only a few centimeters. Addition PVA causing the resulting biofilm to be more elastic. In the authors in Ref. [6] states that PVA has high elasticity and tensile strength, this causes the percentage of elongation to be higher or the elasticity to be higher. The highest yield of breaking length was 22.73% of the composition of 4% tapioca flour: 2% chitosan: 5 grams of PVA. The lowest yield of breaking length was 0.00% of the composition of 4% tapioca flour: 2% chitosan: 0 gram PVA. The yield of breaking length in the biofilm can be increased by adding more PVA as a plasticizer, but this will reduce the resistance of the biofilm to water due to the hydrophilic nature of PVA

3.2 Biofilm Water Resistance

Based on Figure 5, it can be concluded that the greater the mass of PVA, the percentage of water absorbed increases. The results of testing the water resistance value of tapioca-chitosan flour biofilm with variations of PVA ranged from 10.41-13.68%. The highest water resistance results with the lowest adsorbed water value amounting to 10.41% of the biofilm with a composition of 4% tapioca starch: 2% chitosan: 0 grams of PVA. The lowest water resistance results with the highest absorbed water value of 13.69% from the biofilm with the composition of 4% tapioca starch: 2% chitosan: 5 grams of PVA. These results indicate that the tapioca-chitosan flour biofilm without the addition of PVA is more water resistant than the chitosan tapioca flour biofilm with the addition of PVA. The increasing of polyvinyl alcohol (PVA) and starch, the water resistance value decreases, which is indicated by the amount of water absorbed by the biofilm. This is influenced by the composition of chitosan which has weak hydrophilic properties so that the biofilm likes water. In Simanjuntak's research [7] states that polyvinyl alcohol has a high ability to expand in water.

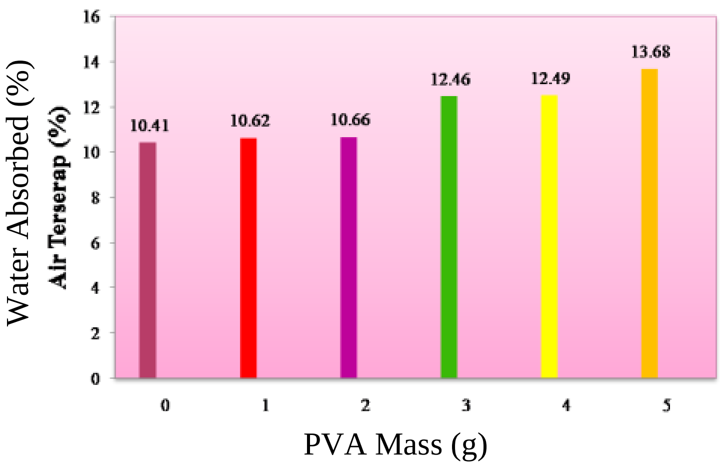

Figure 5. Effect of PVA mass on water resistance of tapioca-chitosan flour biofilm

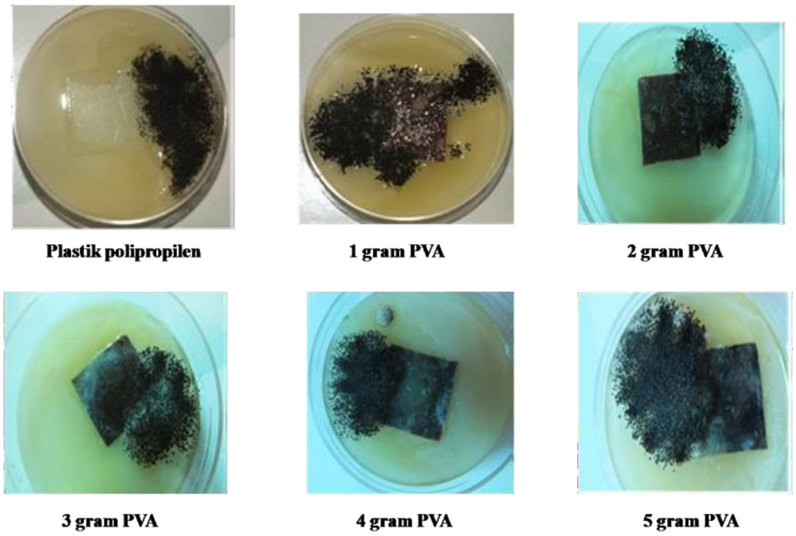

Figure 6. Qualitative testing for biodegradability of tapioca starch-chitosan and PVA biofilm

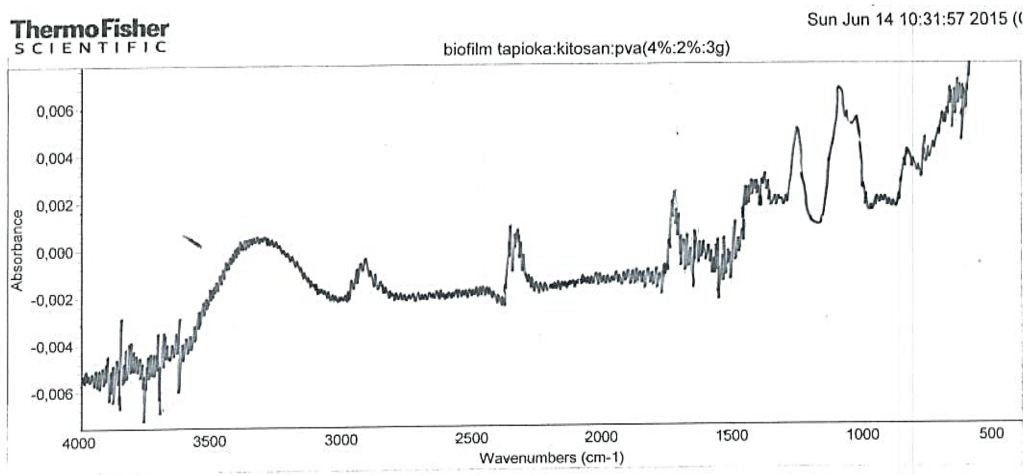

Figure 7. FTIR spectrum of tapioca-chitosan flour biofilm with 3 g PVA

Table 1. Comparative results of polypropylene and biofilm testing

Propylene plastic standard

	Tensile Strength (kgf/cm^2)	Breaking Length (%)
Propylene plastic	Min. 2.116	10-500

Biofilm Test Results

Tapioca Flour Biofilm : Chitosan	Tensile Strength (kgf/cm^2)	Breaking Length (%)	Water Resistance (%)	Biodegradability
0 gram PVA	0.732	0.00	10.41	Yes
1 gram PVA	2.032	3.64	10.62	Yes

2 gram PVA	2.109	8.18	10.66	Yes
3 gram PVA	2.163	13.64	12.46	Yes
4 gram PVA	2.417	13.73	12.49	Yes
5 gram PVA	2.656	22.73	13.68	Yes

3.3 Biodegradability of Biofilms

The results of qualitative biofilm biodegradability testing with Aspergilus niger are shown in Figure 6. In commercial plastics (Figure 6a), there is no visible growth of Aspergilus niger, while Aspergilus niger can be seen growing on biofilm tapioca-chitosan flour and PVA (Figure 6 b, c, d, e, f).

The growth of the fungus is because the biofilm contains nutrients in the form of starch as a nutrient for the growth of fungi. The growth of the fungus indicates a tapioca starch biofilm. Chitosan and PVA can be degraded in the soil. The Aspergilus niger fungus is one of the microbes that is important in degradation, because it can produce enzyme α-amilase, amiloglukosidase that can break down complex compounds into simpler ones. The Aspergilus niger fungus will degrade starch-containing biofilms by breaking the polymer chains of amylose and amylopectin into their monomers (glucose) through enzymes amylase and pectinase produced from these fungi. From these results, the biofilm from tapioca starch-chitosan and PVA can be said to be degraded plastic.

3.4 Optimum PVA Composition on Biofilms Tapioca-Chitosan Flour

The results of the comparison of biofilm testing with polypropylene plastic are shown in Table 1. The results of testing for biofilms made from tapioca-chitosan flour with variations of PVA in Table 1 show that the addition of PVA to tapioca-chitosan flour biofilms can produce an increase in tensile strength and breaking length in these biofilms compared to tapioca-chitosan flour biofilms without the addition of PVA. However, the addition of PVA as a plasticizer to the biofilm reduces water resistance due to the hydrophilic nature of PVA. The results of the biofilm test made from tapioca-chitosan flour with variations of PVA in Table 1 when compared with the results of the 4-plastic test. polypropylene showed that the results of the optimum mechanical properties of the biofilm made from tapioca-chitosan flour were found in the biofilm with the addition of 3 grams of PVA. The results of tensile strength on tapioca flour biofilm-chitosan with 3 grams of PVA exceeds the tensile strength of polypropylene plastic, which is 2.163 kgf / cm^2, while the breakdown length of biofilm is still in polypropylene plastic standards (10-500%) of 13.64% with low water resistance of 12.46% . The tapioca-chitosan flour biofilm with the resulting variation of PVA can also be degraded as evidenced by the growth of Aspergilus niger on the biofilm.

3.5 Results of Biofilm Functional Group Analysis with FT-IR

The results of the FT-IR biofilm with 3 grams of PVA are shown in Figure 7. The results of the FT-IR analysis of the tapioca-chitosan flour biofilm with 3 grams of PVA in Figure 7 show the presence of a spectrum that ranges from wave numbers 3995.85-455.13 cm^{-1}. The spectrum of the OH functional group is present at a wave number of about 3300 cm^{-1}, the spectrum of the alkane functional group CH is at a wave number of about 2900 cm^{-1}, the spectrum of the secondary amine functional group (NH_2) is at a wave number of about 3800 cm^{-1}, the spectrum of functional groups Primary amines (NH) are present at a wave number of about 1600 cm^{-1}, the CO spectrum is present at a wave number of about 1300 cm^{-1} and the spectrum of the CN functional group is present at a wave number of about 1100 cm^{-1}. In this biofilm spectrum, the spectrum is the same as its constituent components, meaning that the constituents of the biofilm are homogeneous and linked to each other.

4. CONCLUSIONS

Based on the results of research analysis on biofilms, it can be concluded that the addition of PVA to tapioca-chitosan flour biofilm can increase the tensile strength and breaking length of the biofilm. The resulting biofilm is more elastic than the biofilm without the addition of PVA, but the addition of PVA can reduce the water resistance of the biofilm. The results of the optimum mechanical properties of the tapioca-chitosan flour biofilm were found in the biofilm with the addition of 3 grams of PVA. The results of the tensile strength on the tapioca-chitosan flour biofilm with 3 grams of PVA exceeded the tensile strength of the polypropylene plastic which was 2.163 kgf / cm^2, while the breaking length of the biofilm was still in the standard polypropylene plastic (10-500%) of 13.64% with water resistance as water which was

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absorbed by 12.46%. In the qualitative biodegradability test, Aspergilus niger fungus could not grow on polypropylene plastic, but could grow on tapioca-chitosan flour biofilms with various variations of PVA, so the biofilm can be said to be degraded plastic. The functional group test with FT-IR on tapioca-chitosan and PVA flour biofilms showed the presence of functional groups of the biofilm constituent materials, namely CH, CO, NH_2, NH, OH and CN.

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