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Mechanical Characteristics of Bio Thermoplastic Composite Pellets Made from Modified Cassava Starch, Glucomannan and Polylactic Acid in Bio Filler Variations

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***Abstract*:** The development of composite pellets based on modified cassava starch (MS), glucomannan (GM) and polylactic acid (PLA) has been carried out, but the quality has not all met SNI 7818-2014 so that its characteristics need to be improved using biofillers. The purpose of this study was to determine the type and concentration of the right biofiller in making biothermoplastic composite pellets MS/GM/PLA. This study used a Completely Randomized Design with treatment without biofiller, using 2.5 and 5% microfibril cellulose (MFC), 2.5 and 5% nanofibril cellulose (NFC), 2.5 and 5% nanocrystalline cellulose (NCC) which was repeated 4 times. The observed variables were tensile strength, elongation at break, Young modulus. The results showed that biothermoplastic composite pellets MS/GM/PLA using 2.5% NCC produced the best characteristics with a tensile strength value of 35.33 MPa, elongation at break of 3.36% and Young's modulus of 3.03 GPa. These results meet SNI 7818-2014 so that they have the potential for the development of eco-friendly packaging.

Keywords: bio thermoplastic composite pellets, modified starch, glucomannan, polylactic acid, type and concentration of bio filler

1. Introduction

The development of eco-friendly plastic packaging using the casting method widely and commercially has many obstacles [1] because it requires a lot of time, equipment and costs so that it is inefficient [1]. Possible development alternatives use the blowing and hotpress methods [2] but require semi-finished materials in the form of biothermoplastic composite pellets [3]. Harsojuwono et al [4], have developed biothermoplastic composite pellets from modified cassava starch (MS), glucomannan (GM) and polylactic acid (PLA). The biothermoplastic composite pellets have characteristics of tensile strength of 23.56 MPa, elongation at break of 7.18% and Young modulus of 1548.34 MPa. These characteristics do not all meet SNI 7818-2014. Therefore, it is necessary to improve the quality of these pellets.

The success of improving the quality or characteristics of biothermoplastic composite pellets for eco-friendlyplastic packaging is greatly influenced by many factors including the type and concentration of fillers, especially biofillers [5]. Several studies are reported as follows. Biothermoplastic composites from a mixture of thermoplastic starch (TPS) and polylactic acid (PLA) experience increased stress, strain and flexural modulus along with increasing levels of bagasse fiber as a biofiller at certain concentrations [6]. TPS/PLA biothermoplastic composites using cellulose derivatives experience increased mechanostatic properties [7]. Meanwhile, TPS/PLA biothermoplastic composites reinforced with sisal fiber show increased flexural modulus and storage modulus at room temperature [8]. PLA biothermoplastic composites reinforced with 5% NFC show increased tensile strength [9]. PLA biocomposites with the addition of microcellulose (MC) and nanocrystalline cellulose (NCC) 1 - 5% increase flexural mechanical properties by up to 40%, storage modulus by around 35% at room temperature. Meanwhile, Nazrin et al., [5] explained that TPS/PLA/PBS biothermoplastic composites supplemented with nanocellulose (NC) cause increased mechanical properties. The tensile strength of TPS/PLA composites increases with increasing levels of hemp fiber added in the range of 1–25% of the matrix weight [10].

The description above explains that the addition of biofiller, especially the type and concentration, plays a very important role in improving biothermoplastic composite pellets. However, no one has yet informed the type and concentration of biofiller that can improve the mechanical properties of MS/GM/PLA biothermoplastic composite pellets. Therefore, it is very important to research the use of biofiller to determine the right type and concentration in making MS/GM/PLA biothermoplastic composite pellets. With the hope that its characteristics meet SNI 7818-2014, so that it can be used as a raw material for eco-friendly plastic packaging. The purpose of this study was to determine the type and concentration of biofiller that produces MS/GM/PLA biothermoplastic composite pellets with the best characteristics.

2. Materials and method

2.1. Materials

Materials used: modified cassava starch (MS) and glucomannan (GM) (CV Nura Jaya), glycerol and aquadest (CV Brathacem), polylactic acid (CV Bandung), anhydrous maleic acid (CV Sukses Makmur), cellulose microfibrils (MFC), cellulose nanocrystals (NCC) and cellulose nanofibrils (NFC). Tools used: screw extruder, rheomix 3000, mixer, grinder, autograph-sidmazu mechanical test equipment based on ASTM D638.

2.2. Method

2.2.1. Experimental design

The experimental design in this study was a Randomized Block Design with 7 biofiller treatments, namely control (0% biofiller), 2.5% MFC, 5.0% MFC, 2.5% NCC, 5.0% NCC, 2.5% NFC, 5.0% NFC. Each combination of treatments is grouped into 4 based on the pellet making process time so that there are 28 experimental units.

2.2.2. Research implementation

Making Biothermoplastic Composite Pellets of Modified Starch (MS), Glucomannan (GM) and PLA

Making pellets is divided into 2 stages, namely (1) making thermoplastic modified starch (TPMS) and thermoplastic glucomannan (TPGM), (2) making biothermoplastic pellets, as below.

Preparation of thermoplastic modified starch (TPMS) and thermoplastic glucomannan (TPGM)

Weighing of materials for the preparation of thermoplastic modified starch (dough 1) includes 2.5 kg of glycerol, 1.5 kg of distilled water and 10 kg of modified cassava starch. Weighing of materials for the preparation of thermoplastic glucomannan (dough 2) includes 0.83 kg of glycerol, 0.5 kg of distilled water and 3.33 kg of glucomannan. The method of making dough 1 is as follows: glycerol and distilled water are mixed and then stirred until homogeneous. The solution is added with modified starch gradually until it runs out while stirring using a mixer at 240 rpm for 10 minutes. Then the dough is aged for 8 days. Dough 2 was made in the same way as dough 1. Dough 1 and 2 after aging, were rheomixed at a temperature of 90oC with a rotation speed of 50 rpm for 15 minutes with the results in the form of thermoplastic modified starch lumps (TPMS) and thermoplastic glucomannan (TPGM). Both The chunks were ground separately with a grinder and then sieved using a 100 mesh size.

Making TPMS/TPGM/PLA biotemoplastic composite pellets

Weighing 10 kg of TPMS and 3.33 kg of TPGM. Both materials are mixed and stirred until homogeneous using a mixer at a speed of 240 rpm for 10 minutes and used as a thermoplastic material. Furthermore, the manufacture of experimental units is carried out as follows: weighing 32.5 g of thermoplastic material (a mixture of TPMS and TPGM), 60 g of PLA, 7.5 g of anhydrous maleic acid and biofiller according to the treatment (type and concentration of biofiller). All materials that have been weighed are mixed and stirred at a speed of 240 rpm for 10 minutes, then extruded at a temperature of 110oC at a speed of 75 rpm. The next process is to print pellets with a diameter of 0.5 cm and a length of 1 cm, then cooled at room temperature for 1 hour. For the test sample, the pellets were made into thin sheets using a hot press at a temperature of 130oC at a pressure of 4.9 MPa for 10 minutes with a thickness of 2 mm, then the thin sheets of pellets were cooled at room temperature for 1 hour and ready to be tested.

2.3. Observation variables and data analysis

Observed variables are tensile strength, elongation at break, Young modulus. The data obtained were analyzed for their diversity and continued with the Duncan test with the SPSS 2.5 program. To determine the best treatment is determined based on the number of quality variables that meet SNI 7818-2014.

3. Result and discussions

3.1. Tensile strength

Analysis of variant shows that the type and concentration of biofiller have a very significant effect on the tensile strength of MS/GM/PLA biothermoplastic composite pellets, with an average tensile strength value ranging from 18.92 to 35.33 MPa, as shown in Figure 1.

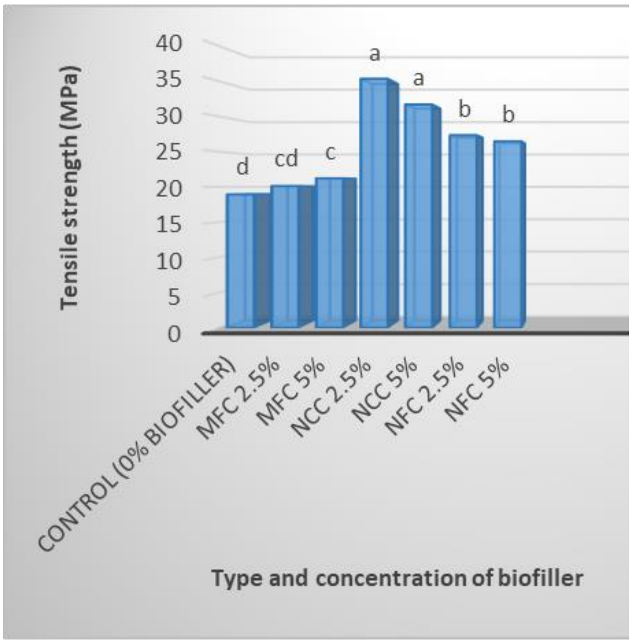

Figure 1. Relationship between type and concentration of biofiller and tensile strength

Figure 1 shows that the highest tensile strength value (35.33 MPa) is possessed by the MS/GM/PLA biothermoplastic composite pellets using 2.5% NCC, which is not significantly different from the pellets using 5.0% NCC. Meanwhile, the lowest tensile strength value (18.92 MPa) is possessed by the MS/GM/PLA biothermoplastic composite pellets that do not use biofiller (0% biofiller), which is not significantly different from those using 2.5% MFC.

The above results indicate that different types and concentrations of biofillers cause differences in the tensile strength of MS/GM/PLA biothermoplastic composite pellets. This is in accordance with the opinion of Kargarzadeh et al. [11] who explained that PLA biocomposite reinforced with nanocellulose can increase tensile strength depending on the concentration of its addition. The addition of 4% NFC to the PLA composite increased

37% tensile strength compared to pure PLA [12]. Meanwhile, Ilyas et al. [13] explained that NCC as a filler reinforcing starch-based polymers has ideal properties as a filler because of the presence of many -OH groups on the NCC surface which are responsible for hydrogen bonds between the non-polar matrix and the -OH groups. Bazan et al. [14] emphasized that increasing mechanical strength can use NCC as a filler in engineering new biodegradable materials. In addition, Ilyas et al. [13] reported that the use of 0.5% by weight of aren nanocellulose has increased the tensile strength of aren starch biocomposites by 11.47 MPa.

Tensile strength value of 35.33 MPa from biothermoplastic composite pellets MS/GM/PLA, when compared with SNI 7818-2014, it has met the standard.

3.2. Elongation at break

Analysis of variant shows that the type and concentration of biofiller have a very significant effect on the elongation at break of MS/GM/PLA biothermoplastic composite pellets, with an average value of elongation at break ranging from 3.21 to 7.18%, as shown in Figure 2.

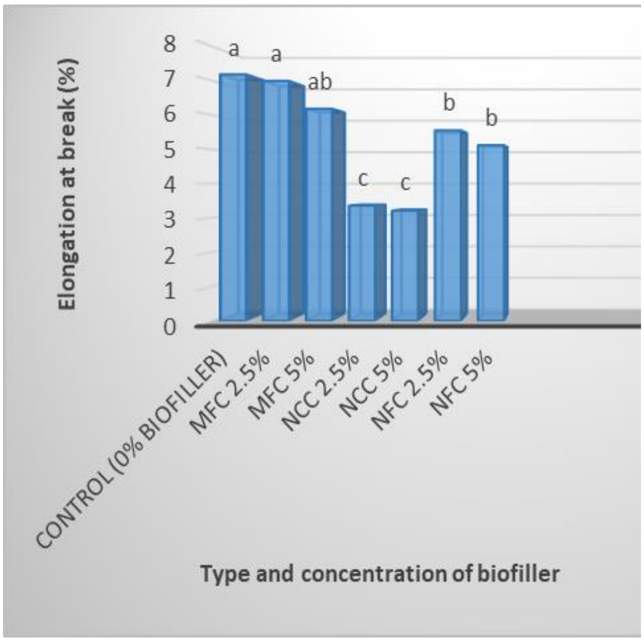

Figure 2. Relationship between type and concentration of biofiller and elongation at break

Figure 2 shows that the highest elongation at break value (7.18%) is found in MS/GM/PLA biothermoplastic composite pellets that do not use biofiller (0% biofiller), which is not significantly different from pellets using 2.5 and 5.0% MFC. Meanwhile, the lowest elongation at break (3.21 -3.36%) is found in MS/GM/PLA biothermoplastic composite pellets using 2.5 and 5.0% NCC, which is significantly different from the others.

The results above indicate that different types and concentrations of biofillers cause differences in elongation at break of MS/GM/PLA biothermoplastic composite pellets. This is in accordance with the opinion of Simangungson et al [15] who explained that the use of NCC at inappropriate (optimal) concentrations causes an increase in elongation at break which has an impact on reducing other mechanical properties. This explanation is proven by the information that PLA biocomposites using 1% NCC have a high elongation at break of 19.02%. Meanwhile, the use of 20% NCC in PLA biocomposites produces the highest elongation at break (22.4%) compared to other treatments [16].

Elongation at break value of 3.36% from biothermoplastic composite pellets MS/GM/PLA, when compared with SNI 7818-2014, it has met the standard.

3.3. Young's modulus

Analysis of diversity shows that the type and concentration of biofiller have a very significant effect on the

Young’s modulus of the MS/GM/PLA biothermoplastic composite pellets, with Young’s modulus values ranging from 1.33 – 3.03 GPa, as shown in Figure 3.

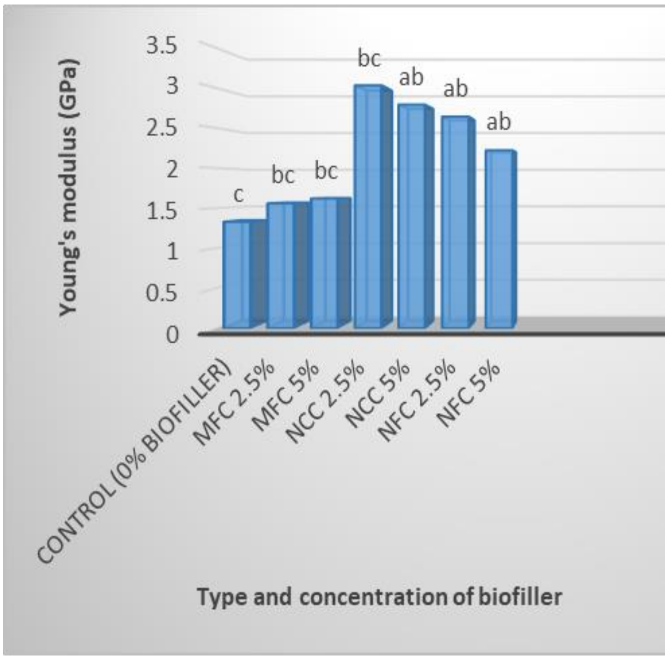

Figure 3. Relationship between type and concentration of biofiller and Young’s Modulus

Figure 3 shows that the highest Young’s modulus value (3.03 GPa) is possessed by the MS/GM/PLA biothermoplastic composite pellets using 2.5% NCC, which is not significantly different from the pellets using 5.0% NCC. Meanwhile, the lowest Young’s modulus value (1.33 GPa) is possessed by the MS/GM/PLA biothermoplastic composite pellets that do not use biofiller (0% biofiller), which is not significantly different from the pellets using 2.5% MFC.

The above results indicate that different types and concentrations of biofillers cause differences in the Young's modulus of MS/GM/PLA biothermoplastic composite pellets. This is in accordance with the opinion of Kargarzadeh et al. [11] who explained that PLA biocomposites reinforced with nanocellulose contributed to an increase in Young's modulus depending on the concentration of its addition. Ilyas et al., [17] reported that the Young's modulus between nanocellulose and matrix materials plays an important role in the performance of the biocomposite interface to achieve efficient load transfer from the matrix to nanocellulose. In addition, Ilyas et al. [13] reported that the use of 0.5% by weight of aren nanocellulose has increased the Young's modulus of aren starch biocomposites by 178.83 MPa. It was further explained that the Young's modulus of biocomposites using nanocellulose was six times higher than using cellulose microfibrils.

Young's modulus value of 3.03 GPa from biothermoplastic composite pellets MS/GM/PLA, when compared with SNI 7818-2014, it has met the standard.

4. Conclusion

The type and concentration of biofiller have a significant effect on tensile strength, elongation at break, Young’s modulus. Biothermoplastic composite pellets MS/GM/PLA using 2.5% NCC produced the best characteristics with tensile strength values of 35.33 MPa, elongation at break of 3.36% and Young’s modulus of 3.03 GPa. These characteristics have met SNI7818-2014.

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Conflict of interest

There are no conflicts of interest between the authors or with other parties.

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