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The Effect of Carboxymethyl Cellulose (CMC) Addition on the Quality of Biodegradable Plastic from Corn Cob

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Abstract: This study aims to determine the effect of CMC addition on thickness, tensile strength, elongation and biodegradation of biodegradable plastic from corn cob starch. In this study, the addition of Carboxymethyl Cellulose which plays a role in increasing the tensile strength of biodegradable plastics. This research was conducted in 2 stages. The first stage is varying CMC as much as 20%, 30%, 40%, 50% and 60% (w/b starch) and the second stage is mixing corn cob starch as much as 2 grams with CMC 20% - 60% w/b starch. The test results showed that the addition of CMC concentration of 20% w/w with corn cob starch mixing material had an effect on increasing the tensile strength value and decreasing the elongation value of the plastic. The addition of CMC concentration as much as 20%-60% w/b starch with corn cob starch blending material has an effect on increasing the percent weight loss of biodegradable plastics.

Keywords: Biodegradable plastic; Carboxymethyl Cellulose (CMC); Corn Cob

Introduction

As the second biggest producer of waste in the world, Indonesia has quite a challenge on its hands. As a highly tropical country that's surrounded by oceans, many natural ecosystems are at stake. If not properly addressed, the plastic waste problem can lead to natural disasters and ecosystem damage. The data on plastic waste in Indonesia is a quantifiable evidence that shows the level of accumulation of plastic waste in Indonesia within a certain period of time. There are many groups and organizations that continue to evaluate the amount of plastic waste in Indonesia. This data continues to grow from time to time. The waste volume will also rise along with the increase in the industrial sector. The food and beverages industry accounts for 65% of the total demand for plastic packaging. Plastic package consumption also accounts for 65% of the total national plastic consumption.

Over the past two centuries, the world's significant population growth and its consumption habits have led to several negative impacts on the environment. The Development of a society with more sustainable mechanisms of production/consumption must consider scenarios such as deforestation, water pollution, soil siltation, and waste accumulation. Concerning plastic waste, they constitute about 12% of the world's solid waste composition (Kaza et al., 2018), and their daily production has been increasing since 1950 and exceeded 6 billion tons of waste generated between 1950-2015 (Geyer et al., 2017).

Since the synthetic plastics can only degrade within 400-600 years, it is necessary to produce plastics that are environmentally friendly, plastics raw materials that are widely available, sustainable, and have the same strength results as synthetic plastics. Looking for alternatives is important in reducing human dependence on non-renewable resources. A biodegradable plastic is a plastic that can be degraded by microorganisms in a faster time compared to synthetic plastics. The biodegradable plastics are offered to protect and safeguard the environment from the hazards caused by conventional petroleum. Therefore, there was a need for research on degradable packaging

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materials. Several researches have come up with the technology of making plastics from natural materials that can degrade in a short time using resources that can be renewed, which is expected to be a solution to environmental pollution. Other benefits of bioplastic are that one of them can help reduce CO2 emissions. One Metric ton of bioplastics produces from 0.8 to 3.2 metric tons less carbon dioxide compared to one metric ton of petroleum-based plastic (Kamsiati et al., 2017).

Bioplastic can be made using materials that contains natural polymers. The materials can be in the type of starch which can be obtained from very abundant raw materials. The main ingredient of bioplastics is starch. Starch is often used in food industry as a bioplastic material to replace plastic polymers because it is economical, renewable and has good physical characteristics. One of the examples of natural resource that contain starch is corn, where corn is a cereal crop that is an important food because it is the second source of carbohydrate after rice. As the production of corn in Indonesia increases, it is undeniable that the presence of corn waste will increase. The resulting waste includes corn cobs. Currently, people consider corn cobs to have no benefits and are only regarded as garbage. From these problems comes the thought of utilizing corn cob waste to be processed into biodegradable plastics supported by the considerable content of cellulose present in corn cobs (Pujiani et al., 2014).

Corn cob starch is one of the possible biopolymers that can be used as raw material for making bioplastics. It is non-toxic, environmentally friendly, rich in renewable resources and affordable. Starch based bioplastics are transparent, colorless, tasteless and odorless (Amin et al., 2019; Rodrigues et al., 2018). However, similar studies have also reported that starch-derived bioplastics are brittle, stiff and brittle (Marichelvam et al., 2019). Therefore, this problem is overcome by the addition of plasticizers and carboxymethyl cellulose. This study uses Carboxymethyl Cellulose (CMC) as a filler in the manufacture of biodegradable plastics. This is due to its low price and easy to obtain. As a CMC filler, it plays a role in increasing the tensile strength of biodegradable plastics. According to previous research, the tensile strength value of biodegradable plastic increases with the increase of CMC concentration. The addition of CMC causes molecular interactions that occur between hydrogen bonds of hydroxyl groups (OH) from starch and carboxylic groups (COOH) from CMC to decrease so that the force of attraction that occurs in each polymer chain is greater. Thereby causing the tensile strength of the resulting plastic to increase (Elean et al., 2018).

Carboxymethylcellulose (CMC) is one of the products of cellulose derivative modified by etherification of cellulose reaction These biomaterials are mostly used stabilizers food thickeners and bioplastics with compound crosslinking (Cai et al., 2018). Based on the research conducted by Hasanah et al. (2016) stated that the additions of CMC have an influence on the speed of biodegradation that occurs in bioplastics. The research showed that the more CMC material added, the easier the plastic is decomposed by microorganisms. But, the plastic will be very hard to dissolve in water, this is because water is trapped in starch molecules, causing the solubility of starch in water to decrease. The additions of CMC will produce a plastic with a smoother surface structure (Hasanah et al., 2016).

Related to the research that has been done before which discusses the manufacture of starch based bioplastics, it can be known that the quality of biodegradable plastics is determined based on the value of tensile strength, elongation and biodegradation produced from biodegradable plastics. In addition, the biodegradable plastic quality is also influenced by the type of starch, filler and plasticizer used in making biodegradable plastic. So, the authors tried to conduct a research on "The effect of the addition of Carboxymethyl Cellulose (CMC) concentration with mixing material in the form of corn cob on the quality of biodegradable plastic".

Method

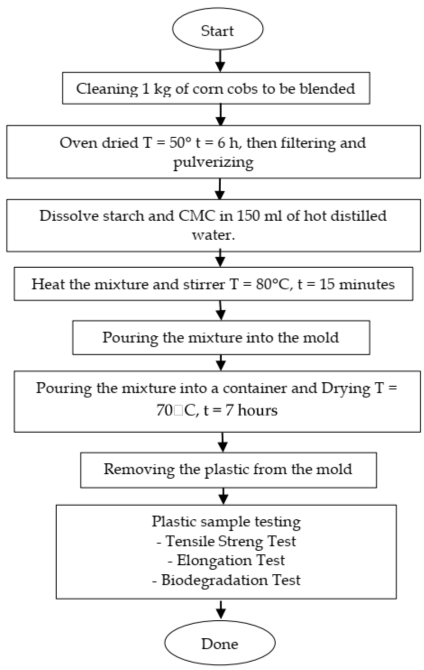

Figure 1. Flowchart of biodegradable plastic manufacturing and test

The type of research is experimental research. This study examines the effect of the addition of

Carboxymethyl Cellulose (CMC) concentration on the quality of biodegradable plastic from corn cob starch which includes thickness test, tensile strength test, elongation test of biodegradable plastic and knowing the effect of mixing corn cob starch and CMC on the quality of biodegradable plastic which includes thickness test, tensile strength test, elongation test and biodegradation test. The stages of making biodegradable plastic from corncob starch are shown in Figure 1.

Tools and Materials

The tools used are an Analytical Scales, Blender, Hotplate, Filter, Magnetic stirrer, Oven, Mini Ultimate Testing Machine, Measuring cup, Beaker, Spray Bottle, Mold, Mortar and mortar, Thermometer, Screw Micrometer , Desiccator. The Materials in this study used Corn cob starch, Carboxymethyl Cellulose (CMC), Humus soil, Distilled water. Sample Preparation Stage, The material used in this research is corn cobs. Corn cob that is used as much as 1 kg. The following procedure is to peel the corn kernels from the corn cob. Then, wash the corn cob thoroughly. In the process of making flour from corn cobs, the first step is to clean the corn cobs and then chop them into small pieces. After chopping, it is then blended until smooth to get the corn cob shape like flour. Then the corn cobs are sieved using a sieve to get corn cob flour that passes the mesh up to 100 mesh. Starch Isolation, at this stage is done to get the starch contained in the raw material, namely corn cobs (removing amylopectin enzymes). Starch extractions are carried out by soaking the raw materials with distilled water for 24 hours. After 24 hours, the mixture is filtered to get the residue (pulp) in the form of starch. The residue is then dried using an oven at 100°C.

Afterwards, the dried starch is in the form of flour and ready to be used for making biodegradable plastic. Making Corn Cob Starch Biodegradable Plastic, making corn cob starch solution, weighing corn cob starch as much as 2 grams, dissolving corn cob starch into a beaker containing 75 ml of distilled water. Furthermore, the solution was stirred using a stirring rod. The following is a picture of corn cob starch dissolved into a beaker containing 75 ml of distilled water Making Corn Cob Starch Biodegradable Plastic with the Addition of Carboxymethyl Cellulose Concentration. The steps of making corn cob starch biodegradable plastic with the addition of carboxymethyl cellulose concentration. Then Weighing Carboximethyl Cellulose as much as 20%, 30%, 40%, 50%, 60% of the weight of corn cob starch as much as 2 grams.

Next is the preparation of Carboximethyl Cellulose (CMC) solution as much as 20%, 30%, 40%, 50%, 60%. Then dissolve the Carboximethyl Cellulose powder into a beaker containing 75 ml of distilled water. The same is done for the manufacture of Carboximethyl Cellulose solution with different concentration. Next, heat the Carboximethyl Cellulose solution using a hot plate and stir the Carboximethyl Cellulose solution using a magnetic stirrer at 75ºC for 30 minutes until the solution is homogeneous (Sitompul et al., 2017; Susilowati et al., 2019). After that, mix the Carboximethyl Cellulose solution with the Corn Cob starch solution. Then the solution is heated at a temperature of 80ºC for 15 minutes, Pouring the mixture into a plastic mold measuring 20 cm x 15 cm. Drying the mixture using an oven at 70ºC for 7 hours and cooled at room temperature (until the plastic condition is dry and does not stick to the mold). Finally the plastic sample is released from the mold.

Figure 2. Plastic from corn cob starch

Characterization

Thickness testing of biodegradable plastics is measured using a screw micrometer. Testing the thickness of biodegradable plastics is done by measuring the thickness of five different positions, namely at the top left, bottom left, top right, bottom right and center of the bioplastic sheet. The thickness values obtained from five different positions on the plastic sample were averaged. Testing the thickness of biodegradable plastics using a screw micrometer tool that has an accuracy of 0.01 mm. Tensile strength and elongation tests were carried out using the Ultimate Testing Machine Mini Series tensile testing equipment conducted at the UNAND Metallurgical Laboratory. Elongation testing was carried out by measuring the initial length of the plastic sample before and after the sample was given a load.

The tensile strength and elongation testing procedures refer to research conducted by Martina (2016) and Haryati et al. (2017). The following is the procedure for testing the tensile strength and elongation of biodegradable plastic from corn cob starch. Your paper must use a page size corresponding to A4 which is 210 mm (8.27") wide and 297 mm (11.69") long. The margins must be set as follows: 1) Top = 19 mm (0.75"), 2) Bottom = 28 mm (1.1") Left = Right = 14.32 mm (0.56").

Biodegradation tests are carried out by planting plastic samples in the soil and then observing the degradation process that occurs in plastic. The biodegradation testing carried out refers to research conducted by Pane et al. (2019) and Rifaldi et al. (2017). The following is the procedure for conducting biodegradation testing of biodegradable plastics from corn cob starch.

Result and Discussion

The Biodegradable plastic samples used for testing in each variation of carboxymethyl cellulose.

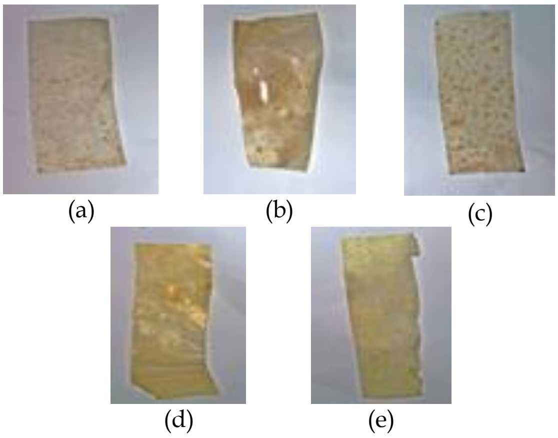

Figure 3. Biodegradable plastic sample from corn cob in each CMC variation. a) 20%, b) 30%, c) 40%, d) 50%, e) 60%

It is known that the addition of antimicrobial agents and antioxidants to biodegradable plastics affects the mechanical properties, the barrier strength and the optical properties of the films formed, with the degree of effect depending on the type of material formed. Ingredients extracted from plant products often affect the color and gloss (opacity) of biodegradable plastics (An et al., 1998; Hong et al., 2000).

Tensile Strength Testing of Biodegradable Plastic from Corn Cob Starch with Added CMC Concentration. Based on the tensile strength testing data of biodegradable plastic from corn cob starch, it shows the effect of the addition of CMC concentration on the tensile strength value of biodegradable plastic from corn cob starch. The following is a graph showing the effect of the addition of corn cob starch as much as 2 grams with CMC variations of 20%-60% w/b starch as shown in Figure 4.

Based on Figure 4, it can be seen that the tensile strength value of biodegradable plastic increased when adding CMC concentration of 20%-60% w/w starch with the resulting tensile strength value ranging from 1.20- 6.50 MPa. However, the tensile strength value of biodegradable plastics decreased when adding CMC concentration of 30% w/w starch. The highest tensile strength value was obtained from the addition of corn cob starch as much as 2 grams and CMC as much as 60% w/w starch with the resulting tensile strength value of 6.50 MPa.

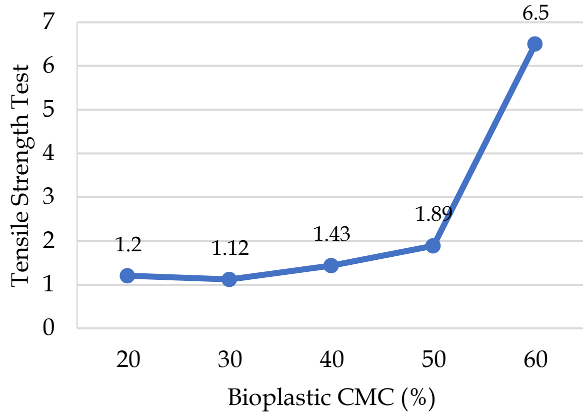

Figure 4. Effect of CMC concentration of biodegradable plastic from corn cob starch

Effect of CMC Addition on Elongation Value of Biodegradable Plastic from Corn Cob Starch. The following is a graph showing the effect of CMC addition on the elongation value of biodegradable plastic from corn cob starch as shown in Figure 5.

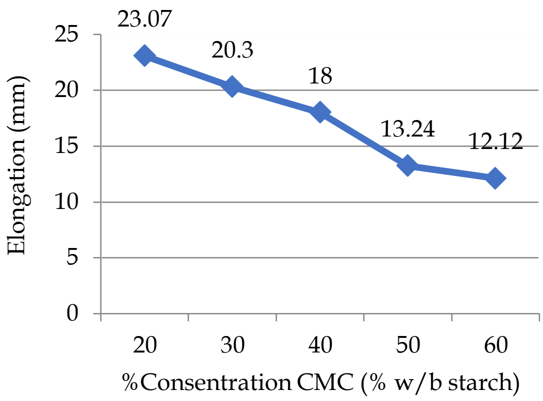

Figure 5. Effect of CMC addition to elongation value of biodegradable plastic from corn cob starch

Based on Figure 5, it can be seen that the highest elongation value obtained from mixing corn cob starch material as much as 2 grams and CMC as much as 20% w/b starch is 23.07%. The addition of CMC concentration resulted in a decrease in the elongation value of biodegradable plastic.

The following is a graph showing the effect of CMC addition with 2 grams of corn cob starch on the percent weight loss of biodegradable plastic as shown in Figure 6, Chart of Biodegradation Test results of Biodegradable Plastic from the Addition of CMC Concentration of 20%, 30%, 40%, 50% and 60% w/w starch.

Based on Figure 6, it can be seen that the percent weight loss of biodegradable plastic from corn cob starch increased from day to day. On day 8, the biodegradable plastic made from corn cob starch is almost completely decomposed. This can be seen from the largest percent weight loss of biodegradable plastic obtained from the addition of CMC concentration of 20% w/b starch with corn cob starch mixing material of 2 grams, which is 85%. The increase in percent weight loss of biodegradable plastic occurs due to the activity of microorganisms such as fungi and bacteria that occur in the soil. This causes the mass of biodegradable plastic made from corn cob starch to decrease.

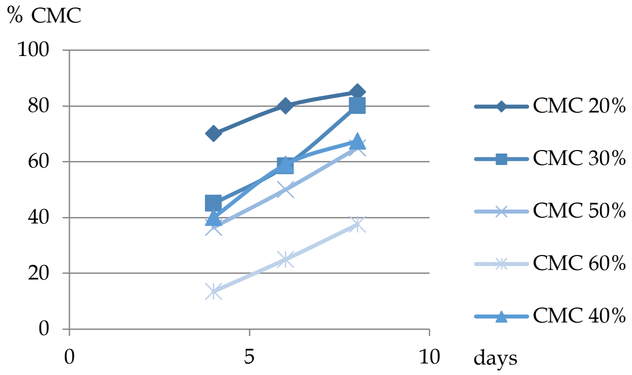

Figure 6. Effect of biodegradation test results of biodegradable plastic from the addition of CMC concentration of 20%, 30%, 40%, 50% and 60% w/w starch

Discussion

In the bioplastic manufacturing research, there were several steps such as making corn cob starch, producing bioplastics and conducting several tests on the bioplastics produced. This study used corn cob starch samples that have been mashed. This corn cob base material is taken from the Tabing area, Padang, corn cobs are also waste that will be discarded F1 tabbing corn. However, this corn cob starch can be utilized as a basic material for the manufacture of bioplastics that are environmentally friendly and easily affordable so that the manufacture of bioplastics can be done first by making corn cob starch extract.

Bioplastic Characteristics

Thickness Test

According Table 1, it can be seen that the thickness of biodegradable plastic from corn cob starch with the addition of CMC concentration of 60% w/b starch is constant at 0.2 mm, due to the same corn cob starch in each CMC concentration variation of 2gr. The thickness value obtained is considered good because it is below the maximum standard of bioplastic thickness according to the Japanese Industrial Standard which is 0.25 mm (JIS, 1975).

Table 1. Testing Results of Biodegradable Plastic Thickness from Addition of CMC Concentration with Corn Cob Starch

Starch Mass (gr)	CMC Concentration (% w/b starch)	Thickness (mm)
	20	0.2
	30	0.2
2	40	0.2
	50	0.2
	60	0.2

Tensile Strength Test

According to Table 2, it can be seen that the tensile strength value of biodegradable plastic increased along with the increase of CMC concentration of 20%-60% w/w starch. However, the highest tensile strength value was obtained from the addition of CMC as much as 60% w/w starch, which amounted to 6.50 MPa. The increased tensile strength value of biodegradable plastics occurs due to the addition of CMC concentration which causes the number of matrix constituent polymers produced to be more and the attractive force that occurs between starch and CMC molecules is getting stronger. Thus causing the strength of the biodegradable plastic produced will be greater. This indicated that the addition of CMC made the molecular structure amorphous. In an amorphous molecular structure, the chains are branched but not tightly arranged so that the distance between molecules becomes longer and the molecular bond strength is weakened.

Table 2. Tensile Strength Test Results of Corn Cob Starch Biodegradable Plastic with Added CMC Concentration Starch

Starch Mass (gr)	CMC Concentration (% w/b starch)	Tensile Strength (MPa)
	20	1.20
	30	1.12
2	40	1.43
	50	1.89
	60	6.50

The weak molecular bond strength in the film causes the force required to break the film to be lower (Delvia, 2006). The thickness is also one of the factors that affect the tensile strength of biodegradable plastics. The results of the previous research showed that the relationship between thickness and tensile strength is directly proportional, i.e. the thicker the plastic, the greater the tensile strength. This is in accordance with research conducted by Ningsih et al. (2019) which states that the addition of CMC causes the tensile strength value of the resulting plastic to increase. However, when adding CMC concentration as much as 30% w/b starch, the tensile strength value decreased because CMC was not dissolved completely in water so that the distribution of CMC particles became uneven.

In addition, the decrease in tensile strength is because the matrix has passed its saturation point so that the movement that occurs between corn cob starch and CMC becomes less than optimal and causes the spread of CMC to be unevenly distributed. As a result, one part of the biodegradable plastic has a different thickness. This will certainly affect the tensile strength of the plastic produced. The homogeneity of a material also affects the value of plastic tensile strength. The more homogeneous a material is, the better the quality of the resulting plastic will be. Based on the data analysis that has been done, the highest tensile strength obtained from the addition of CMC concentration of 60% w/b starch is 6.50 MPa, the results obtained are in accordance with those stated by Zuwanna et al. (2017) which states that the addition of CMC and sorbitol concentrations will increase the tensile strength value of biodegradable plastics. The tensile strength value obtained has met the Indonesian National Standard (SNI) for bioplastics which ranges from 1-10 MPa.

Elongation Test

Based on Table 3 that the addition of CMC concentration of 20%-60% w/b starch causes the elongation value of the biodegradable plastic produced to decrease. This is because the increase in CMC concentration will cause the resulting matrix constituent polymers to become tighter. It causes the tensile strength of the plastic to be stronger. As a result, the biodegradable plastic is more difficult to stretch or elongate. This causes the percentage of elongation of biodegradable plastic to decrease. According to the results obtained, the elongation value and tensile strength of biodegradable plastics are inversely proportional, namely the more CMC concentration added, the tensile strength of the plastic will increase and the elongation produced by biodegradable plastics will decrease.

Table 3. Elongation Test Results of Biodegradable Plastic from Corn Cob Starch with Added CMC Concentration

Starch Mass (gr)	CMC Concentration (% w/b starch)	Elongation (%)
2	20	23.07
	30	20.30
	40	18.00
	50	13.24
	60	12.12

The obtained results are in accordance with the conditions obtained from the research of Rizki et al. (2019) which states that the addition of CMC concentration will cause the elongation value produced will decrease. According to Choi et al. (2017), the breaking elongation increased with increasing concentrations of sorbitol and CMC. The elongation to break is inversely proportional to the tensile strength. This may occur because sorbitol and CMC reduce the intermolecular/intramolecular hydrogen bonds in the starch chain, resulting in increased molecular mobility and a more flexible matrix. This change is related to the interaction between CMC as a reinforcement and distilled water as a plasticizer, that the greater the concentration of CMC, the elongation value of bioplastics will decrease.

This is due to the greater mass of filler used, causing the resulting plastic to decompose easily and causing a decrease in the elongation value of biodegradable plastic. The research results obtained are in accordance with the conditions obtained from the research of Hudha et al. (2020) which states that under certain conditions the addition of plasticizers and fillers will cause the elongation value produced to decrease. One of the reasons is that the amount of filler and CMC is not comparable so that it has an influence on the elongation value produced. According to the previous data analysis, the elongation value obtained from the addition of corn cob starch and CMC 20% w/b starch is better or higher than the elongation value obtained from the addition of CMC concentration of 30% - 60% w/b starch. The elongation value produced has met the Indonesian National Standard (SNI) for bioplastics, which ranges from 10%-20%.

Biodegradation Test

Based on Table 4, the results of biodegradation testing from the addition of corn cob starch and CMC 20% (w/b starch) showed that the percent weight loss of biodegradable plastic increased from day to day. Biodegradable plastic is almost completely decomposed on the 8th day which is indicated by the largest percent weight loss of biodegradable plastic obtained on the 8th day from the addition of CMC concentration of 20% w/b starch, which is 85% while the smallest percent weight loss of biodegradable plastic is obtained from the addition of CMC 60% w/b starch which is 37.5%. Based on the data analysis that has been done before, the decomposition process of plastic made from the addition of corn cob starch concentration and CMC 60% w/w starch lasts longer. This is due to the addition of corn cob starch and CMC 60% w/b starch which is increasingly causing the time required by microbes to decompose biodegradable plastic will be longer.

The percent weight loss of this plastic increases from day to day due to the activity of microorganisms such as fungi and bacteria, which help in the process of biodegradable plastic decomposition in the soil. The biodegradable plastic decomposition begins with the breakage of the plastic chain by microorganisms. The microorganisms will convert the carbon in the plastic chain into carbon dioxide. The addition of corn cob starch and CMC also affects the biodegradation process of biodegradable plastics because CMC has the ability to bind water. This causes sorbitol and CMC to be suitable as a medium for the development of bacteria and microbes that play a role in decomposing biodegradable plastics (Krisnadi et al., 2019).

Table 4. Biodegradation Testing Results of Biodegradable Plastic from Addition of CMC Concentration with Corn Cob Starch

Starch Mass (gr)	CM Concentration (% w/b starch)	Weight loss (%) Day- 4	6	8
	20	70	80	85
	30	45	58.5	80
2	40	40	59	67.5
	50	36.5	50	65
	60	13.5	25	37.5

As a result of the biodegradation process, the molecular weight of the resulting polymer decreases and makes the biodegradable plastic decompose and disintegrate in the soil. The results retrieved are in agreement with the conditions obtained from the research of Zuwanna et al. (2017) which states that the decomposition process of biodegradable plastics by microorganisms will take place faster when the concentration of CMC used is less. Biodegradable plastic made from corn cob starch and CMC 20% w/b starch decomposes faster than the bioplastic quality standard which states that bioplastics can be completely decomposed after 60 days.

Conclusion

The result of the research: The addition of CMC concentration with corn cob starch blending has the effect of increasing the tensile strength and decreasing the elongation and biodegradation values of biodegradable plastics. The highest tensile strength value was obtained from the addition of CMC concentration of 60% w/w starch which amounted to 6.50 MPa; the addition of CMC concentration with corn cob starch and CMC 20% w/b starch will cause the plastic decomposition process to last longer while the percent weight loss of plastic increases from day to day. The biggest plastic weight loss percent was obtained from the addition of CMC concentration of 20% w/b starch with corn cob starch mixing material as much as 2 grams, which was 85%. Biodegradable plastic made from corn cob starch can almost completely decompose after the 8th day.

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Author Contributions
Lead author, M. Bayu Ihsan, contributed to conducting the research, writing the original manuscript and collecting data. The second author, Ratnawulan, contributed to the validation investigation, revising the article and the original manuscript. All contributing parties have reviewed and approved this version of the manuscript for publication.

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Conflicts of Interest
The author declares no conflict of interest.

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