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A Review of Potency of Cassava Peel Waste and Seaweed Carrageenan as Environmentally Friendly Bioplastic

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Abstract

Plastic waste continues to increase every year along with the increasing number of industries and population. Accumulated plastic waste has a negative impact and harm the environmental. The initiative of 3R (reduce, reuse, and recycle) has been widely promoted, but it is not optimally implemented. The use of organic materials to substitute the synthetic materials in plastic become alternative to prevent this problem continues in the future. Bioplastics are naturally decomposed by the soil and made from renewable materials. This review aims to explore the potency of cassava peels (*Manihot esculenta*) and seaweed carrageenan (*Eucheuma cottonii*) as the bioplastic material. The method used is an effective literature review and in accordance with the topic being discussed. The discussion method is carried out based on research results that have been found by previous researchers, which are then integrated with other researchers to get strong results and conclusions. Cassava peel waste and seaweed carrageenan have the potency to be made into bioplastics because they contain polysaccharide that can form a thin layer films based on gelatinization. The development of cassava peel waste and seaweed carrageenan will becoming the promising materials as substitutions for synthetic plastic, and also could help prevent the negative impact of plastic waste. Furthermore, since the cassava and seaweed are naturally abundant, it will promoting the environmental sustainability.

Keywords: bioplastic; carrageenan; cassava peel; waste; sustainability

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INTRODUCTION

Since the 1930s, petrochemical-based such as PP-Polypropylene; PE-Polyethylene; PVC-Polyvinyl chloride; PUR-Polyurethane; PET-Polyethylene terephthalate; other plastics: ABS-Acrylonitrile butadiene styrene; PBT-Polybutylene terephthalate; PC-Polycarbonate; PMMA-Polymethyl methacrylate; PTFE-Polytetrafluoroethylene; PS + EPS-PolyStyrene + Expanded PolyStyrene are widely used in industry because of its advantages such as low cost, easy availability, light weight, attractive appearance, versatility, and excellent thermal properties (Cooper, 2013; Kumar et al., 2014; Chisti et al., 2014; Gadhave et al., 2018). In 2019, the distribution of global plastic production of various types can be seen in quite a number of presentations **(Figure 1)** (Kopecká et al., 2022). They are useful in almost all fields such as construction, packaging, automotive, pharmaceutical, engineering, electronics, agriculture, etc (Gadhave et al., 2018; Al-Salem et al., 2017; Sharuddin et al., 2016). The largest application of plastic is for packaging due to the increase of single-use containers (Jambeck et al., 2015). Considering the fact that plastic food packaging and containers have the shortest lifetime compared to others, causing them to be disposed of more quickly and become waste (Andeady, 2015).

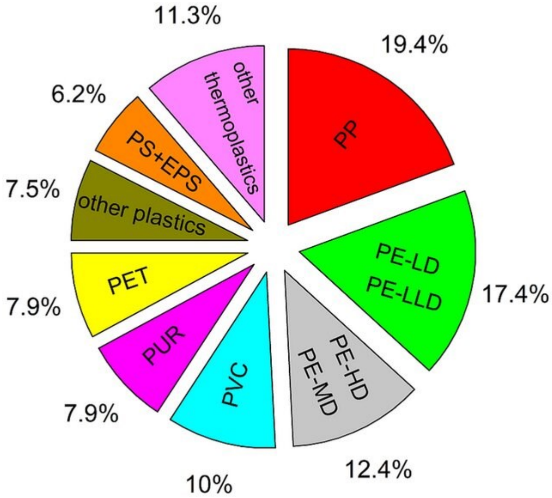

Figure 1. Distribution of global plastic production in 2019; PP-Polypropylene; PE-Polyethylene; PVC-Polyvinyl chloride; PUR-Polyurethane; PET-Polyethylene terephthalate; other plastics: ABS-Acrylonitrile butadiene styrene; PBT-Polybutylene terephthalate; PC-Polycarbonate; PMMA-Polymethyl methacrylate; PTFE-Polytetrafluoroethylene; PS + EPS-PolyStyrene + Expanded PolyStyrene (Kopecká et al., 2022).

Jambeck (2015) reported that around 381 million tons of plastic waste are generated per year by humans and this number will double by 2034. More than 300 million tons of plastic were used in the world in 2015, and Indonesia was in the second place after China as the world's largest producer of plastic waste that produces 187.2 million tons of plastic waste to the oceans (Hendiarti, 2018). Plastic waste brings negative impact to the environment, such as soil fertility reduction, harms the marine life, and causing the air pollution if burned (Purwaningrum, 2016). The 3R initiative (reduce, reuse, and recycle) has been widely promoted to prevent those problems (Septiani et al, 2019), but it was not optimally implemented. Sushmitha et al. (2016) reported that only 7% plastic waste were recycled, and 93% were burned and also dumped into the sea. This initiative needs to be supported with another innovation by substitute the synthetic materials in plastic with the organic material which known as bioplastics.

Bioplastics mostly came from organic compounds such as starch, and then cellulose, protein, or lipids, so they are easily decomposed or degraded by the microorganisms (Jacoeb et al., 2014). The basic principle of bioplastic production is by gelatinization of starch suspension and then casted into a glass layer and dried to form a thin layer with good biodegradability properties (Rusli et al., 2017; Suryati et al., 2016). Maneking et al. (2020) stated that since the source of starch are abundant in nature and renewable, it is very promising in the future for wide use of bioplastic. Therefore, the potential and promising resources of starch from other materials for bioplastic needs to be explored.

Cassava has starch content around 34% (Baratter et al., 2017) and it is become one of the agricultural commodities that are widely used as industrial raw materials, especially in the tapioca industry. They also produce solid waste in the form of cassava peel and pulp from the cassava starch extraction process. Every 1 kilograms of cassava produces 15–20% of cassava peel waste (Kawijia et al, 2017). Suryati et al. (2016) reported that the solid waste of cassava peel has low economic value and will produce unpleasant odor if not processed further. The use of cassava peel waste into the bioplastic could become a promising material and will increase its economy value, since it has high potency of starch. Suryati (2016) and Pulungan et al. (2020) reported that bioplastics made from cassava peel waste has good biodegradability and mechanical properties with the addition of plasticizers. Based on these studies, cassava peel waste has a high potential to be used as bioplastic.

Seaweed (Eucheuma cottonii) can be made into bioplastics because it contains polysaccharide. The use of starch hydrocolloids in the manufacture of bioplastics has drawbacks, such as weak mechanical properties such as elasticity, tensile strength, elongation at break and low elongation strength (Sabella, 2019). So it is necessary to add seaweed carrageenan and plasticizer (glycerol) to improve the quality of the bioplastics produced. Glycerol functions as a plasticizer which is used to increase the elasticity of the resulting bioplastics (Sinaga et al, 2014). Therefore, this review explores the potency of cassava peel waste and seaweed carrageenan to be applied as a bioplastic.

METHOD

The method used is an effective literature review and in accordance with the topic being discussed. The discussion method is carried out based on research results that have been found by previous researchers, which are then integrated with other researchers to get strong results and conclusions.

RESULTS AND DISCUSSION

Petroleum-Based Plastic Waste

Despite its many benefits, petroleum-based plastic has a threat to the environment because it cannot be degraded naturally and the danger of this highly persistent plastic waste accumulating and polluting the world's oceans, freshwater bodies and soils is becoming real (Gasperi et al., 2015; McCormick et al., 2014). Quoted from Condorferries.co.uk, Currently the world produces around 381 million tons of plastic waste per year and will double by 2034. The total amount of plastic produced to date is around 8300 million metric tons and the plastic waste generated is estimated at 6300 Mt , of which only 9 percent has been recycled and 12 percent has been incinerated while the remaining 79 percent is piled up in landfills in the environment. If the current trend persists, around 12.

Plastic poses many problems and has many disadvantages. First, they are not biodegradable which allows them to remain in the environment for decades after being disposed of as waste (Sanyang et al., 2016). Second, the plastic production process involves the use of large amounts of energy and third, plastic poses a serious threat to the environment (Azahari et al., 2011; Avérous and Pollet, 2012; Jones et al., 2013). In addition, humans are becoming increasingly dependent on plastics as the world's economic growth and development increases its demand, resulting in the buildup of plastics in landfills. This causes various diseases such as risks to human and animal health as well as environmental pollution problems such as groundwater pollution and sanitation problems etc. (Al-Salem et al. , 2017). Plastics are non-biodegradable and have a tendency to float in water resulting in the spread of plastic pollution throughout the world's oceans. The fact that plastics can remain afloat on the ocean surface has caused them to accumulate in certain areas of the world's oceans. One of the most famous and largest of these plastic accumulation zones is located between California and Hawaii and is called The Great Pacific Garbage Patch. According to estimates provided by (Lebreton et al., 2018) at least 79,000 tonnes of plastic waste is accumulated in this 1.6 million km 2 area. About 8% of this plastic waste is in the form of microplastics, while 94% is in the form of floating plastics. According to some researchers, Plastic waste pollution in the ocean should be considered as hazardous waste because toxins are absorbed into plastic particles as they move in the environment (Teuten et al., 2007; Mato et al., 2001; Rochman et al., 2007; Mato et al., 2001; Rochman et al. al., 2013). In addition, the negative impact of plastic pollution due to consumption and entanglement of marine animals, such as cetaceans, seabirds and reptiles etc. already known. More than 1 million seabirds and 100,000 marine animals die from plastic pollution every year (Gregory, 2009). Seeing from the problems caused by these non-renewable materials, it encourages researchers to immediately explore substitute materials that can cover the existing problems (Ismail et al., 2016).

Bioplastic as An Environmentally Friendly Alternative Plastic Material

The development of effective and environmentally friendly plastics are urgently needed. Many researchers are exploring to develop biodegradable plastics due to the many environmental, economic and health problems posed by conventional plastics, commonly known as bioplastics. Bioplastics have proven to be an environmentally friendly alternative to hazardous petroleum-based plastics (Reddy et al., 2013).

Generally, bioplastics are environmentally friendly plastics made from natural materials (Boonniteewanich et al., 2014). According to the European Bioplastic Association, bioplastics are biodegradable, bio-based or both (European bioplastics, 2017). Currently, bioplastics are another alternative to almost all conventional plastics (European bioplastics, 2017). Currently, bioplastics are commercially available and will continue to emerge. According to the bioplastics market data for 2017, the production capacity of bioplastics is expected to increase from about 2.05 million tons in 2017 to around 2.44 million tons in 2022 (European bioplastics, 2017).

Bioplastics are synthesized from natural organic materials such as polysaccharides, proteins and lipids. Starch, chitin, lignin and cellulose are common polysaccharides used for the synthesis of bioplastics while gelatin, casein and gluten, and plant oils and animal fats are natural proteins and lipids, respectively (Song et al., 2009). Several studies using starch as a matrix for bioplastics (Tang and Alavi 2011; Dean et al. 2008; Bodros et al. 2007; Enrione et al. 2010) have confirmed the potential of biodegradable polymers. There are various films or composites from various starch sources: corn (Ghanbarzadeh et al., 2010; Zhang et al., 2007; Kaushika et al., 2010); bananas (Zamudio-Flores et al. 2009); banana peel (Sultan & Johari, 2017); cassava (Ortiz et al., 2010; Mantovan et al., 2018); potato (Wu et al. 2009); potato peel waste (Arikan & Bilgen, 2019); mango (Agustiniano-Osornio et al. 2005); wheat (Galdeano et al., 2009); peas (Zhang and Han 2008; Ma et al. 2009); rice (Bourtoom & Chinnan, 2008; Marichelvam et al., 2019); sweet potato (Shen et al. 2010); tamarind & berry seed (Chowdhury et al., 2022), and wheat (Chivrac et al. 2008; Wan et al. 2009). There also studies reported using microalgae and green algae from brown seaweed as bioplastic material (Hempel et al., 2011; Cinar et al., 2020; Kanagesan et al., 2022). Despite all the diversity, most uses of starch sources are based on corn and/or cassava due to their availability.

The method of making bioplastics **(Figure 2)** can be different for each material used, the characteristics of the bioplastic produced, and the configuration of the product varies (Hagemann & D'Amico, 2009). According to previous research, Figure 1 summarizes the general process for each material and each process has different methods, materials and compositions used for bioplastic production. Pre-treatment includes processes such as milling, drying, hydrolysis of materials. Not all parts of the waste are used in the process of making bioplastics, such as extracting only the starch and cellulose. And the most important thing is the characterization of materials such as the addition of plasticizers, odor control agents, etc. (Hagemann & D'Amico, 2009). Most of previous study used casting method to prepared the bioplastics, including the mixing of the solution (containing starches, plasticizers, fillers, and solvent), casting to a plate (glass/alumunium foil), and drying (to remove the solvent). **Table 1** summarizes the variations of process conditions in bioplastic preparation from previous study.

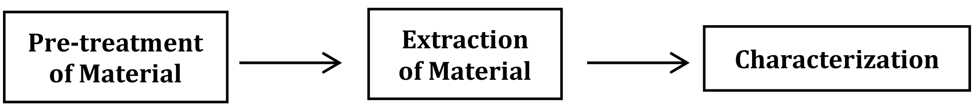

Figure 2. General process of making bioplastics (Ramadhan & Handayani, 2020)

Table 1. Variations of process condition in bioplastic preparation with casting method

Materials	Additives	Process condition	References
Cassava starch	Glycerol, Levan	Mixing temperature: 95°C Mixing duration: 10 minutes Drying temperature: 35 °C Drying time: n.a.	Mantovan et al. (2018)
Potato peel waste starch	Glycerin, vinegar	Mixing temperature: 100°C Mixing duration: 20 minutes	Arikan & Belgen (2019)

		Drying temperature: n.a (air dry) Drying time: 48 hours	
Corn starch, Banana peel starch	Glycerol	Mixing temperature: n.a, Mixing duration: n.a, Drying temperature: 130 °C Drying time: 30 minutes	Sultan & Johari (2017)
Corn starch, rice starch	Glycerol, gelatin	Mixing temperature: 100 °C Mixing duration: 70 minutes Drying temperature: n.a Drying time: 3-4 days	Marichelvam et al. (2019)
Corn starch	Glycerol, vinegar, titanium dioxide	Mixing temperature: n.a. Mixing duration: 5 minutes Drying temperature: 25°C (room temperature) Drying time: 10 days	Amin et al. (2019)
Corn starch	Glycerol, citric acid, cellulose	Mixing temperature: 90°C Mixing duration: 30 minutes Drying conditions: drying at 60°C for 6 hours, further cured at 120 °C for 1 hours	Yang et al. (2022)
Tamarind seed starch, berry seed starch	Glycerol, vinegar	Mixing temperature: 100 °C Mixing duration: 7 minutes Drying temperature: n.a. Drying time: 12 hours	Chowdhury et al. (2022)

Potency of Cassava Peel Waste

Cassava pulp and cassava peels are produced in large quantities in the tapioca flour industry (Widiarto, et al., 2017). Cassava peel is one of the agro-industry wastes that can be used to make bioplastics. Cassava peel is easy to obtain and one of the components that has the potential to be used in the manufacture of bioplastics (Ramadhan, et al., 2020). Cassava peel can be processed into flour or cassava peel starch so that it can be processed. One component of cassava is starch as much as 34%, of which 83% is amylopectin and 17% amylose. Based on the Central Statistics Agency, cassava production in Indonesia reached 20 million tons in 2015. The amount of cassava peel waste produced is about 15-20% per one kilo of cassava. Thus, the amount of cassava peel produced in Indonesia is 3.6-4.8 million tons (Pulungan, et al., 2020). Meanwhile, based on Muller et al, (2017), stated that the amylose content in cassava starch was 16% and the amylopectin content was 84%. Based on Raphael et al., (2011), cassava starch has amylose content of 20-30% and amylopectin 70-80%.

Because of its starch content, cassava peel is one of the agro-industrial wastes that can be used as an ingredient in the manufacture of bioplastics. Starch is renewable, universal, and easy to obtain, making it a very potential material for production bioplastics. The process of starch extraction begins with cleaning cassava peel waste from dirt and dust. Then, the cassava peel is cut into small pieces, weighed and mashed with a blender with a ratio of cassava peel: water (1:1) and squeezed until all the juice comes out. Furthermore, the water extracted from the cassava peel waste then stored for 6 hours. Then the cassava peel starch was dried in an oven for 30 minutes at a temperature of 60°C which was then followed by drying using sunlight for 6 hours. Finally, the cassava peel starch was weighed and then sifted and weighed the final weight so that the yield was obtained.

The color of the starch obtained is white-brownish, with the yield from the starch extraction process of cassava peel waste ranging from 2,73 – 4,35 %. Based on the research literature conducted by Susanti et al. (2017), the result was obtained that the starch produced from 2 kg of cassava peel was 311 g with average yield of 10,7% and the color of starch was white-brownish. Based on the description above, cassava peel starch has great potential and can be used as material for the manufacture of bioplastics because the main constituents are amylose and amylopectin which are quite high. The content of amylose and amylopectin can affect the level of crystallinity and mechanical strength of bioplastics. Cassava starch can be increased its mechanical strength by adding a plasticizer. However, the selling price of biodegradable plastic made from cassava peel starch is 2-2.5 times more expensive than conventional plastic (Kamsiati, et al., 2017).

Fathanah et al. (2013) has been studied bioplastic made from cassava peel by combining starch with chitosan as a plasticizer by adding sorbitol. The production of bioplastic from cassava peel begins with starch extraction from cassava peel. Next, the cassava peel starch solution was made at 10% (w/v), while the chitosan was dissolved in glacial acetic acid with a concentration of 20% (w/v). Cassava peel starch was mixed at a certain temperature ratio and then stirred at a gelatinization temperature (80°C) for 25 minutes. Then mixed with sorbitol at a certain concentration. Then, homogeneous solution poured on a plate with a thickness of 2.5 mm and then dried at 60°C for 5 hours to form a bioplastic sheet (Fathanah, et al., 2013). The results showed that the best mechanical properties of bioplastic with this material had a tensile strength value of 1.37 MPa obtained by the addition of 30% sorbitol with a ratio of starch: chitosan (7:3). The modulus value of 3.7 MPa was obtained with the addition of 30% sorbitol with a starch:chitosan ratio (8:2) and an elongation value of 26 was obtained.

Other studies by Maulida et al. (2016) shows that the addition of microcrystalline cellulose (MCG) can increase the tensile strength value up to 9.12 MPa using sorbitol with a concentration of 20%. The bioplastic enhancement by strengthening MCG can be attributed to the strong bond between the hydroxyl groups of the PKS filler interface and the starch matrix. This formation is influenced by the percolation mechanism.

Carrageenan

Indonesia is the largest carrageenan producer in the world with 3399 thousand tons with a percentage of 60.5% of total production in the world (Mufrodi, 2019). *Eucheuma cottonii* is one type of seaweed that is used as an alternative material for making bioplastics. *Eucheuma cottonii* type seaweed is often chosen because it has a large amount of carrageenan compared to other types. Carrageenan is a polysaccharide extracted from red seaweed from the class Rhodophyceae. The percentage of carrageenan in *Eucheuma cottonii* was 61.54%, Eucheuma Spinosum was 46.64%. and Eucheuma Edule by 54.56%. The difference in the percentage of carrageenan is seen from the strength of the gel in each type. *Eucheuma cottonii* carrageenan has a gel strength of 1140 g/cm^2. The 3,6 Anhydro-D-galactose chain of kappa carrageenan forms a secondary helix structure. The gel strength value indicates that the product to be made will have better strength. A good gel is obtained from a solid emulsion because the gel is a semi-solid emulsion formed from half solid and half liquid. The gel strength value according to the Indonesian National Standard (SNI) number 8391-1:2017 is at least 700 g/cm^2 (Wullandari, et al., 2021).

The production of bioplastic from *Eucheuma cottonii* carrageenan begins with washing. The seaweed with water and then soaking it in water for 24 hours. Then cut into pieces with a size of approximately 2 cm. Boiling process carried out at a temperature of 120°C. The temperature was lowered slowly at 80°C for 1 hour. Filtration is carried out to separate a small amount of solid from the gel. Filtration was repeated after the gel was boiled again using the same method. The filtrate containing algae gel was then poured on a frame with a size of 210 mm x 297 mm and dried in the sun for 3 days. Research shows that bioplastics from *Eucheuma cottonii* carrageenan are better when added with glycerol with a concentration of 15% (Machmud, et al., 2013).

In a study conducted by Maryuni et al., (2018), the production of bioplastic using carrageenan flour with 5 weight variations, 0.6 g, 0.8 g, 1 g, 1.2 g and 2 g, with each added into a 100 ml measuring cup and then add 100 ml of distilled water. Next, the mixture was stirred using a magnetic stirrer at a temperature of 60°C. Then 0.5% (v/v) sorbitol was added while stirring and heated at 80°C which was maintained for 5 minutes. Then the solution is cooled and the impurity air bubbles are removed by vacuum. After there are no air bubbles of impurity, pour it into a 10x18 cm^2 glass plate mold and then dry for 24 hours at 50°C until a thin layer is obtained. After the cold layer, separate from the glass plate and then packed. Based on the treatment, it was found that the carrageenan concentration of 2% produced a thicker layer of 0.053 mm than the carrageenan layer with a concentration of 1.2% of 0.033 mm. This is because the number of carrageenan polymers is increasing in the bioplastic matrix, where each monomer is connected by intermolecular hydrogen bonds which result in the formation of cavities in the bioplastic.

The tensile strength at a concentration of 2%, which is 39.163 MPa, is greater than the 1.2% concentration of 32.912 MPa. This is because the increase in the concentration of carrageenan which functions as a mixing biopolymer can increase the molecular interaction between carrageenan and sorbitol in the matrix, so that the polymer bond is stronger and a large enough force is needed to break the bond which makes the tensile strength value greater. The elongation value obtained by carrageenan with a concentration of 2% was 41.533% lower than the concentration of 1.2% which was 78.067%. This is because the higher the percent elongation value, the more plastic the coating is, on the other hand, the lower the percent value, the less plastic or brittle. The water vapor transmission rate at 1% concentration has the highest value of 404.311 g/m^2 hour compared to 0.8% concentration of 404.009 g/m^2 hour. This is because the addition of sorbitol causes the cavity in the bioplastic to be denser because it is filled with sorbitol and causes the water rate transmission value to be lower. The use of carrageenan has a potential to improve the physical and mechanical properties of bioplastic (Maryuni et al., 2018).

Potency and Application of Bioplastic from Cassava Peel Waste and Carrageenan

According to the Food and Drug Administration (FDA), cassava starch and carrageenan can be used both as food ingredients and as food packaging. From the previous research, the effect of combining commercial carrageenan with cassava starch was studied with the addition of PVA and glycerol as a plasticizer. The films were prepared by casting method with slight modification. Glycerol and PVA were dissolved in distilled water with magnetic stirring. Then the desired concentration of carrageenan and cassava starch was added to the glycerol and PVA solution with magnetic stirring for 20 minutes. Then the mixture was heated at 90°C for 30 minutes with magnetic stirring to prepare the polymer and support the formation of starch gelatinization. After that, the mixture was added to an ultrasonic bath for 10 minutes at a temperature of 25°C to remove the air bubble component. Then transferred to a petri dish after which the solvent was evaporated at a temperature of 40°C for 16 hours. After solvent evaporation, each film was removed from the petri dish and stored in suitable packaging at room temperature for further analysis. This method produces 5 different films containing 25% by weight of glycerol and 25% by weight of PVA regarding the concentration of polysaccharides (5w) in the mixture. Films were prepared at a weight ratio of carrageenan:starch 100:0 (100k-c), 75:25 (75k-c), 50:50 (50k-c), 25:75 (25k-c) and 0:100 (0k-c) c) (Barizão, et al., 2020).

In general, the production of bioplastics using *Eucheuma cottonii* carrageenan and cassava peel waste starch has never been done. However, several studies involving these materials have been carried out, such as making bioplastics from *Eucheuma cottonii* seaweed and cassava peel starch with the addition of avocado seed starch (Putri, 2019) and biodegradable films derived from k-carrageenan and cassava starch to obtain higher production values (Barizão, et al., 2020). The combination of starch from cassava peel waste and carrageenan could become promising and sustainable bioplastic materials with better mechanical properties.

Cassava peel commonly used as compost and fodder by the community. The high starch content of cassava peel allows it to be used as a biodegradable plastic film. This potential can be used as an opportunity to add value to cassava peel as a basic material in the manufacture of bioplastics. Biodegradable plastic is plastic that is used like conventional plastic, but will be broken down by the activity of microorganisms into water and carbon dioxide after being used up and discharged into the environment. Makalakhsmi (2004) explained that degradation of bioplastic especially caused by enzymatic activity from microorganism and leading to chemical structure change of the material. The measurement of weight loss is one of standard method to analyse the biodegradation process of polymer.

Biodegradable plastics are environmentally friendly plastics. The sample can be tested for their biodegradability by burying the plastic in the soil up to 20 cm deep and 20x20 cm wide and weighing before burial and after being buried every week until it decomposes. This degradability test process is needed to study the level of resistance of the plastic produced which is related to the influence of microbial decomposition, soil moisture and temperature and even other physical chemical factors. Chemically, the plastic produced is clearly biodegradable, this is because the raw materials used are organic and natural raw materials that easily interact with water and other microorganisms and are even sensitive to physical or chemical environmental influences (Suryati et al., 2016).

Syuhada et al. (2020) studied the characteristics and biodegradation of chitosan-based bioplastic with cassava peel starch addition, in soil and water river media. The higher proportion of cassava peel starch resulting the lower water resistance and tensile strength. However, it significantly increases the degradability rate both in soil (-62.95%) and water river media (-53.69%) after 14 days. The hydrophilic structure of bioplastic leads to faster degradation in water river media and since the starch polymer favored by the soil microorganisms, it resulting the larger pore and cracks in bioplastic which decrease the weight of bioplastics (Alam et al., 2018). Plasticizers also plays an important role in degradation of bioplastics. Wahyuningtiyas & Suryanto (2017) analyzed the biodegradation process of bioplastic from cassava starch with the variation of glycerol concentration. The higher concentration of glycerol improves the moisture absorption and accelerate the biodegradation process. Bioplastics containing 1,5% glycerol completely degraded in 12 days, and the degradation became faster in 9 days on the higher concentration of glycerol (2-3%). Due to the higher hydroxyl group after glycerol addition, the bioplastic absorbing more water from the soil and leads to hydrolysis reaction resulting decomposition of cassava starch-based bioplastic into smaller part (Kyong et al., 2005).

The process of biodegradation of packaging films in the natural environment begins with the chemical degradation stage, namely the molecular oxidation process to produce polymers with low molecular weights. The next process (secondary process) is the attack of microorganisms (bacteria, fungi and algae) and enzyme activity (intracellular, extracellular). Permeability of a packaging film is the ability to pass gas particles and water vapor in a unit area of material under certain conditions. The permeability value is strongly influenced by the chemical properties of the polymer, the basic structure of the polymer, and the properties of the permanent components. Generally, the permeability value of packaging films is useful for estimating the shelf life of packaged products (Akbar, et al., 2013).

CONCLUSION

This review includes information on petroleum-plastic waste, bioplastics, potential materials for making bioplastics, manufacturing processes, and applications of bioplastics. Petroleum-based plastics are very dangerous for life and the environment, therefore bio-plastics are needed as a substitute for petroleum-based plastics. Bioplastics can be a new innovation since they are biodegradable, sustainable and renewable. Bioplastics can be synthesized from natural organic materials such as polysaccharides (starch, chitin, and lignin), proteins, and lipids, but starch-based bioplastics are more promising to be used as bioplastics. Several previous studies have proven that various kinds of starch can be made into bioplastics such as corn starch, banana, cassava, cassava peel, potato, mango, wheat, peas, rice, sweet potato, wheat, seaweed (carrageenan) etc. Of several materials that have the potential to be used as bioplastics, cassava peel and carrageenan are superior materials. In addition to the starch content in it, maximizing waste from cassava peels and maximizing the potential of seaweed is also a concern so that it can produce bioplastic products that are safe and encourage environmental sustainability.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest concerning the publication of this article. The authors also confirm that the data and the article are free of plagiarism.

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