Preparation and characterization of Seaweed based Bioplastic Blended with Polysaccharides derived from various seeds of Avocado, Jackfruit and Durian

Y Yusmaniar1*, D I Syafei1, M Arum1, E Handoko2, C Kurniawan3 and M R Asali4

1Department of Chemistry, Faculty of Mathematics and Sciences, Universitas Negeri Jakarta, Jl. Rawamangun Muka, Jakarta Timur 13220, Indonesia
2Department of Physics, Faculty of Mathematics and Sciences, Universitas Negeri Jakarta, Jl. Rawamangun Muka, Jakarta Timur 13220, Indonesia
3Research Center for Physics Indonesian Institute of Sciences, Lembaga Ilmu Pengetahuan Indonesia, Puspiptek, Serpong, Indonesia
4National High Jakarta School, Jln. Raya Pos pengumben no.41 Jakarta 11630, Indonesia

* yusmaniar@unj.ac.id

Abstract. Anticipating the global trends of biodegradable plastic and its application to packaging industries, this study was conducted to prepare a seaweed (Eucheuma cottonii) based biodegradable plastic blended with polysaccharides derived from various tropical fruit seeds which are abundantly available in Indonesia such as avocado, jack fruits and durian. The objective is to prepare an environmentally friendly and edible bioplastic. The various polysaccharides were obtained through extraction and the bioplastic blends were heated at 80°C for 30 minutes. The characterization conducted include mechanical properties, thermal and biodegradability analysis, spectral and surface analysis through Fourier Transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscope (SEM) respectively.

1. Introduction

Synthetic plastics has been widely used in all applications since 1950 and Asian counties have been the biggest consumers of plastics which accounts for 30% of the total world production [1]. Because synthetic plastics were designed for uses that require resistance to degradation, plastics waste has become a serious issue for the environment. According to the Indonesian Central Bureau Statistics, synthetic plastics waste ranked second in an amount of 5.4 million metric tons (Mt) per year or 14% of total waste produced in Indonesia [1]. In fact, as of 2015 it is estimated that approximately 6300 Mt have been produced to date and 79% has accumulated as plastic waste and rest in landfills or in the ocean [2].

As a response to the environmental concerns, composite materials derived from biodegradable polymers such as cellulose, polysaccharides, lipids and proteins have been widely studied focusing specifically on the composition of these polymers to achieve characteristics and physical properties for a certain bioplastics’ application. Several distinct advantages of bioplastics compared to the synthetic
Plastics are on the 1) non-toxicity - widely applied in food packaging, 2) availability – sources are from agriculture products or marine products 3) biodegradability [3].

In this research the sources used for the biodegradable polymer blend are seaweed and polysaccharides derived from various seeds of avocado, jackfruit, and durian. Dry seaweed (Eucheuma contii) was obtained from the seaweed cultivation in West Sumba (Wainyapu). Seaweed based bioplastics has a big potential especially for Indonesia since Indonesia has emerged as the second largest producer of cultured seaweed in the world following China with a total production of 11.3 Mt in 2015 [4]. One of the main characteristics of seaweed-based bioplastics is that it has a high mechanical strength due to a high cellulose content specifically 17.47% which reinforces bonding, while the common polysaccharides, such as alginate, carrageenan and agar, provide a good gelling capability during the forming of the film sheet [5]. Cellulose has been widely used to improve mechanical properties of pure polysaccharides-based bioplastics.

The most common polysaccharides used in the bioplastic research community is starch due to its affordability and availability [6]. There are two main natural polymers in starch: amylase and amylopectin. Amylose is a straight chain polymer of D-glucose units with alpha 1–4 glycosidic linkages, and amylopectin is a branched chain polymer of D-glucose units with alpha 1-4 and alpha 1-6 glycosidic linkages [7]. Due to its straight chain structure amylose contributes more on the mechanical strength compared to amylopectin [8,9].

The polysaccharides used in this research were sourced from the waste of tropical fruits which are abundantly available in tropical countries like Indonesia. The seeds of Avocado, Jackfruit and Durian were selected based on their availability and also their polysaccharide content. Their major polysaccharides contents in those seeds are shown in Table 1 below:

| Seed       | Content (%) |
|------------|-------------|
|            | Starch  | Amylose | Amylopectin |
| Avocado [10] | 73.62   | 22.07   | 51.55       |
| Jack fruit [11] | 70.22   | 58.83   | 16.39       |
| Durian [11] | 76.65   | 22.33   | 54.32       |

2. Methods

2.1. Materials
The dried Seaweed (Eucheuma contii) was obtained from the traditional village cultivation in Wainyapu (South West Sumba). The seeds of the Avocado, Jackfruit and Durian were collected from the wet market in Jakarta. Commercially available corn starch was used in this work.

2.2. Preparation and fabrication
Dry seaweed was washed with water to eliminate impurities, soaked in the water for 7 days and rinsed daily. On the eighth day water was added to the seaweed in a ratio of 1 to 1 and blended to form gelatinized solution.

For the all the seeds, they were washed several times, had their seed coat (spermoderm) removed and were cut into small pieces. The durian seeds were soaked in CaCO3 (1 gr/L) solution for 12 hours and then were rinsed with distilled water. Each type of seed was put into a blender to form a homogeneous slurry and sieved using a sieving cloth, and the filtrate was allowed to settle for 24 hours. The remaining sediment was then dried in an oven at +/-650C for 24 hours. The dried polysaccharides were grinded and sieved to form the homogenous powder form.
The composite biofilms were prepared by mixing seaweed slurry, polysaccharides from fruits, corn starch and water in the ratio of 1:3:8:12. It was heated at 80°C for 30 minutes with continuous agitation until a clear and homogenous solution was formed. The solution was then casted on the 18 cm by 20 cm acrylic plate, dried and labelled. The labels for the biofilm blended with Avocado, Jackfruit and Durian are KSA, KSN and KSD respectively.

2.3. Characterization of bio films

The monitoring of functional groups in the blended biofilms was conducted using a Fourier Transform Infrared Spectrophotometer (FTIR) and the surface morphology was examined with a scanning electron microscope (SEM). Thermal characteristics were measured using a Differential Scanning Calorimeter (DSC) from Toyoseiki.

The tensile strength was tested using a tensile strength Strograph in reference to ASTM (American Standard Testing Method) D638 [12]. Sample size of 60mm x 20mm was used in the measurements.

Water solubility test of the biofilms was conducted through a simple water uptake analysis in which the biofilm was cut into a 20 mm x 20 mm sample and immersed into a beaker filled with 50 ml of distilled water at room temperature. After 24 hours, the film was removed from the water, dried with filter paper and its weight was measured. The soaking process was repeated until it a constant weight was obtained.

Biodegradability tests were conducted to examine the rate of biodegradability of the films by microorganism in nature. The method used was a soil burial test in which the films were immersed in soil for 14 consecutive days. Film samples were cut into the dimension of 20 mm x 50 mm and immersed into the soil at 20 mm depth. Using the initial weight and the dry weight of the films, the amount degraded, amount left and the percent weight loss were calculated.

3. Result and discussion

![Figure 1. FTIR Spectra of Avocado (KSN), Durian (KSD) and Jackfruits (KSN).](image)

The FTIR spectra (Figure 1) of the samples with three different sources of seeds showed specific functional groups of polysaccharides. The peak at 3265 cm⁻¹ was attributed to O-H stretching vibration of the hydroxyl groups from polysaccharides and the band around 2900 cm⁻¹ to 3000 cm⁻¹ was attributed to C-H stretching vibration. A broad band in the region of 1420 cm⁻¹ to 1340 cm⁻¹ show a bending vibration of O-H. Absorption band at 1151 cm⁻¹ correspond to the C – O stretching of the C-O-H group, and absorption band at 1019 cm⁻¹ shows the C-O stretching of the C-O-C in the anyhydro-glucose ring. The results suggested that all samples analysed have –OH, C-H, C-O-H and C-O-C in the anyhydro-glucose ring [13,14].

From the micrographs at Figure 2, 3 and 4 it can be observed that there was a slight difference between the surface structures among the film composite of KSD, KSA and KSN. The KSA and KSN
especially had rougher surfaces and bigger particles on aggregate embedded in the matrix and more uniform distribution. On the other hand, the KSD showed a more uniform surface which implied a better homogeneity throughout the film’s structure. Based on the content analysis, Durian seeds, which has the highest amylopectin content which will reflect its adhesive nature, resulted in the most homogeneous nature compare to the other seeds tested [15]. The uniformity of the film matrix increases polymers integrity, hence raising the mechanical properties of the films [16].

![Figure 2. Surface Structure of KSA.](image)

![Figure 3. Surface Structure of KSD.](image)

![Figure 4. Surface Structure of KSN.](image)

The DSC curve analysis (Figure. 5) indicates that the film composite of KSA, KSD and KSN showed a denaturation peak started at 200°C and ended at around 2800°C, however, KSN had the lowest melting point at 108.37 °C. KSA and KSD has a melting point of 116.65 °C and 115.8 °C respectively.

![Figure 5. DSC curve of KSA, KSD and KSN.](image)

Tensile strength is the maximum stress that a material can withstand while being pulled or stretched before it breaks. The result of the mechanical properties for these three different composite materials is shown in Table 2. It shows that KSD had the highest tensile strength at 4.69 MPA, and a yield extension of 1.92% and elongation at break of 2.02%. One of the reasons is that the amylose content of Durian seed is lower than that in Jackfruit and Avocado. Amylose plays a very important role in the forming of the strong film sheet. The higher the amylose content, the less elastic the film sheet is [17]. These results are consistent with those obtained by Li et al. [7], Rindlav-Westling et al. [18] and Cano et al. [19].

Water solubility or water resistance tests were conducted through water uptake analysis corresponding to the ASTM D570-98 standard [20]. The results of the tests are shown in Table 3.
Table 2. Result of mechanical properties test.

| Film Composite | Tensile Strength (MPA) | Yield Extension (%) | Elongation at break (%) |
|----------------|------------------------|---------------------|-------------------------|
| KSN            | 2.69                   | 1.11                | 0.01                    |
| KSD            | 4.69                   | 1.92                | 2.02                    |
| KSA            | 1.01                   | 0.93                | 0.5                     |

Table 3. Result of water resistance test.

| Film Composite | Water Resistance Test (%) |
|----------------|---------------------------|
| KSN            | 43.56                     |
| KSD            | 68.84                     |
| KSA            | 55.61                     |

Based on the results above, it can be concluded that the Durian based film composite produced the highest water resistance capability at 68.84%. This result was attributed to the non-polar nature of polysaccharides, in which Durian seeds has the highest content.

The biodegradation test was carried out to determine the length of time required for plastic films to be destroyed in the soil. The method of soil burial test with direct contact was used to test the film composite. The results are shown in Table 4.

Table 4. Result of biodegradable test.

| Film Composite | Biodegradability in 14 days (%) |
|----------------|----------------------------------|
| KSN            | 79.65                            |
| KSD            | 87.43                            |
| KSA            | 53.54                            |

4. Conclusion
The bioplastic films of three different seeds have shown different characteristics. Based on the mechanical characteristics, water resistance and biodegradability, film composite blended with Durian seeds showed a promising characteristic for bioplastics application in packaging industry. Further works need to be conducted to explore the impact of different composition of seaweed content in the film composite.

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