Development of biodegradable plastic made from recycling of polypropylene (PP) with corn stalks powder

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Abstract. The objectives of the study are to develop biodegradable plastic composite and to investigate the mechanical characteristic and water absorption. It was made from polypropylene (PP) mixed with corn stalks powder. In this study, the weight fraction of polypropylene and powder was varied as 95% : 5%; 90% : 10%; 85% : 15%. For the water absorption test, the specimens were soaked in the water for 1, 7, and 14 days. The highest value of the tensile test was delivered from a specimen of 95% : 5% weight fraction. The tensile test of the soak specimen for 0, 1, 7, 14 days was obtained 17.41 MPa, 16.94 MPa, 16.11 MPa, 13.51 MPa respectively. The strain was 1.07, 1.19, 1.01, and 0.87%. The modulus of elasticity was 1686.74, 1500.42, 1712.1, and 1558.49 MPa. By adding the powder to the plastic, it was able to absorb water. The water absorption after 1, 7, and 14 days of water soak was 0.607, 1.468, and 4.651% respectively. The specimen of biodegradable plastic composites with a 95% : 5% ratio have compatible characteristics with commercial plastics and can be degraded easier than the origin plastic.

1. Introduction

In Indonesia, plastic waste production is the second rank in the domestic waste producer at 5.4 million tons per year. The fact about national waste has already quite troubling. Indonesia is the second rank in the world producing plastic waste into the sea after China. According to Indonesian retail merchant association, in every 100 stores will produce 10.95 million pieces of plastic bag waste a year.

Today, plastics used in the market are synthetic polymers. It made from petroleum base (non-renewable materials) that cannot be degraded by microorganisms in the environment for a short time. One of the synthetic plastics is polypropylene (PP). Polypropylene plastic is the most popular plastic in the market due to the chemical resistance. Therefore, PP plastic is become the top rank on the amount of plastic waste. Polypropylene is a thermoplastic type. It made from propylene monomers which has properties such as rigid, odorless, and resistant to chemical solvents, acids, and bases. It have used in wide applications such as automotive components, loudspeakers, laboratory equipment, and containers [1].

Polypropylene has a melting point of ~ 160 ° C (320 ° F), as determined by Differential Scanning Calorimetry (DSC). PP has high mechanical strength but it cannot be degraded by the environment easier [2]. To overcome the problem, biodegradable plastic was developed. It made by mixing synthetic plastic with natural polymers. Natural polymers have several disadvantages such as low mechanical properties, brittle, and weak in high temperatures. Therefore, developing biodegradable plastic by using natural fibres was conducted. The plastic product with the properties such as environmentall friendly,
able to decompose by microorganism and high mechanical properties. Plastic waste was used for concrete as well [3-10].

Indonesia is an agrarian country that it has considerable potential to utilize fibers obtained from agricultural waste. Therefore, in this research, the development of biodegradable plastic used corn stalk as natural fibre. The corn stalks usually burned by the farmers due to useless and considered as garbage. Corn stalk has cellulose content around 40% of weight. It was potentially used as row material as natural fibre in developing biodegradable plastic. Japan, Germany and USA have developed biodegradable plastic by using corn stalks fibre. In Indonesia, the corn production was 18,506,287 tons from 3,820,161 ha land. It has great potential to use corn stalk fibre for composite materials [11].

Biodegradable plastics composites made from High Density Polyethylene (HDPE) and cassava skin starch was developed. In the study, the weight fraction of HDPE and cassava peel starch was varied as 8:2, 7:3, 6:4, 5:5, and 4:6 grams. The result shows that the highest tensile strength was delivered from fraction 7:3. It was 19,4433 N/mm², the elongation value as 18.1403%, and the Young Modulus value of 107.1833 N/mm². That material characteristics was similar with commercial plastics and it can be degraded by microorganisms [10,12].

HDPE and hull fiber of corn have developed as bioplastic composit. The composite degradation was investigated under UV (Ultraviolet) accelerated weathering for 2000 h. The specimen with hull fiber content less than 5% was shown the better resistance then the filler contents of 18%. After the UV weathering, the broken chain of HDPE was increased and crystallinity polymer as well. Therefore the degradation of HDPE-hull fiber was easier than the virgin HDPE [11].

Biocomposit plastic can be made from recycle polyethylene (RPE) and eco-degradant PD04. The material usually called as Chitosan Biocomposites. The increasing of eco-degradant PD04 could increase the tensile strength, the Young's Modulus and the water absorption but reduces the Elongation At Break. The water resistant of Chitosan Biocomposite during water absorbtion was better than the other biocomposite without eco-degradant PD04 [13-15].

2. Materials and Methods
Biodegradable is ability material to break down or decompose by bacteria or microorganisms. Biodegradable plastic developed by using recycle PP plastic and corn stalk powder. Corn stalk powder is used to make grow bacteria or microorganisms after exposed to water. Microorganism will break the C chain of plastic. The variation of specimens was shown in table 1. Tensile test and water absorption of the materials was carried out to investigate the mechanical properties. Tensile test was conducted according to the standard of ASTM D 638-04.

PP plastic selected for recycled material usually from mineral water bottles. Plastic is then washing by using water and cutting to be small pieces in square as 2 cm². While the preparation of corn stalk is starting from drying process under sun light for a week. The drying process is continued by using oven machine in 60°C for 24 hours. To get powder, the crushing machine is used to process the stalk become powder. The corn stalk powder size was 0.5835 mm after sieving by using mesh number 60.

| No | Specimen weight fraction (%) | Water absorption (day) | Tensile test |
|----|-----------------------------|-----------------------|--------------|
|    | PP  | Corn stalk             |               |              |
| 1  | 100 | 0                     |               | √            |
| 2  | 95  | 5                     | 0, 1, 7, 14   | √            |
| 3  | 90  | 10                    | 0, 1, 7, 14   | √            |
| 4  | 80  | 15                    | 0, 1, 7, 14   | √            |
3. Results and Discussion

Figure 1 shows that the highest tensile stress was delivered from the specimen without soaking in water. It was in the 95% weight fraction given the tensile stress of 17.41 MPa. The lowest tensile stress was came from the specimen with weight fraction of 85%. It has 13.14 MPa.

After one day water immersion, the highest tensile stress was 16.94 MPa, from the specimen with 95% weight fraction. While the lowest tensile stress was 11.77 MPa, from 85% weight fraction. After 7 days of water immersion, the highest tensile stress came from 95% weight fraction was 16.11 MPa. The lowest tensile stress was 10.17 MPa, from 85% weight fraction. After 14 days, the highest tensile stress at 90% was 13.59 MPa, while the lowest tensile stress was in the weight fraction of 85% at 9.99 MPa. Other researchers were resulted the same trend in this experiment [15], [16].

The strain of specimens can be seen in figure 1. In the specimen of 100% weight fraction, it was not decrease significantly during the water immersion. It means that the material can not absorb the water. Therefore the strain is not decrease. The strain was 0.81, 0.72, 0.84 and 0.61. While the material with the weight fraction of 85% was able to absorb water. It can be seen from the stain after water immersion. The strain was 1.07, 0.99, 0.81, 0.61. By decreasing the tensile stress and strain after water immersion, it can be said that the material can be degrade after contact with water.

![Figure 1. Tensile stress and strain to the water soak of the specimens.](image1)

![Figure 2. Young modulus of the specimens.](image2)

Figure 2 shows the material elasticity. The highest modulus of elasticity without soaking water was 1937.59 MPa. It was delivered from specimen of 100% weight fraction. The lowest elasticity was came
from 85% weight fraction specimen. After water immersion for 14 days, the lowest elasticity was delivered from specimen with 95% weight fraction. For the specimen of 85% weight fraction, it was delivered the lowest elasticity after 1 day water immersion. It can be caused by the contents of corn powder. The more corn powder contents, it able to absorb water quickly.

From the tensile test results, the best average tensile strength was came from the specimen with 95% plastic, 5% corn stalk powder. It caused by the perfect bond between matrix and powder. While the lowest tensile strength was delivered from specimen of 85% plastic and 15% corn powder. More corn stalk powder can decrease the strength.

The water absorption test result of the specimens was shown in figure 3. From the figure 3, it can be seen that the best water absorption in 1 day water immersion was came from the specimen with the weight fraction of 85%. While the lowest water absorption was came from the specimen without natural fibre or 100% made from plastic. After 7 days, the best water absorption was from the weight fraction of 85%. After 14 days, the best water absorption was from the weight fraction of 85%. It was 6.497%.

The more water absorbed by the materials, the strength was decreased. There were many air cavities between the composite material bonds and the properties of the material itself which can absorb water. It can be seen during the water absorption testing. Materials with 85% plastic and 15% corn powder have the best water absorption but it have the lowest strength. In this study, the addition of corn stalk powder can increase the water absorption. Therefore, the material can be degradable by organism easily.

![Figure 3. The water absorption of the specimens.](image)

The macro structure observation of biodegradable plastic composites was seen clear color section as a plastic zone. While the corn stalk fiber was seen brownish as shown in figure 4 and 5. The dispersion and density of the corn stalk fiber of the 85% weight fraction (figure 5) was denser than the 90% (figure 4).

The water soaking was conducted to grow up microorganism in the natural fiber or corn stalk powder. Microorganisms absorb macromolecules as food and utilize them to fuel their metabolic processes. PP plastic has a long chain of carbon. The microorganisms was broken the carbon chain of PP during their metabolic process. The broken chain was decreased the strength. Figure 1 shows the tensile strength was decreased during increasing water soak time. Therefore, the longer time of water soak was grown up more microorganisms to break down the carbon chain of PP plastic [13]. In this paper, the grow up of microorganisms and their metabolic were not investigate.
4. Conclusions
The biodegradable plastic composite was successfully developed from recycle plastic and corn stalk powder. Tensile strength is inversely proportional to the immersion time. The longer immersion time decreases the tensile strength of the material. The water content was increased as well. The increasing number of corn powders on composites will increases the water absorbency of its material. It was shown on the composite fraction of 85% polypropylene plastic and 15% corn husk powder. The water absorption was 2.155% in 1 day immersion and 6.497% after 14 days.

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