Mechanical Properties of Microcrystalline Cellulose from Coconut Fiber Reinforced Waste Styrofoam Composite: The Effect of Compression Molding Temperature

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Abstract. Coconut fiber contains 36-43% of cellulose and has a potential to hydrolyze into microcrystalline cellulose. Microcrystalline cellulose (MCC) from coconut fiber can be used as composites filler. The objective of this research was done to find out the best composition of MCC and compression molding temperature for styrofoam composites filled MCC. MCC composition was varied from 0-10% (wt). Molding temperature was varied from 110-150°C. The results exhibited that addition of 8% (wt) of MCC with 130°C of molding temperature have showed the best mechanical properties such as tensile, flexural and impact strengths. The study has indicated that MCC filled the pores of styrofoam and some of the pores have been lost due to proper heating during molding.

1. Introduction
Styrofoam or expandable polystyrene (EPS) is a thermoplastic material that obtained from polymerisation process of styrene monomer. Styrofoam usually used as packaging materials. Wasted Styrofoam can cause serious environmental problems. However, this wasted Styrofoam can be recovered by recycling it to make a new composites product but it will have poor mechanical properties. There is some research that already used Styrofoam as polymer matrix such as Nasution et al which make expanded polystyrene composites reinforce with sawdust and Poletto et al which make expanded polystyrene composites reinforced with wood flour [1-3].

Microcrystalline cellulose (MCC) can be used as reinforced agent for Styrofoam composites, microcrystalline cellulose is a promising reinforcement agent for polymer because it has many advantages such as being biodegradable, low density, renewable and has good mechanical properties [4]. In this research, coconut fiber was used because it contained 36-43% of cellulose [5]. There is some research that already used microcrystalline cellulose as composite reinforcement agent such as Kiziltas et al which make thermoplastic nylon composites reinforced with microcrystalline cellulose and Ashori and Amir which make polypropylene composites reinforced with microcrystalline cellulose [6, 7].

Meanwhile, temperature during compression molding process can affect mechanical and physical strength of composites. The optimal compression molding temperature will reduce voids in composites. Voids are formed by the entrapment air, solvent and moisture. The quality and performance of thermoplastic composites is for large determined by the void content [8]. The purpose of this research is to study the effect filler composition and compression molding temperature on properties of MCC reinforced Styrofoam composite.
2. Materials and Methods

2.1. Materials
Coconut fiber, Styrofoam, chloroform, hydrochloric acid, sodium hydroxide and sodium hypochlorite, aquadest.

2.2. Isolation of Microcrystalline Cellulose
Coconut fibers added with sodium hydroxide solution 2% to remove the lignin. The filtrates washed with water until its neutral and then bleached using sodium hypochlorite. The filtrated washed with aquadest then added 17.5% of sodium hydroxide to purified the cellulose. The filtrate washed using aquadest then bleached again using sodium hypochlorite. The cellulose was hydrolysed using 2.5 N hydrochloric acid. The microcrystalline cellulose washed using aquadest until its neutral and then dried using oven at temperature 60 °C.

2.3. Composite Manufacturing Process
Styrofoam was diluted in chloroform the diluted Styrofoam was mixed with microcrystalline cellulose with composition ratio 2, 4, 6, 8 and 10% (wt). The blend was poured into the mold. Pre heat the composite mixture for 15 minutes and then pressed it for 10 minutes using compression molding with temperature of 110 °C, 120 °C, 130 °C, 140 °C and 150 °C and pressure 125 kg/m².

2.4. Composite Characterization

2.4.1. Fourier Transform Infrared (FT-IR). Fourier Transform Infrared characterization was considered to identify and show structural changes of composites. The FT-IR were carried out using Shimadzu IR-Prestige 21.

2.4.2. Tensile Strength. Tensile strength was investigated with ASTM D 638 Type IV using Universal Testing Machine RTF-1325.

2.4.3. Flexural Strength. Flexural strength was investigated with ASTM D 790 using Universal Testing Machine Gotech AI-7000.

2.4.4. Impact Strength. Impact strength was investigated with ASTM D 4812-11 using Impact Testing Machine with Izod method.

3. Results and Discussion

3.1. Fourier Transform Infrared (FT-IR)
Figure 1 shows the FT-IR spectra of the Styrofoam composites, microcrystalline cellulose reinforced Styrofoam composites from figure, it revealed the presence of absorbance in the wavelength number of 3416 cm⁻¹ which indicated the existence of –OH group that obtained from addition of microcrystalline cellulose.
3.2. Tensile Strength

Figure 2 shows the results of the tensile strength of styrofoam composites reinforced microcrystalline cellulose with various molding temperature.

Figure 2. Tensile strength of styrofoam composites reinforced with microcrystalline cellulose in various molding temperature

Figure 2 show the effect of various composition of MCC with various molding temperature on composites tensile strength. The highest tensile strength of composites was found in 8% composition of MCC and 130°C of molding temperature. This is caused by the placement of voids by fillers in the matrix increasing the composition of MCC which has an effect on the effectiveness of load transfer from the matrix to the filler [9]. Increasing molding temperature will reduce the viscosity of matrix which has an effect on reducing voids content in composites. Voids in composites are caused by volatiles such as air, solvent and moisture [8].
3.3. Flexural Strength
Figure 3 shows the results of the flexural strength of styrofoam composites reinforced microcrystalline cellulose with various molding temperature.

![Figure 3. Flexural strength of Styrofoam composites reinforced with microcrystalline cellulose in various molding temperature](image)

Figure 3 shows the effect of various composition of MCC with various molding temperature on composites flexural strength. The flexural strength increase with the addition of MCC composition until 8% with fixed molding temperature. This is caused by the placement of voids by fillers in the matrix with the increase of the MCC composition [9]. However, an increasing the MCC composition after optimal composition have decreased the flexural strength due to lower interaction between matrix and filler [10]. Increasing molding temperature until 130°C with fixed composition of MCC will increase the flexural strength of composites. Viscosity of matrix will be reduced with the increase of molding temperature which has an effect on lower voids content in composites but excessive molding temperature will degrade styrofoam to benzene, toluene and styrene [11]. The highest flexural strength of composites was found in 8% composition of MCC with 130°C of molding temperature.

3.4. Impact Strength
Figure 4 shows the results of the impact strength of Styrofoam composites reinforced microcrystalline cellulose with various molding temperature.

![Figure 4. Impact strength of Styrofoam composites reinforced with microcrystalline cellulose in various molding temperature](image)
Figure 4 shows the effect of various composition of MCC with various molding temperature on composites impact strength. The impact strength increase with the addition of MCC composition until 8% with fixed molding temperature. This is caused by the placement of voids by fillers in the matrix with an increase of MCC composition [9]. Voids in composites are caused by volatiles such as air, solvent and moisture [8]. Increasing the MCC composition after optimal composition will reduce interaction between matrix and filler which has an effect on lower impact strength [10]. Increasing molding temperature until 130°C with fixed composition of MCC will increase the impact strength of composites. Increasing the molding temperature has decreased the viscosity of Styrofoam; this causes the density of the composite to increase due to reduction of pores formation. The highest impact strength of composites was found in 8% composition of MCC with 130°C of molding temperature.

4. Conclusion
The highest mechanical strength such as tensile strength, flexural strength and impact strength were obtained in addition microcrystalline cellulose composition of 8% with 130°C of molding temperature. Microcrystalline cellulose has filled the pores in the styrofoam, so that when given a load the composite strength becomes better. In addition, as the temperature in compression molding increases during the molding process, the viscosity of styrofoam decreases so that the formation of pores is also reduced, hence increase the density of matrix.

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