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Characterization of biodegradable plastic from jackfruit seed waste with the addition of rice straw cellulose

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Abstract. Biodegradable plastic is an environmentally friendly plastic; most of the components come from renewable raw materials. Biodegradable plastic can be made from starch derived from waste such as jackfruit seeds. Biodegradable plastics made only from starch have poor physical and mechanical properties, so adding reinforcement such as cellulose is necessary. One of the wastes that contain cellulose is rice straw waste. This study aimed to obtain the best ratio of jackfruit seed starch and rice straw cellulose to biodegradable plastic's physical and mechanical properties. This research was carried out experimentally using a Completely Randomized Design (CRD) with five treatments, namely the ratio of starch and cellulose PS1 (1:0,3), PS2 (1:0,4), PS3 (1:0,5) PS4 (1:0,6), and PS5 (1:0,7) with three repetitions, 15 experimental units were obtained. The data obtained was analyzed statistically using analysis of variance (ANOVA). If Fcount ≥ Ftable data is obtained, it will be continued with Duncan's Multiple Range Test (DMRT) at the 5% level. The selected treatment was PS5 (starch ratio 1:0,7 cellulose) with had water absorption rate of 34,82%, water vapor transfer rate of 19,12 g/m2hour, tensile strength of 20,21 MPa, elongation of 5,33%, and biodegradation for 6 days. The results showed that the addition of rice straw cellulose had a significant effect on the value of water absorption, water vapor transfer rate, tensile strength, elongation and biodegradation of the resulting biodegradable plastic.

1 Introduction

The use of plastic cannot be separated from the life of modern society. Starting from meeting basic needs such as tableware or food packaging to tertiary needs such as accessories and other needs. According to data from the Ministry of Environment and Forestry [1], plastic waste in Indonesia reaches 67 million tons per year. In a global study, Indonesia is among the second-largest waste-producing countries in the world [2].

Plastic waste cannot be destroyed even though it is landfilled for a very long time, causing environmental damage. Efforts can be made to reduce plastic waste accumulation by recycling, reusing, reducing, and using renewable resources. One way to use renewable

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resources is by producing *biodegradable* plastics. Biodegradable plastic is a plastic polymer that is environmentally friendly, most of its constituents are made from renewable raw materials. *Biodegradable* plastics are polymers consisting of organic monomers such as starch, cellulose, and proteins [3].

Starch is a natural polymer whose availability is widely found, starting from tubers, corn, stem sources, and grains [4]. The starch that can be used in the manufacture of *biodegradable* plastics is starch from jackfruit seeds. The starch content in jackfruit seeds is quite high at around 70.26% [5]. According to data from the Central Statistics Agency, jackfruit production in Riau Province in 2020 was 20,424 tons [6]. Jackfruit production produces quite a lot of jackfruit seed waste, so the production of *biodegradable* plastics with starch raw materials from jackfruit seeds will reduce jackfruit production waste.

Previous research has carried out the manufacture of biodegradable plastic from jackfruit seed starch by adding polyvinyl alcohol and sorbitol [7]. The best treatment results are at a concentration of *polyvinyl alcohol* 3 grams and sorbitol 2 mL to produce *biodegradable* plastic with a *tensile strength* value of 2.2 MPa and a percent *elongation* of 1.3%. *Biodegradable* plastics made only from starch have drawbacks, namely low mechanical properties [8]. Improving the mechanical properties of *biodegradable* plastics can be done by adding reinforcement in the form of cellulose. The use of cellulose in the production of biodegradable plastics will be able to improve the mechanical and physical properties of *biodegradable* plastics [9].

Cellulose is a polymer having a long chain and includes polysaccharide compounds that are widespread in nature [10]. Molecularchains in cellulose can bind to starch molecules in *biodegradable* plastics so as to improve the mechanical properties formed [11] Cellulose can be obtained from plant waste such as rice straw. Rice straw includes waste from rice plants in the form of stalks and stems from dried rice plants.

Rice straw contains 37.71% cellulose, the content can be used as a material for the production of *biodegradable plastics* from rice straw as bioplastic using organic solvent treatment [12]. The best treatment was obtained at the ratio of tapioca starch and rice straw cellulose (1:0.5) with cellulose delignification using 35% ethanol, resulting in a tensile strength value of 8.773 MPa, elongation of 6.5% and a water vapor transmission rate of 12 $g/m^2/day$ [13] . The novelty of this research is the use of jackfruit seeds as a source of starch in making plastic with the addition of rice straw fibre to strengthen the mechanical properties of biodegradable plastic jackfruit seed starch. Therefore, it is hoped that by utilizing both agricultural and plantation waste, it will strengthen the physical and mechanical properties of plastic which produces plastic that meets standards.

2 Materials and methods

2.1 Materials and tools

This research uses raw materials in the form of jackfruit seeds obtained in the household industry of making chips on Jl. Raya Pekanbaru-Bangkinang and rice straw were obtained from the Main Seed Center (BBI) of the Kampar Regency Agriculture Office. The chemicals in this study are NaCl, NaOH, ethanol, glycerol, soil as a decomposing medium, NaCl aquades, and acetic acid. The tools in this study used a blender, sieve, spatula, oven, mold 25 cm x 15 cm thickness 0.2 cm, stirring rod, hot plate and magnetic stirrer, beaker, analytical scale, camera, stationery, scissors, knife, desiccatator, porcelain cup.

2.2 Research methods

This study was conducted using a complete randomized design (RAL) consisting of five treatments, and each treatment was repeated three times. Thus, a total of 15 experimental units were obtained with the following comparative treatment. PS1 (starch 1 : 0.3 cellulose), PS2 (starch 1 : 0.4 cellulose se), PS3 (starch 1 : 0.5 cellulose), PS4 (starch 1 : 0.6 cellulose), PS5 (starch 1 : 0.7 cellulose).The data obtained in this study will be analyzed statistically using the Analysis of Variance (ANOVA) or fingerprint test. If F counts ≥ F table, it will be continued with the Duncan Multiple Range Test (DMRT) at the level of 5%. If F counts ≤ F table, then the analysis is not continued.

2.3 Conduct of research

2.3.1 Making jackfruit seed starch

Jackfruit is peeled and sliced into small pieces and washed thoroughly. 200 grams of jackfruit seed slices are mashed using a blender, and then 100 mL of water is added and squeezed. The acyl is precipitated for 24 hours until a precipitate is formed. Precipitate starch is taken and then heated using an oven at 30ºC for 12 hours so that the moisture content decreases. After the dried starch is mashed and strained using a 100 mesh sieve [14].

2.3.2 Manufacture of rice straw cellulose

Rice straw cellulose extraction refers to Setiawan [13]. The rice straw is first crushed using a blender and filtered using a 60 mesh sieve. Rice straw that has been finely lignified using organic treatment. Amount 100 g of fine rice straw is put into a beaker with a capacity of 1000 mL. The rice straw that has been put into the baker is then soaked in ethanol with a concentration of 35% v/v. The ratio of fine straw to ethanol is 1:10v/v. The mixture is heated at 80ºC for 2 hours. Heated rice straw is allowed to stand at room temperature for 24 hours. Furthermore, straw pulp is added 500 mL NaOH 1% w/v so that the remaining lignin content disappears. The solids obtained are filtered and washed using distilled water so that the remaining ethanol and NaOH disappear. The straw pulp is further dried in the oven at 50ºC ± 3 hours. Cellulose is soaked in 10% acetic acid ±2 hours at 90ºC to make the cellulose smoother and cleaner. Then, it is washed using an aqueous and dried in the oven.

2.3.3 Manufacture of biodegradable plastics

The production of biodegradable plastics refers to Setiawan [13]. Biodegradable plastics are made by mixing starch and cellulose according to treatment. Furthermore, the mixture added aqueous as much as 65 mL and 20% glycerol from the weight of starch. Then stir, the solution and heated ± 10\u201215 minutes with a temperature of 90ºC until thickened. The solution is then printed with a size of 25 cm x 15 cm with a mold thickness of 0.2 cm and then dried at room temperature until it is in the form of a biodegradable plastic sheet.

2.4 Research parameters

2.4.1 Water absorption

The sample to be tested was previously cut at 3 x 1 inch. Then, the plastic is weighed, and the initial weight of the plastic is recorded. Then, the plastic sample is put into the water until it is completely submerged for 2 hours. After soaking the plastic, samples are taken, and removed water that is on the surface is using a dry cloth. The biodegradable plastic is then weighed repeatedly to a constant weight [15]. The water absorption of biodegradable plastics can be calculated by the formula:

$$Weight\ percentage\ (\%) = \frac{W - W0}{W0} \times 100 \quad (1)$$

Information:
W = Final weight of plastic
W0 = Starting weight of plastic

2.4.2 Water vapor transfer rate

The plastic sample is inserted into the mouth of a round dish 7 cm in diameter containing 10 g of silica gel. The cup is then placed in a vessel containing 40% NaCl solution (w/v). Water vapor diffused through the resin will be absorbed by silica gel, thus increasing the weight of silica gel. Plastic samples are tested for 7 hours and weighed every 1 hour (from 0 to 7 hours). Weight gain indicates how much speed of diffusion water vapor passes through the plastic [16] . The water vapor transfer rate g/m^2/hour is calculated using the following formula:

$$WVTR = \frac{Rise\ slope\ (g/jam)}{Plastic\ Surface\ Area\ (m^2)} \quad (2)$$

Information:
Water Vapour Transmission Rate (g/m^2/hour)

2.4.3 Tensile strength

In the tensile strength test, biodegradable plastics are allowed to stand in a 24-hour room, and the sample plastic is then cut with a size of 2 x 8 cm. Test this is done by clamping both ends of the sample, then the initial length is recorded when before adding the load. Biodegradable plastics are then tested by clamping and adding weights. The tensile strength of the plastic is determined based on the maximum load that the plastic sample can withstand before breaking [17].

$$Tensile\ strength = \frac{Pull\ Force\ (F)}{Surface\ area\ (A)} \quad (3)$$

Information:
F: Tensile strength force (N); A: Sample surface area (mm2)

2.4.4 Elongation

The sample is allowed to stand in a 24-hour room, the sample plastic is then cut with a size of 2 x 8 cm. Uji this is done by clamping both ends of the sample, and then the initial length is recorded when before adding the load. Biodegradable plastics are then tested by clamping and adding weights. Elongation is determined based on the increase in length of the plastic before breaking [17].

$$Elongation\ (\%) = \frac{L\text{-}Lo}{Lo} \times 100 \quad (4)$$

Information:
L: Length after break(mm); Lo : Initial length (mm)

2.4.5 Biodegradation

The biodegradable plastic sampled was cut into 4 cm x 4 cm in size, and then the sample was buried in a plastic cup containing black soil with a depth of 12 cm. Qualitative observations were made on biodegradable plastics [18]. Observations were made in a span of 2 days for 6 days until the sample experienced degradation in the soil.

3 Results and discussion

3.1 Water absorption

Water absorption testing is a test used to assess the extent of a plastic's ability to water. Variations in the addition of cellulose from rice straw in the plastic-making process have shown significant changes in the plastic's ability to absorb water. The average percentage of water absorption analysis results in biodegradable plastics can be found in Table 1.

Table 1. Average biodegradable plastic water absorbency test value.

Treatment	Swelling (%)
PS1 (Ratio Starch : cellulose 1 : 0,3)	18,66[a]
PS2 (Ratio Starch : cellulose 1 : 0,4)	19,79[a]
PS3 (Ratio Starch : cellulose 1 : 0,5)	23,73[b]
PS4 (Ratio Starch : cellulose 1 : 0,6)	31,31[c]
PS5 (Ratio Starch : cellulose 1 : 0,7)	34,82[d]

Note: Numbers followed by different lowercase letters indicate significant differences according to the DMRT test at the 5% level

The data in Table 1 shows that the average value of water absorption of biodegradable plastic PS1 treatment is significantly different from PS3, PS4, and PS5 treatment but not real difference from PS2 treatment. The water absorption capacity of biodegradable plastics with the addition of rice straw cellulose ranges from 18.66-34.82%. The water absorption value of biodegradable plastic with a low value was obtained in the PS1 treatment with a starch ratio of 1:0.3 cellulose, which was 18.66%, while the highest biodegradable plastic water absorption test value was obtained in the PS5 treatment with a starch ratio of 1:0.7 cellulose, which was 34.82%.

The data shows that the more rice straw cellulose is added, the more water absorption test value in biodegradable plastics increases. This is because cellulose in biodegradable plastics is water-binding. The water-binding properties cause biodegradable plastics soaked in water to absorb water. The lower the percentage of water absorption in biodegradable plastic, the better the biodegradable plastic to use, while the higher the percentage of water absorption, the nature of the plastic will be easily damaged [19]. Biodegradable plastics used as packaging media should have a low percentage of water absorption [20]. The best water absorption value in this study used a ratio of starch and cellulose 1: 0.3, while the study used starch treatment of 4 g and cellulose 25%.

The value of the water absorption test found in biodegradable plastic is lower than research on biodegradable plastics from jackfruit seed starch and chitosan [21], namely the treatment of 4 g starch and 25% cellulose. Produced a water absorption value of 29.48–53.84%, while the water absorption test value in this study was 18.66–34.82%. This study has differences in the cellulose raw materials used, this study uses rice straw cellulose. The difference in the low value of water absorption in biodegradable plastics is also caused by the concentration of materials in the form of reinforcement added.

3.2 Water vapor transfer rate (WVTR)

The water vapor transfer rate is a test that aims to determine the amount of moisture missed through biodegradable plastics. The results showed that the addition of cellulose to the production of biodegradable plastics had a significant influence on the value of the moisture transfer rate of biodegradable plastics. The average value of the water vapor transfer rate analysis can be seen in Table 2.

Table 2. Average value of biodegradable plastic moisture transfer rate analysis.

Treatment	WVTR (g/m2/hour)
PS1 (Ratio Starch : cellulose 1 : 0,3)	11,32[a]
PS2 (Ratio Starch : cellulose 1 : 0,4)	11,82[a]
PS3 (Ratio Starch : cellulose 1 : 0,5)	12,66[ab]
PS4 (Ratio Starch : cellulose 1 : 0,6)	14,51[b]
PS5 (Ratio Starch : cellulose 1 : 0,7)	19,12[c]

Note: Numbers followed by different lowercase letters indicate significant differences according to the DMRT test at the 5% level

The data presented in Table 2 show that there is a significant difference in the value of moisture transfer rate in plastic between PS1 treatment and PS4 and PS5 treatment. However, there is no significant difference between the treatment of PS1 and the treatment of PS2 and PS3. The value of the water vapor transfer rate in biodegradable plastics ranges from 11.32 $g/m^2/h$ to 19.12 $g/m^2/hour$. The lowest water vapor transfer rate was recorded in the PS1 treatment with a starch ratio of 1:0.3 cellulose, which was 11.32 $g/m^2/hour$, while the highest value was recorded in the PS5 treatment with a starch ratio of 1:0.7 cellulose, which was 19.1 2 g/m 2/hour.

The data shows that the value of the water vapor transfer rate increases with the increase in cellulose addition. This is because the addition of cellulose to biodegradable plastics has hydroxyl groups that bind water. The hydroxyl group in cellulose can also bind water vapor in the air, causing the rate of water vapor transfer in biodegradable plastics to increase with each treatment. The OH group contained in cellulose causes water in the air to be absorbed, this results in the value of water vapor transfer increasing [18].

The added jackfruit seed starch also affects the value of the moisture transfer rate in the plastic. Amylose has hydrophilic properties, and the rate of vapor transfer occurs in parts of the film that have hydrophilic properties then the high amylose content in starch will increases the rate of water vapor transmission in biodegradable plastics [22]. The expected biodegradable plastics are plastics that have a low water vapor transfer rate. This is because the low rate of water vapor transfer will maintain the freshness of the product when packaged.

3.3 Tensile strength

The tensile strength test is the maximum tensile strength that can be withstood before the plastic is torn or broken. The results of variance showed that the addition of rice straw cellulose had a significant effect on the tensile strength value of biodegradable plastic. The results for the average strength value of biodegradable plastic can be seen in Table 3.

Table 3. Average tensile strength analysis values of biodegradable plastics.

Treatment	Tensile Strength (MPa)
PS1 (Ratio Starch : cellulose 1 : 0,3)	13,03[a]
PS2 (Ratio Starch : cellulose 1 : 0,4)	15,89[b]
PS3 (Ratio Starch : cellulose 1 : 0,5)	17,17[c]
PS4 (Ratio Starch : cellulose 1 : 0,6)	18,29[c]
PS5 (Ratio Starch : cellulose 1 : 0,7)	20,21[d]

Note: Numbers followed by different lowercase letters indicate significant differences according to the DMRT test at the 5% level

The data listed in Table 3 shows that there is a significant difference in the tensile strength of biodegradable plastic between the PS1 treatment and the PS2, PS3, PS4, and PS5 treatments. However, in the PS3 treatment, there was no significant difference from the PS4 treatment. The tensile strength test value of biodegradable plastic with the addition of cellulose from rice straw ranges from 13.03 to 20.21 MPa. The lowest tensile strength value was recorded in the PS1 treatment with a starch ratio of 1:0.3 cellulose, which was 13.03 MPa, while the highest tensile strength value was recorded in the PS5 treatment with a starch ratio of 1:0.7 cellulose, which was 20.21 Mpa.

Table 3 shows that the more rice straw cellulose added to each treatment, the higher the tensile strength test value. This may happen because cellulose from rice straw has hydroxyl groups which have the ability to form hydrogen bonds. These hydrogen bonds form layers of bonds in the form of fibers that can strengthen each other. Increasing in tensile strength was due to the added cellulose, so the interaction of the attractive forces between molecules increased [23]. This has a linkage to the hydroxyl group so that they can make a bond with each other in the form of intermolecular hydrogen bonds and strengthen each other.

Significant differences in tensile strength values between this study and previous research can be caused by several factors. One of the main factors is the difference in the type of starch raw material used [13]. The highest average value of the tensile strength test in this study met the criteria of SNI 7818:2014 regarding biodegradable plastic bags with a minimum tensile strength value of 13.7 MPa. The tensile strength value of this research is higher when compared to previous research conducted by Setiawan [13], regarding the manufacture of plastic using tapioca flour and rice straw cellulose in a ratio of 1: 0.5. The tensile strength test results in this research were 8.733 MPa. This difference occurs due to differences in the weight of cellulose used in the treatment. The best treatment for the tensile strength test value in this research is to use a ratio of 1: 0.7. Another difference also occurs in the type of starch raw material used, in this study jackfruit seed starch was used.

3.4 Elongation

The elongation test is the percentage change in length of the plastic from the initial size when the plastic is pulled until it breaks. The variance results show that the addition of rice straw cellulose significantly affects the elongation value of biodegradable plastic. The average elongation analysis value of biodegradable plastic can be seen in Table 4.

Table 4. Average elongation analysis values for biodegradable plastics.

Treatment	Elongation (%)
PS1 (Ratio Starch : cellulose 1 : 0,3)	2,47[a]
PS2 (Ratio Starch : cellulose 1 : 0,4)	3,60[b]
PS3 (Ratio Starch : cellulose 1 : 0,5)	3,79[b]
PS4 (Ratio Starch : cellulose 1 : 0,6)	4,77[c]
PS5 (Ratio Starch : cellulose 1 : 0,7)	5,33[d]

Note: Numbers followed by different lowercase letters indicate significant differences according to the DMRT test at the 5% level

The data listed in Table 4 shows that there is a significant difference in plastic elongation values between PS1 treatment and PS2, PS3, PS4, and PS5 treatments. However, there was no significant difference between PS2 and PS3 treatments. The elongation test value of biodegradable plastic with the addition of cellulose from rice straw ranged from 2.47% to 5.33%. The lowest elongation value was recorded in the PS1 treatment with a starch ratio of 1:0.3 cellulose namely 2.47%, while the highest elongation value was recorded in the PS5 treatment with a starch ratio of 1:0.7 cellulose, namely 5.33%.

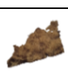
The increase in the average elongation test value for biodegradable plastic occurred due to the addition of cellulose to the treatment. This is because cellulose contains hydroxyl groups. The hydroxyl groups in cellulose form hydrogen bonds, which makes the plastic flexible. According to Budianto [18], cellulose has a long polymer chain, which causes cellulose to become flexible and affects the elongation value of biodegradable plastics. The more use of cellulose can increase the percent elongation.

The best average elongation value in this study was lower compared to Simarmata by regarding biodegradable plastic made from banana weevil starch and rice straw cellulose with a ratio of 1:1.5 [24]. The results of the biodegradable plastic elongation test in this study were 6.8%. This difference is influenced by the concentration of cellulose added to the treatment of biodegradable plastic production. The concentration of cellulose used in this study was a starch ratio of 1:0.7 for cellulose.

3.5 Biodegradation

Biodegradation testing aims to see how long biodegradable plastic can be degraded by microorganisms in an environment. This test is carried out in the soil because the soil contains microorganisms such as bacteria, fungi, and algae, so these microorganisms will affect the process of biodegradation. This test was carried out qualitatively based on visual observation. Biodegradation test results data can be seen in Table 5.

Table 5. Qualitative test of biodegradation of biodegradable plastic.

Treatment	Days		
	2	4	6
PS1			
PS2			
PS3			

PS4			
PS5			

The qualitative data shows that the biodegradable plastics in this study degraded for 6 days. On the 6th day, all biodegradable plastics had already degraded in the soil. The table shows that the biodegradable plastics in this study degraded for 6 days, and on the 6th day, all plastics biodegradable has undergone a process of degradation in the soil. This is indicated by the observation of biodegradable plastic samples that have become small fragments. The result of this biodegradation is faster than plastic using tapioca and rice straw cellulose with a degradation time of 10 days [13]. This difference occurred due to the additional weight of the cellulose material added to the treatment. This study used the weight of starch and cellulose at 1:0.7, while used a weight of starch and cellulose of 1:0.5 [13] .

The biodegradation process is related to water absorption, if more cellulose is used, more and more water will be absorbed by biodegradable plastics and can be easily degraded in the soil. According to Budianto [18], the link between biodegradation and water absorption is that water is a place for microbes and bacteria to grow in the soil, the more water that is absorbed, the more it will accelerate the process of degradation of biodegradable plastics in the soil.

3.6 Recapitulation of the results of the selected treatments

Good biodegradable plastic is plastic that can be easily degraded or decomposed. Biodegradable plastic is expected to be able to protect products such as plastic packaging in general. The recapitulation of the results of the analysis of the selected treatments can be seen in Table 6.

Table 6. Recapitulation of the results of the selected treatments.

Research Parameters	SNI 7818:2014	Treatments				
		PS1	PS2	PS3	PS4	PS5
Swelling (%)	-	18,66^{a}	19,79^{a}	23,73^{b}	31,31^{c}	34,82^{d}
WVTR (g/m2/hour)	-	11,32^{a}	11,82^{a}	12,66a^{b}	14,51^{b}	19,12^{c}
Kuat tarik (MPa)	Min13,7	13,03^{a}	15,89^{b}	17,17^{c}	18,29^{c}	20,21^{d}
Elongasi (%)	400-1120	2,47^{a}	3,60^{b}	3,79^{b}	4,77^{c}	5,33^{d}

Note: Numbers followed by different lowercase letters indicate significant differences according to the DMRT test at the 5% level

The data in Table 6 indicates that the addition of cellulose has a significant impact on the parameters that have been analyzed, such as water absorption capacity, water vapor transfer rate, tensile strength, elongation, and biodegradation rate of biodegradable plastic. The tensile strength value of biodegradable plastic in this research is in accordance with the SNI 7818:2014 standard, while the elongation value still does not reach this standard. The biodegradation test for biodegradable plastic lasted for 6 days, and on the 6th day, all samples experienced degradation in the soil, which was indicated by the observation that the biodegradable plastic samples had become small fragments. Based on the summary data in Table 10, the PS5 treatment with a ratio of starch and cellulose of 1:0.7 has been selected as the selected treatment. The selection of PS5 was based on statistical analysis, which showed that biodegradable plastic in the PS5 treatment had a water absorption capacity of 34.82%, a water vapor transfer rate of 19.12 g/m2/hour, a tensile strength of 20.21 Mpa, an elongation of 5, 33%, and has been degraded for 6 days. PS5 was chosen as the selected treatment because the biodegradable plastic in this treatment has higher tensile strength and elongation values, in accordance with good quality standards for biodegradable plastic according to SNI 7818:2014.

4 Conclusion

Based on the results of the analysis that has been carried out, adding cellulose to the production of biodegradable plastic can influence the water absorption test values, water vapor transfer rate, tensile strength, elongation, and biodegradation produced. PS5 has a water absorption capacity of 19.79%, a water vapor transfer rate of 19.12 g/m^2/hour, a tensile strength of 20.21 MPa, an elongation of 5.33%, and a degradation time of 6 days.

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