MOLEKUL
eISSN: 2503-0310

Articles
https://doi.org/10.20884/1.jm.2024.19.1.7628

# Physicochemical Properties and Biodegradability of Biofilm Based on Taro Starch and Duck Bone Gelatin

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**Received** January 19, 2023; **Accepted** February 02, 2024; **Available online** March 20, 2024

**ABSTRACT.** Biofilm is an environmentally friendly plastic that is easily biodegradable. However, not all biodegradable plastics have the desired properties for packaging because they are made from renewable natural materials. The biofilm in this study was made from renewable natural raw materials that had never been used before, namely taro starch and duck bone gelatin. Mixing the two materials improve their physical properties and biodegradabilily This study was to to investigate the effect of adding duck bone gelatin 0%, 5%, 15%, 25% and 35% on physicochemical properties, namely color, oxygen permeability, and metal content (Pb and Cd) as well as biodegradability of biofilms. The method used in this research was solution casting. The results obtained from the color parameter with the highest lightness (L) value were produced in the addition of 15% of 85.26, for the highest value of color a was produced in the addition of 0%, namely 0.94, and the value of color b with the addition of 35% resulted in the highest color value of 1.67. The highest percentage of biodegradability was produced on day 14 with the addition of 35% duck bone gelatin in compost soil to produce a percentage of 100%, while for barren soil the yield was 54.54%-66.66%. The content of Cd and Pb in the biofilm is below the SNI limit. Biofilm is impermeable which can be used as food packaging.

**Keywords**: Biodegradability, biofilm, gelatin, physicochemical, starch

## INTRODUCTION

The use of plastic in people's daily life is unavoidable. People use plastic products for many things such as human daily needs, industries, and various types of food packaging. Plastic which is currently used in the market is made of synthetic polymers. It originated from crude oil *(non-renewable)* which cannot be degraded by microorganisms in the environment (Mulyadi et al., 2004). Plastic packaging is considered better than any other packaging material because it is light, strong, transparent, waterproof, cheap, and affordable for most people (Rastini et al., 2020) This makes plastic packaging more popular among people and more people use more plastic in their daily life. As a result, plastic waste increases in the environment. The weakness of plastic, i.e., *non-degradable* or difficult to be decomposed by (Asngad et al., 2018) the nature becomes one factor that causes pollution and environmental damage as well. Therefore, it is necessary to create an alternative plastic packaging that is environmentally friendly and degradable. The alternative degradable plastic packaging is called biofilm*s.* In general, biofilms are made from cellulose, chitosan, starch, protein, or a combination of the aforementioned components. Starch can form colorless and transparent matrix polymers, so they are mostly used in food packaging. Starch is a natural substance that contains amylose and amylopectin (Triwitono et al., 2017). It also has degradable properties. One of the most easily found starch is taro tubers, but they have not yet been used to make biofilms. Taro tubers contain more starch than cassava starch and corn starch. The percentage of taro starch from taro tubers is 80%, cassava starch from cassava tubers is 72.17%, and corn starch from corn is 71.3% (Rahmawati, 2012)This research used taro starch with an amylose content of 5.55% and amylopectin 74.45%.

Taro starch resist a low-polarity compound in making biofilms, but it is not effective enough to resist water vapour because of its hydrophilic nature. Besides, taro starch yields stiff and brittle biofilms. Therefore, it is still necessary to use another material to reduce the stiffness of taro starch. One natural substance that can be used to reduce the stiffness of taro starch is gelatin (Mulyadi et al., 2004)Gelatin can be extracted from cow bones, cow skins, or pork skins (Santosa et al., 2018)and poultry including chickens, birds, and ducks (Puspawati et al., 2017)Gelatin properties will give natural flexibility and elasticity in biofilms if combined with starch (Illing & Satriawan, 2017) In this research, the gelatin used was extracted from duck bones because their consumers always throw them away after eating the meat. It differ from

chicken bones which are often eaten after consumers finish eating the meat due to its softer texture. Other studies used more expensive and commercially available gelatin. Therefore, it is necessary to find another existing alternative source of gelatin. In addition, the use of gelatin from duck bone waste in the manufacture of biofilms can affect the color of the resulting film because duck bone gelatin tends to have a yellow to light brown color (Khirzin et al., 2019). Combining two natural ingredients, protein and starch, can improve the properties of the resulting biofilms. Gelatin-based biofilms have good barrier properties against oxygen and can accelerate the degradation process in the environment (Chaves Da Silva et al., 2018). Film degradation is the breakdown of film molecules from complex chains into shorter ones. The degradation is influenced by humidity, pH, the chemical structure of plastic, temperature, availability of oxygen, and nutrients for degrading agents (Sangale, 2012). Biofilms can be decomposed in soil within 6 months to 5 years, depending on the content and types of microorganisms present in the soil. The more fertile the soil, the faster the rate of biodegradation of environmentally friendly plastics (Zhao et al., 2022). The biodegradation process is influenced by the number and combination of microorganisms, environmental conditions, and the enrichment of microbes that can degrade in the soil. The film becomes a carbon source used by degrading agents (microorganisms) in metabolism and growth during degradation. In addition to its biodegradability, to be used as environmentally friendly food packaging, the biodegradable films must be ensured to be free from the dangers of heavy metals which can be harmful to the health of human body and the environment. In this research, the effect of adding gelatin from duck bone waste to taro starch film on color, oxygen permeability, heavy metal content (Pb and Cd), and film biodegradability in compost and barren soils was studied.

## EXPERIMENTAL SECTION

### Chemicals and Materials

Taro tubers (Rogojampi traditional market, Banyuwangi, Indonesia), duck bones (duck bone waste obtained from food scraps), sodium hydroxide (NaOH, analytical grade, Merck KGaA, Darmstadt, Germany), Hydrochoric Acid (HCl, analytical grade, PT Smart Lab Indonesia), distilled water (CV Makmur Sejati, Malang, Indonesia), glycerol (CV Sahabat Lab Indonesia).

### Characterization Methods

The initial stage of this research was making starch from taro tubers. The taro tubers were peeled, washed, and cut. They were then mashed with a grater and some distilled water was added. The proportion of the composition was in one kilogram of taro tubers, two liters of distilled water were added. The taro tubers were then stirred until they were homogeneous. After that, the dregs and the filtrate were separated, squeezed, and the filtering process was carried out. The filtrate was then deposited for 24 hours to separate the suspension and water. The suspension was dried at 60°C using an oven for 24 hours until it formed a dry solid powder, then crushed and sifted until fine taro starch was obtained.

The methode of extracting gelatin from duck bones uses the acid base methode (Ulfa et al., 2015). The first step conducted in the process of making duck bone gelatin was by cleaning the rest of the meat from the bone. Then, the bones were boiled for 2 hours. The bones were drained, dried, and then cut into small pieces with a size of 2 to 3 cm to make the process of cleaning the marrow inside the bones easier. The clean bones were soaked in 0.5 M NaOH solution in a ratio of 1:5 of the bone weight for 2 hours. Furthermore, the bones were soaked using 5% of HCl solution for 24 hours with a ratio of 1:5 of the weight of the bones. Then, the soft bones were neutralized again using distilled water. The ossein was immersed in distilled water with a ratio of 1:5 by weight of the bones and boiled at 70°C for 2 hours to produce filtrate and sediment. The filtrate and sediment were carried out filtering using a cheesecloth. The filter results in the form of filtrate were put in petri dishes were dried. Drying of the filtrate is carried out use an oven at a temperature of 60°C for 24 hours to obtain powdered gelatin.

The method used in the manufacture of biodegradable films was solution casting (Tongdeesoontorn et al., 2012). The concentration of duck bone gelatin used was varies, namely 0%, 5%, 15%, 25%, and 35% of the total weight of the solids. Taro starch and duck bone gelatin were prepared according to the treatment. The taro starch was dissolved in 10 ml of distilled water using a hot plate and stirred by a magnetic stirrer at a temperature of 70°C and a speed of 375 rpm. The gelatin was dissolved in 10 ml of distilled water using the same speed and temperature as dissolving starch. The starch and gelatin solution were mixed and then heated and stirred. Then 0.5 ml of glycerol and 5 ml of distilled water were added. The solution was heated, stirred, and kept at a constant temperature of 70°C, then waited for the gelatinization process to occur for 40 minutes. The solution was poured into a petri dish mold and then it was put in an oven for 24 hours at a temperature of 60°C. The sample was allowed to stand at room temperature after it was removed from the mold.

### Oxygen Permeability Test

The oxygen permeability characteristics were measured by using the Oxygen Permeability Tester ASTM D-3985 method. A 4 x 4 cm film sample with a thickness ranging from 0.6 to 2.8 mm (depending on the film layer formed by the difference in the concentration of the material) was prepared with a moisture content of 2.5%. The permeability tester used

was a pressure gauge, a temperature regulator tube, and a temperature fitting. The sample was placed in the center of the tube. The measurements were carried out at room temperature using oxygen gas as a flow tester on one side of the tube. The pressure loss was proportional to the amount of oxygen that diffused through the film.

### Metal Content Test

The instrument used in the metal content test was the Shimadzu AA-7000 Atomic Absorption Spectrometer. The metal test was done by testing the destruction of 1 gram of sample using $HClO_4$ and $HNO_3$ solutions and then measured with the Instrument Atomic Absorption Spectrophotometer (AAS) at a wavelength of 589 nm.

### Biodegradability

The degradability test was test conducted to observe the level of biofilm resistance to the influence of microorganisms, soil moisture, temperature, and psycho-chemistry in the soil. The biodegradability test was carried out by cutting the sample with a size of 3 cm x 2 cm and buried in compost soil and barren soil at 12 cm under fertile for 14 days (Pine et al., 2021). Compost soil had many nutrients and was soft, while barren soil has few nutrients, the soil was hard and dry. The samples were observed with a span of once a day by removing the sample and measuring its weight loss using the following equation:

$$W = (W_1-W_2)/W_1 \times 100\%$$

Where :

$W$ = Weight loss (%)

$W_1$ = initial sample weight (mg)

$W_2$ = sample weight before 14 (mg)

### Color

A colorimeter from the PCE Instrument (Meschede, Germany) was used to measure the opacity and color of the biofilms. The colorimeter was calibrated against a standard black-and-white background. The measurements were made by placing the sensor head colorimeter on a sample against a black or white background and pressing the start button. The step was repeated five times for each sample. The following values are recorded by colorimeter: L* = brightness, a* from green (-) to red (+), and b* from blue (-) to yellow (+). The values of L = 0 (dark) to 100 (bright), a = -60 (green) to +60 (red), and b = -60 to +60 (yellow) (Fatma et al., 2015).

### Statistical Analysis

The analysis was carried out by using the SPSS calculator software (version 17.0, SPSS, Chicago, ILL). The effect of added gelatin concentration of duck bone waste to taro starch-based biofilms on color, biodegradability, oxygen permeability, and metal content was analyzed by analysis of variance (ANOVA). When the mean differences existed, multiple comparisons were performed using the Duncan Multiple Range Test (DNMRT). The results of significant differences were indicated by $p < 0.05$.

## RESULTS AND DISCUSSION

### Biofilm Color

The phase of determining biofilm color is very important because it can affect consumers' interest in packaged products. The color was measured with a color rader tool, with L, a, and b color units. The L unit indicates the brightness of the biofilms. While the a and b units are the chromacity coordinates which indicate the color direction. The average color value can be seen in **Table 1**. The data in **Table 1** showed that the difference in bone gelatin concentration had a significant effect ($p \leq 0.05$) on the lightness of the biofilms. The highest lightness (L) value which was resulted from the addition of 5% duck bone gelatin was 85.26. While the lowest value that was produced without the addition of duck bone gelatin (0%) was 82.99. The highest value for lightness (L) was found in the addition of 5% duck bone gelatin. This was caused by the lightness color L of duck bone gelatin which was equal to 30.35 (Khirzin et al., 2019), and taro starch which had the L color value of 69.9 (Hawa et al., 2020). Then, mixing duck bone gelatin and taro starch produced biofilms with the L color value of 85.26 and could increase the lightness value. This was caused by the process of making biofilms through the gelatinization stage of taro starch which made the color of the biofilms brighter. The L value with greater gelatin concentration than 5% made L value lower because the duck bone gelatin itself being slightly yellow in color. So, if too much is added to the biodegradable film, the lightness of the biodegradable film will lower.

The data in **Table 1** showed that the data value of colors with the addition of duck bone gelatin had a very significant effect ($p \leq 0.05$) on biofilms. The highest value color a was produced on the addition of 0% duck bone gelatin of 0.94. Whereas, the lowest value which resulted in the addition of 5% was 0.37. The result of the chromaticity diagram value color a was gray. Subroto, (2020) reported that amylose contained in taro starch provided blue on the iodine test . This is the factor that caused the obtained color on the *biofilms* without the addition of duck bone gelatin (0%) to be gray. The data in **Table 1** showed that color b with the addition of duck bone gelatin concentration of 0%, 5%, 15%, 25%, and 35% obtained successive values of -1.713, -2.523, -0.593, -0.507, and 1.673. The highest value for color b was 1.673. It was obtained by adding 35% of duck bone gelatin. While the lowest value was -2.523. It was obtained by adding 5% of duck bone gelatin. The addition of duck bone gelatin was very significant ($p \leq 0.05$) against color b biofilms. The research results showed that the higher the additional concentration of duck bone gelatin was, the higher the score of yellow color on biofilms would be. The higher the score of b was, the more yellow the resulting biofilm*s* would be. This was caused by duck bone gelatin itself was yellow and its value of color b was 3.51 (Khirzin et al., 2019).

As a result, if it was added to taro starch biofilms, it would make it more yellow. The result of color value in this research was different from the previous studies. Hurley et al.(2013) reported that biodegradable materials that were based on kinds of proteins such as commercial gelatin, fish skin gelatin, soy protein isolate, myofibrillar protein, whey protein concentrate, and polyvinyl chloride resulted in L values 91.2, 92.11, 88.6, 92.2, 88.8 and 92.6 and a- values -121, -0.95, -2.86, -0.30, 2.28 and -1.18, for b values were 0.83, 0.60, 2.38, 0.14, 3.17 and 0.04. While this study used taro starch and duck bone gelatin as the basic ingredients which resulted in an average L color value of 82.99-85.26, a value of 0.37 to 0.94, and a b value of -0.507 to 1.67. The difference in the resulting values was due to the differences in the basic ingredients in the production of biofilms.

### Oxygen Permeability

Oxygen permeability is the ability of a material to pass oxygen gas in a unit area of material under certain conditions. The permeability value is strongly influenced by the chemical properties and structure of the polymer (Jabar et al., 2013). The value of oxygen permeability in biofilms is useful for estimating the shelf life of packaged products. In this research, the oxygen permeability test of the biofilm was carried out using standard ASTMD 3985-95 at a temperature of 27.5-28.2°C and relative humidity of 65-68% with a pressure of 0.98 kPa. The value of oxygen permeability of the biofilms obtained without the addition of duck bone gelatin up to the addition of 35% duck bone gelatin is 0 ($cm^3/m^2.d.kPa$). The data in **Table 2** showed that the data results of oxygen permeability. It means that the biofilms are impermeable. Therefore, no oxygen can pass through the biofilms. This means that biofilms can be used as food packaging. The value of permeability to oxygen gas is strongly influenced by the polymer structure, where the polymers with a crystalline structure are more difficult to be penetrated by gases. In contrast, polymers with an amorphous structure are more easily penetrated by gases (Hasan & Hanum, 2010. A crystalline structure is a structure in which the polymer molecular chains that make up the plastic are arranged in an orderly manner. While an amorphous structure is a structure in which the polymer molecular chains are random. Taro starch has a semi-crystalline structure, duck bone gelatin has an amorphous structure, and the biofilm product has a semi-crystalline structure. On the other hand, protein-based films are generally an excellent barrier to oxygen (Bourtoom et al., 2006), carbon dioxide, and some aromatic compounds, but their mechanical properties are unsatisfactory due to their application limitation (Tongdeesoontorn et al., 2012). Polymers with high polarity (polysaccharides and proteins) generally produce low-oxygen permeability values, but high-water vapor permeability. This is because polymers have large hydrogen bonds. Taro starch has a large number of hydroxyl groups which can create strong polymer chain interactions. The interaction between taro starch and duck bone gelatin in making biodegradable film can be seen from FTIR test results (Laksanawati et al., 2021).

The chain interactions limit the chain movement and cause low-oxygen permeability (Zhong & Xia, 2008). Other factors that affect the oxygen permeability value are the thickness of the material and environmental factors such as relative humidity and temperature (Cheng et al., 2016). **Teble 2** shows that adding duck bone gelatin with different concentrations to the biodegradable film based on taro starch had no effect on the thickness. In addition, other factors affect the permeability of biofilms such as the type of material and the concentration of plasticizers that play a major role in the polymerization process (Spada et al., 2014). The use of glycerol plasticizer has large influence on the solubility of taro starch films, due to its hydrophilic nature character. The interaction process between taro starch, duck bone gelatin, and glycerol occurs in the polymerization process. If the polymerization process is maximal, it can form a film matrix which can affect oxygen permeability.

**Table 1.** Color of Biofilms

| Parameters (Color) | Gelatin Composition | | | | |
|---|---|---|---|---|---|
| | 0% | 5% | 15% | 25% | 35% |
| L | $82.99\pm0.375^{b}$ | $85.26\pm1.255^{a}$ | $84.76\pm1.325^{ab}$ | $84.41\pm0.100^{ab}$ | $83.02\pm1.115^{a}$ |
| a | $0.94\pm0.180^{a}$ | $0.37\pm0.055^{c}$ | $0.50\pm0.075^{bc}$ | $0.658\pm0.036^{b}$ | $0.67\pm0.090^{b}$ |
| b | $-1.713\pm0.135^{c}$ | $-2.523\pm0.535^{c}$ | $-0.593\pm0.083^{b}$ | $-0.507\pm0.32^{b}$ | $1.673\pm0.965^{a}$ |

Note : Notation $^{abc}$ in different columns shows a significant effect ($P\leq0,05$), while the same notation shows no significant effect ($P\geq0,05$). L = brightness; a = green (-) to red (+); b = blue (-) to yellow (+).

**Table 2.** Oxygen Permeability of Biofilms

| Parameters | Gelatin Composition | | | | |
|---|---|---|---|---|---|
| | 0% | 5% | 15% | 25% | 35% |
| Thickeness (mm) | 0.191 | 0.192 | 0.192 | 0.193 | 0.194 |
| Oxygen permeability ($cm^3/m^2.dkPa$) | 0 | 0 | 0 | 0 | 0 |

### Metal Content of Biofilms

The results of metal content analysis in taro starch biofilms with the addition of duck bone gelatin concentrations of 0%, 5%, 15%, 25%, and 35%, namely lead (Pb) and Cadmium (Cd) have met the Indonesian National Standard (SNI 7188.7 -2016), where the quality standard for metals in bioplastics is Cd: < 0.5 ppm Pb: < 50 ppm in SNI 7188.7:2016. The results of lead and cadmium metal content in all treatment processes are below the SNI standard. This indicates that the biofilms as the result of the research are safe and can be used for food packaging materials. Biodegradable packaging causes heavy metal contamination during the manufacturing process if the raw materials used to process it are contaminated (Rada-Mendoza et al., 2018). Moreover, the results of the research show that heavy metal content (Pb and Cd) are still found even though the amount is below the SNI standard. This is because taro starch and duck bone gelatin which become the raw materials for biofilms can probably cause cross-contamination during their production process, during the process of extracting gelatin and taro starch, during storage time, from equipment, or water used during the production process (Obanijesu & Olajide, 2009). Therefore, it is very important to pay attention to the process of making raw materials and the production of biofilms because these processes can determine the presence of heavy metals in the final product. Among the existing natural heavy metals, the two metals are the most dangerous because they are carcinogenic and long-term exposure to those metals can cause mitochondrial damage, cancer, and death (Järup, 2003). If the biofilm packaging contains both of the metals, they will likely stay in the human body because they are used for food packaging.

### Biodegradability

Biodegradability is the process of breaking down organic matter carried out by microorganisms such as bacteria and fungi that live in the soil. In this research, biodegradability testing was carried out using the soil burial test method on two different soil media, i.e.: barren and compost soil. The biodegradability value is the result of reducing the initial weight with the final weight divided by the initial weight (Susilawati et al., 2019).

The results of the biodegradability test observations can be seen in **Table 3**. Based on the data in **Table 3**, the percentage of biofilm burial on barren soil from 0% treatment without the addition of duck bone gelatin to the addition of 35% duck bone gelatin respectively on the first day was 11.76%, 15.78%, 16%, 19.04 %, and 20%. After 14 days of burial, the percentage was 54.54%, 58.33%, 62.50%, 64.28%, and 66.66%. Burial of biofilms on compost soil from 0% addition of duck bone gelatin to 35% addition of duck bone gelatin successively on the first day had a percentage value of 21.05%, 25%, 31.57%, 35%, and 66.66%. After 14 days, burial of biofilm has a percentage value of 100%. After 14 days of burial in compost soil, the biofilm showed perfect decomposing results. Han et al. (2020) reported that the biofilm biodegradation process is caused by microorganism factors, soil moisture, and water content in the soil. Materials used for making biofilms come from natural materials and also affect the degradation process in the soil. The biodegradability process is characterized by a reduction in the amount of weight present in the biofilm (Dzaky et al., 2022).

Biofilms grown on barren soil for 14 days can be degraded by 66.66%. The results obtained are above the minimum biodegradation limit, where the biodegradation threshold is 60% (OECD 308) for 10 to 28 days. The biofilms decompose but physically they do not change their shape even though their color change to a slightly brownish color. The mechanism of biofilm biodegradation is influenced by physical, chemical, and biological properties. Chemical structure, melting point, molecular weight, hydrophilic, hydrophobic properties, and surface area greatly affect the speed of the degradation process (Tokiwa et al., 2009). The biodegradability level of biofilms grown on compost soils is higher than those grown on barren soils. This is due to the total number of microorganisms found in compost soil which is 1.3 x $10^9$ CFU (colony forming unit)/gr compared to barren soil which has microorganisms of 2 x $10^8$ CFU (colony forming unit)/gr. Microorganisms play a role in breaking down complex polymers into simpler ones. The mechanism for breaking down microorganism biofilm polymers is assisted by the amylase enzyme which converts polysaccharides into disaccharides and the pepsin enzyme which converts polypeptides into amino acids so that they become an energy source for microorganisms (Shahrim et al., 2022). Microorganisms will absorb and metabolize for growth so that the biofilms are degraded. In addition, soil moisture, water content, and materials used also affect the biodegradability process. Compost soil has a higher water and moisture content so that it can facilitate microorganisms in the biofilm degradation process. This research used taro starch and duck bone gelatin which have OH groups (Laksanawati et al., 2021) and can initiate a hydrolysis reaction after absorbing water in the soil so that the biofilms will decompose into small pieces and can decompose completely in the soil. (Anita et al., 2013) reported that polymer degradation is caused by damage or decreased quality caused by chain breaks in the biofilm-forming polymers. The more addition of duck bone gelatin, the faster the biofilm degradation process will be. This is caused by the addition of hydroxyl groups present in biofilms which makes it easier for microorganisms to degrade biofilms (Herrmann & Bucksch, 2014). The addition of hydroxyl groups to the biofilm makes the film surface hydrophilic and causes the surface of the polymer to have the ability to absorb water. The condition makes

it easier for microorganisms to carry out the degradation process (Herrmann & Bucksch, 2014). In addition, by increasing the hydrophilic nature of the film, it can increase the ability of microorganisms to stick to the surface of the film and then grow and form colonies. Microorganisms or bacteria that have grown and formed colonies on the surface of the plastic will break down the complex polymers of the biofilms so that they become simpler compounds, namely carbon dioxide, water, and methane.

According to international standards (ASTM 5336), the decomposition of bioplastics for PLA (poly lactic acid) and PCL (polycaprolactone) types of plastic takes 60 days to be fully 100% degraded (Coniwanti *et al.,* 2014). The biodegradability produced in this research is 14 days at 100% in compost soil. In addition, the requirements for the European standard EN13432 biodegradable film are 90% degraded due to water, $CO_2$, and biomass for six months (Amin et al., 2019). This proves that the results of this research have fulfilled the biodegradability criteria of biodegradable plastic. The results of the percentage of biodegradability in this research are in line with some previous studies. Resalina et al. (2013) reported that making a plastic mixture of used polyethylene terephthalate and sago starch with gelatin powder reported that the percentage of biodegradability increased with the addition of gelatin powder concentration and burial time. In this research, the percentage of biodegradability increased frequently with the addition of the concentration of duck bone gelatin and the length of cultivation time. (Susilawati et al., 2019) reported that biofilms were made from tapioca flour as the basic ingredient with the addition of chitosan and fish bone gelatin. The percentage of biodegradability on the fourteenth day was 98.6% to - 99.84%. The percentage of biodegradability decreased with the increasing concentrations of chitosan and fishbone gelatin. The decrease in the percentage of biodegradability was caused by the formation of hydrophobic bonds between chitosan and fishbone gelatin which can reduce the hydrophilic groups contained in the resulting biofilms. The previous research is different from this research which is based on taro starch with the addition of duck bone gelatin. The more concentration of duck bone gelatin added, the higher the percentage of biodegradability.

**Table. 3** Metal Content Lead (Pb) dan Cadmium (Cd) of Biofilm

| Heavy Metal | Gelatin Concentration | Metal Content (ppm) | Requirements (SNI 7188.7-2016) |
|---|---|---|---|
| Cadmium (Cd) | 0% | 0.026 | Cd : < 0.5 ppm |
| | 5% | 0.077 | |
| | 15% | 0.079 | |
| | 25% | 0.049 | |
| | 35% | 0.042 | |
| Lead (Pb) | 0% | 4.799 | Pb : < 50 ppm |
| | 5% | 3.522 | |
| | 15% | 1.516 | |
| | 25% | 4.246 | |
| | 35% | 0.158 | |

**Table 4.** Biodegradability of Biofilm in Compost Soil

| Gelatin Composition | Weight Loss | |
|---|---|---|
| | On day 1 | On day 14 |
| 0% | 21.05% | 100% |
| 5% | 25% | 100% |
| 15% | 31.57% | 100% |
| 25% | 35% | 100% |
| 35% | 66.66% | 100% |

**Tabel 5.** Biodegradability of Biofilm in Barren Soil

| Gelatin Composition | Weight Loss | |
|---|---|---|
| | On day 1 | On day 14 |
| 0% | 11.76% | 54.54% |
| 5% | 15.78% | 58.33% |
| 15% | 16% | 62.50% |
| 25% | 19.04% | 64.28% |
| 35% | 20% | 66.66% |

## CONCLUSIONS

Biofilms with varying concentrations of duck bone gelatin and taro starch (*Xanthosoma sagittifolium*) had a significant effect on color with the L color value between 85.26 and 82.99, the color value between 0.94 and 0.37, and the b color values between 1.67 to -0.50. The percentage value of biodegradability in compost soil on day 1 was between 21.05% to 66.66% and on day 14 it completely decomposed 100%. Whereas, the percentage value of biodegradability on barren land on day 1 was between 11.76% and 20%, and on day 14 between 54.54% to 66.66%. The content of cadmium and lead metals in biofilms is below the SNI limit. Thus, the biofilms produced from duck bone gelatin and taro starch is impermeable and can be used as food packaging.

## ACKNOWLEDGEMENTS

This research was funded by State Polytechnic of Banyuwangi through Research Induk Penelitian (RIP) grant with contract number 2543.15/PL36/LT/2022.

## REFERENCES

Amin, M. R., Chowdhury, M. A., & Kowser, M. A. (2019). Characterization and performance analysis of composite bioplastics synthesized using titanium dioxide nanoparticles with corn starch. *Heliyon*, *5*(8). https://doi.org/10.1016/j.heliyon.2019.e02009

Asngad, A., Amelia, R., & Aeni, N. (2018). Utilization of a combination of peanut shells with banana cobs and jackfruit seeds for the production of biodegradable plastics with the addition of glycerol. *Bioeksperimen: Jurnal Penelitian Biologi*, *4*(1), 11–19. https://doi.org/10.23917/ bioeksperimen.v4i1.5924

Bourtoom, T., Chinnan, M. S., Jantawat, P., & Sanguandeekul, R. (2006). Effect of plasticizer type and concentration on the properties of edible film from water-soluble fish proteins in surimi wash-water. *Food Science and Technology International*, *12*(2), 119–126. https://doi.org/10.1177/1082013206063980

Chaves Da Silva, N. M., Fakhouri, F. M., Fialho, R. L. L., & Cabral Albuquerque, E. C. D. M. (2018). Starch-recycled gelatin composite films produced by extrusion: Physical and mechanical properties. *Journal of Applied Polymer Science*, *135*(19), 1–9. https://doi.org/10.1002/app.46254

Cheng, S., Zhang, Y., Cha, R., Yang, J., & Jiang, X. (2016). Water-soluble nanocrystalline cellulose films with highly transparent and oxygen barrier properties. *Nanoscale*, *8*(2), 973–978. https://doi.org/10.1039/c5nr07647a

Coniwanti, P., Laila, L., & Alfira, M. R. (2014). Making biodegradable plastic film from corn starch with addition of chitosan and glycerol plasticizer. *Jurnal Teknik Kimia,* 20(4), 22-30.

Dzaky, M., Sulmartiwi, L., Pujiastuti, Y., & Kelautan, D. (2022). Application of modified starch on bioplastic spoon based carrageenan from eucheuma cottonii on biodegradability. *Journal of Marine and Coastal Science,11*(02), 40-48. https://doi.org/10.20473/jmcs.v11i2.30488

Fatma, Malaka, R., & Taufik, M. (2015). Characteristics of edible film made from dangke whey and agar using different percentage of glicerol. *Jitp*, *4*(2), 63–69.

Han, Y. N., Wei, M., Han, F., Fang, C., Wang, D., Zhong, Y. J., Guo, C. L., Shi, X. Y., Xie, Z. K., & Li, F. M. (2020). Greater biofilm formation and increased biodegradation of polyethylene film by a microbial consortium of arthrobacter sp. And streptomyces sp. *Microorganisms*, *8*(12), 1–15. https://doi.org/10.3390/ microorganisms8121979

Hasan, M., & Hanum, L. (2010). Synthesis for food packaging from chitosan shrimp waste and tapioca starch, with palm oil as plasticize*r*. *Jurnal Purifikasi*, 171–174.

Hawa, L. C., Wigati, L. P., & Indriani, D. W. (2020). Analysis of physical properties and nutritional content of taro flour (*Colocasia esculenta* L.) at different drying temperatures. *Agrointek*, *14*(1), 36–44. https://doi.org/10.21107/agrointek.v14i1.6156

Herrmann, H., & Bucksch, H. (2014). Biodegradable. *Dictionary Geotechnical Engineering/ Wörterbuch GeoTechnik*, *2*(2252), 126–126. https://doi.org/10.1007/978-3-642-41714-6_21579

Hurley, B. R. A., Ouzts, A., Fischer, J., & Gomes, T. (2013). Effects of private and public label packaging on consumer purchase patterns. *Packaging and Technology and Science*, *29*(January), 399–412. https://doi.org/10.1002/pts

Illing, I., & Satriawan, MB. (2017). Uji ketahanan air bioplastik dari limbah ampas sagu dengan penambahan variasi konsentrasi gelatin. *Prosiding Seminar Nasional Universitas Cokroaminoto Palopo*, *03*(1), 182–189.

Jabar, S., Saleha, S., & Sulaiman, S. (2013). Preparation and characterization edible film packaging from carrageenan biodegradable plastic project view project slow release fertilizer view project. *October*. https://www.researchgate.net/publication/304649221

Järup, L. (2003). Hazards of heavy metal contamination. *British Medical Bulletin*, *68*, 167–182. https://doi.org/10.1093/bmb/ldg032

Khirzin, M. H., Ton, S., & Fatkhurrohman, F. (2019). Extraction and characteriization of duck bone gelatin using acid extraction method. *Jurnal Sain Peternakan Indonesia*, *14*(2), 119–127. https://doi.org/10.31186/jspi.id.14.2.119-127

Laksanawati, T. A., Khirzin, M. H., & Amaniyah, M. (2021). Biodegradable film based on taro starch with variations of duck bone gelatin concentration: physical and barrier properties. *Ukrainian Food Journal*, *10*(4), 749–760. https://doi.org/10.24263/2304

Mulyadi, S., Basa, D., & Yetri, Y. (2004). Mekanik dan biodegradabilitas plastik campuran (Mechanics and biodegradability of mixed plastics). *Jurnal Fisika Unand*, *2*(1), 26–32.

Obanijesu, E.O., & Olajide, J.O. (2009). Trace metal pollution study on cassava flour's roadside drying technique in Nigeria. *Appropriate technologies for environmental protection in the developing world.* Dordrecht: Springer, 333-339.

Pine, A. T. D., & Base, N. H. (2021). Characteristics and mechanical properties of biodegradable plastic from banana stems (*Musa paradisiaca*) with variations in cellulose concentrations. media farmasi, *17* (2), 116-126.

Puspawati, N. M., Widihati, I. A. G., & Widana, I. N. (2017). Amino acid composition and halal gelatin protein band pattern from broiler chicken skin. *Jurnal Kimia*, 36–42. https://doi.org/10.24843/jchem.2017.v11.i01.p06

Rada-Mendoza, M. D. P., Villamiel-Guerra, M. del M., Hoyos-Saavedra, O. L., & Alvira, L. F. (2018). Quantification of lead using atomic absorption spectrometry in thermoformed and biodegradable flexible films made from cassava (*Manihot esculenta* crantz). *DYNA (Colombia)*, *85*(207), 236–242. https://doi.org/10.15446/dyna.v85n207.72347

Rahmawati. (2012). Characterization of taro starch (*Colocasia esculenta* (L.) Schott) as an alternative starch source in Indonesia. *Jurnal Teknologi Kimia Dan Industri*, *1*(1), 348–351.

Rastini, E. K., Astuti, S., Handoko, F., & Vitasari, P. (2020). Training on making bioplastics to increase student creativity at Malang national high school. *JASTEN Jurnal Aplikasi Sains Teknologi Nasional*, *01*(01), 7–13.

Resalina, Basa, S. M. D., & Yetri, Y. (2013). Effect of addition of gelatin powder on the mechanical properties and biodegradability of plastic mixture of used polyethylene terephthalate and sago starch. *Jurnal Fisika Unand*, *2*(1), 26–32.

Sangale, M. K. (2012). A Review on Biodegradation of Polythene: The Microbial Approach. *Journal of Bioremediation and Biodegradation*, *03*(10), 1-9. https://doi.org/10.4172/2155-6199.1000164

Santosa, H., Abyor H, N., Guyana, N. L., & Dwi Handono, S. F. (2018). Hidrolisa kolagen dalam ceker ayam hasil perendaman dengan asam asetat pada proses pembuatan gelatin (Hydrolysis of collagen in chicken feet resulting from soaking with acetic acid in the gelatin making process). *Gema Teknologi*, *20*(1), 32-36. https://doi.org/10.14710/gt.v20i1.21224

Shahrim, N. A., Sarifuddin, N., Azhar, A. Z. A., & Zaki, H. H. M. (2022). Biodegradation of Mango Seed Starch Films in Soil. *IIUM Engineering Journal*, *23*(1), 258–267. https://doi.org/10.31436/IIUMEJ.V23I1.1620

Spada, J. C., Da Silva, E. M., & Tessaro, I. C. (2014). Production and characterization of pinhão starch biofilms. *Revista Brasileirade Ciencias Agrarias*, *9*(3), 365–369. https://doi.org/10.5039/agraria.v9i3a3704

Subroto, E. (2020). Review on the analysis methods of starch, amylose, amylopectinin food and agricultural products. *International Journal of Emerging Trends in Engineering Research*, *8*(7), 3519–3524. https://doi.org/10.30534/ijeter/2020/103872020

Susilawati, S., Rostini, I., … R. P.-W. S., & 2019, U. (2019). Characterization of bioplastic packaging from tapioca flour modified with the addition of chitosan and fish bone gelatin. *World Scientific News*, *135*(September), 85–98.

Tokiwa, Y., Calabia, B. P., Ugwu, C. U., & Aiba, S. (2009). Biodegradability of plastics. *International Journal of Molecular Sciences*, *10*(9), 3722–3742. https://doi.org/10.3390/ijms10093722

Tongdeesoontorn, W., Mauer, L. J., Wongruong, S., Sriburi, P., & Rachtanapun, P. (2012). Mechanical and physical properties of cassava starch-gelatin composite films. *International Journal of Polymeric Materials and Polymeric Biomaterials*, *61*(10), 778–792. https://doi.org/10.1080/00914037.2011.610049

Triwitono, P., Marsono, Y., Murdiati, A., & Marseno, D. W. (2017). Isolation and characterization the properties of some Indonesian local varieties mung beans (*Vigna radiata*) starch. *Agritech*, *37*(2), 192–198.

Ulfa, M., Trisunaryanti, W., Falah, I. I., & Kartini, I. (2015). Characterization of gelatines extracted from cow bone for carbon synthesis. *IOSR Journal of Applied Chemistry (IOSR-JAC*, *8*(8), 57–63. https://doi.org/10.9790/5736-08825763

Zhao, F., Wei, Z., Zhou, G., Kristiansen, K., & Wang, C. (2022). Effects of different storage temperatures on bacterial communities and

functional potential in pork meat. *Foods*, *11*(15). https://doi.org/10.3390/foods 11152307

Zhong, Q. P., & Xia, W. S. (2008). Physicochemical properties of edible and preservative films from chitosan/cassava starch/gelatin blend plasticized with glycerol. *Food Technology and Biotechnology*, *46*(3), 262–269.

Zulisma Anita, Fauzi Akbar, & Hamidah Harahap. (2013). Pengaruh penambahan gliserol terhadap sifat mekanik film plastik biodegradasi dari pati kulit singkong (Effect of adding glycerol on the mechanical properties of biodegradable plastic film from cassava peel starch). *Jurnal Teknik Kimia USU*, *2*(2), 37–41. https://doi.org/10.32734/jtk.v2i2.1437