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Research Article

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Mechanical Properties of Hybridized Kenaf/Chitosan Fibres Reinforced Polyethylene Biocomposites

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Abstract In this research, natural fibre such as kenaf core fibre (KCF) was used as filler for preparation of the biocomposites. Low-density polyethylene (LDPE) has been selected as a polymer matrix for preparation of the biocomposites due to its low production cost. Besides that, chitosan was used as secondary filler to investigate its effect on mechanical properties of the prepared biocomposites. Brabender internal mixer was used to composite the materials at temperature of 150°C. The process was taken about 15 minutes to complete the compositing. After that, the biocomposites were moulded into sheet with 1 mm thickness by using compression moulding machine at 150 °C for 2 minutes. Then, the samples were cut into dumbbell and rectangular shapes to perform tensile and impact tests, respectively. For tensile test, the machine used was Instron universal testing machine which done according to the ASTM D638-10, while for impact test, the machine utilised was Instron impact testing machine which conducted in accordance with the ASTM D256-10. The results of tensile stress,tensile modulus, tensile strain and impact strength were recorded and analysed at the end of the tests.

Keywords Biocomposite, tensile, impact, kenaf, chitosan

1. Introduction

There is a growing attention in the development of new materials which enhance optimal utilization of natural resources [1]. Natural fibres such as jute, coir, kenaf, hemp, sisal, chitosan, etc. are renewable resources. They will play an important role in emerging "green" economy based on energy efficiency where the use of this renewable feed stocks in polymer product are optimized [2]. It is an industrial process that reduces carbon releases and ecological materials that reduce waste. Natural fibres gained increasing interest and wider application during the past decade due to their benefits of low cost and low density. Moreover, they have low energy consumption and certainly wide varieties of fibres are locally available [3].

By using natural fibres as alternative primary filler for polymer composites, it has become attractive to researchers and industries. Natural fibres can replace synthetic fibres such as glass, aramid and carbon, as they have low density, low cost, renewable, non-abrasive, and good mechanical properties (high specific strength and high toughness). Besides, natural fibres have a low manufacturing energy demand compared to commonly use synthetic fibres as well. Hence, this indirectly produces polymer biocomposites with a very low production cost. Natural fibres also do not produce any by-products or residues that dangerous to humans and the environment during manufacturing and disposing processes of the composites [4].

In this research, kenaf core fibre (KCF) was utilized as primary filler and chitosan was used as secondary filler, whereas low-density polyethylene (LDPE) was applied as polymer matrix for preparation of hybridized natural fibres reinforced polymer biocomposites. The use of dual natural fillers is very promising due to they can

mutually assist between each other in the reinforcement of the biocomposites [5]. The main purpose of this research is to identify the effects of chitosan addition on the processing and mechanical properties of the polyethylene/kenaf biocomposites. The main difference between chitosan and KCF is it easy to acquire (derived from shrimp shell), biocompatible, and it also has anti-microbial character [6].

2. Materials and Methods

LDPE (coating grade) was purchased from the Lotte Chemical Titan (M) Sdn. Bhd., Malaysia. KCF (420 μm) was obtained from the National Kenaf and Tobacco Board, Malaysia [5]. Chitosan was procured from the Sigma-Aldrich (M) Sdn. Bhd., Malaysia. All materials were consumed as attained without further refinement [7].

Brabender internal mixer machine was used to prepare the biocomposites. The machine was equipped with a real-time processing recorder. The compositing was done at a temperature of 150°C, and the rotor speed was fixed at 60 rpm. First of all, 24 g of LDPE was inserted into the mixing chamber, and allowed to melt for 3 minutes. After that, 16 g of KCF was added into the chamber, and permitted to composite for 6 minutes. Finally, chitosan was incorporated into the composite, and allowed to blend for 6 minutes. The period of the whole process was 15 minutes [5]. The contents of the chitosan were varied from 3 to 18 wt.%. The biocomposite containing only LDPE and KCF was also prepared for comparison purposes.

The prepared biocomposite samples were converted into a 1 mm sheet through the compression moulding technique by using a hydraulic hot press machine. The moulding processes involved are preheating of mould containing the sample at 150°C for 7 minutes, compression of the sample at the same temperature for 2 minutes, and then cooling of the sample at 20°C for 5 minutes [8].

The sheet-shaped biocomposite samples were cut into dumbbell (types V) and rectangular (60 × 13 mm^2) shapes by using die cutter and scroll saw, respectively. The dumbbell- and rectangular-shaped samples were dried in an oven at a temperature of 70°C for at least 24 hours prior to characterizations [2].

The maximum tensile stress, tensile modulus, and tensile strain properties of biocomposite samples were measured according to the ASTM D638-10 at a room temperature (25°C) by using an Instron universal testing machine (model 5567) equipped with a 30 kN load cell. The crosshead speed and gauge length were 5 mm min^{-1} and 40 mm, respectively. 10 replicates were done for each sample to determine the average values, and the standard deviation ranges were reported to show the error range [9].

The impact strength of biocomposite samples was determined in accordance with the ASTM D256-10 at a room temperature (25°C) by using an Instron impact testing machine (CEAST 9050) equipped with a 0.5 J pendulum. The samples were notched up to 1 mm depth by using a V-notch machine (CEAST Notchvis). The average values from 10 replicates of each sample were calculated, and the ranges of standard deviation were also indicated [9].

3. Results and Discussion

3.1 Processing Characteristics

Processing torque is one of the processing characteristics, it has been recorded during the processing of the materials. Figure 1 showed the processing torque-time curves of the LDPE/KCF biocomposites with different contents of chitosan. The increased torque curves at around the first minute for all samples are due to the unmelted LDPE that increased the resistance on the internal mixer rotors. The curves then decreased at around the second minute because the melting of LDPE took place. The torque curves started to increase again at around the fourth minute after KCF added to all samples. This is due to it required more force for distributing the KCF filler in the molten LDPE. Then, the torques obviously started to decrease again when the KCF thoroughly dispersed in the LDPE matrix.

The processing torque for the sample with 0 wt.% of chitosan decreased and persisted almost unchanged at a certain level until the end of mixing time. For the sample with 3 wt.% of chitosan, there was a slight increase of the processing torque at around the tenth minute compared to the previous sample. It showed that a small amount of friction from the chitosan acting on the molten biocomposites. On the other hand, for the samples with 6 to 18 wt.% of chitosan, there were significant increases in the processing torques due to large amounts of

friction exerted on the molten biocomposites. Nevertheless, the torques slowly decreased once the chitosan is completely dispersed in the molten biocomposites [4]. Then, the torques of all samples started to maintain stable at around the thirteen minute until the end of processing. This is due to the LDPE, KCF and chitosan have been mixed well during the processing [2].

Figure 2 demonstrated the influence of chitosan on the stabilization torque of the LDPE/KCF biocomposites. The torque values specifically at the fifteenth minute were regarded as the stabilization torque values [5]. The diverse values of stabilization torque were based on the fact that the contents of chitosan added into mixing chamber are varied with one another. In Figure 2, the graphs showed that the stabilization torques increased for the samples added with chitosan from 3 to 18 wt.%. Moreover, for the biocomposites with more chitosan they tend to have higher stabilization torques compared to the samples with less chitosan although at similar loading of LDPE/KCF. This is due to the more addition of secondary filler to the biocomposites, the higher viscosity of the molten biocomposites attained [5].

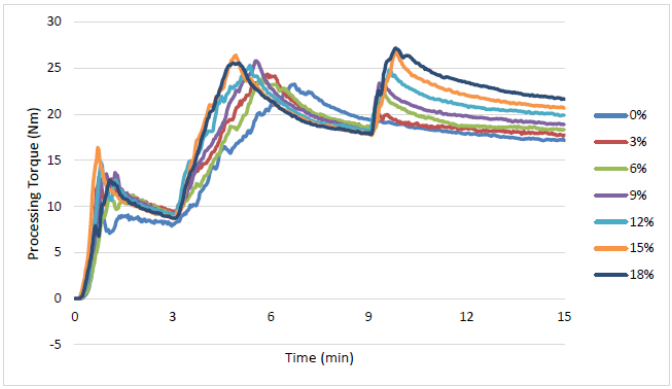

Figure 1: Processing torque-time curves of the LDPE/KCF biocomposites

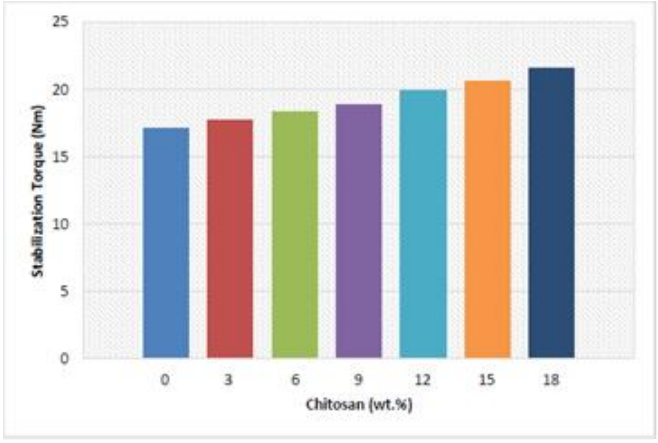

Figure 2: Stabilization torque-chitosan graphs of the LDPE/KCF biocomposites

3.2 Mechanical Properties

Figures 3 and 4 exhibited the tensile stress and tensile modulus results of the LDPE/KCF biocomposites with different percentages of chitosan. It can be seen that the tensile stress and tensile modulus of the chitosan-added biocomposites were actually higher than the biocomposite without chitosan. This showed that there are enhancements in the mechanical properties even though less chitosan were added in the biocomposites. It also can be observed that the tensile stress and tensile modulus of the biocomposites with more content of chitosan are higher than the biocomposites with less content of chitosan. The percentage increment of chitosan to the biocomposites has increased the tensile stress due to the more chitosan added, the higher load required to break the biocomposites. In addition, a parallel trend was also found for the tensile modulus of the biocomposites that have been added with chitosan. The results demonstrated that the LDPE/KCF biocomposites added with chitosan are more stiff and rigid than the biocomposite without chitosan.

Figure 5 indicated the tensile strain result of LDPE/KCF biocomposites with different percentage of chitosan. From the obtained result, it can be observed that the tensile strain of the chitosan-added biocomposites is low compared to the biocomposites without chitosan. The result displayed that the tensile strain is inversely proportional to the tensile stress and tensile modulus results. The decreasing trend of the tensile strain continued as more chitosan added into the biocomposites. This is because of the decrease in the elasticity and ductility of the biocomposites [10]. On the other hand, Figure 6 demonstrated the impact strength result of LDPE/KCF biocomposites with different percentage of chitosan. The impact strength decreased after chitosan added to the biocomposites. Moreover, it also showed that the impact strength of the biocomposites also decreased as the percentage of chitosan increased. Therefore, this can prove that the addition of chitosan as secondary filler to the LDPE/KCF biocomposites has decreased the flexibility of the biocomposites.

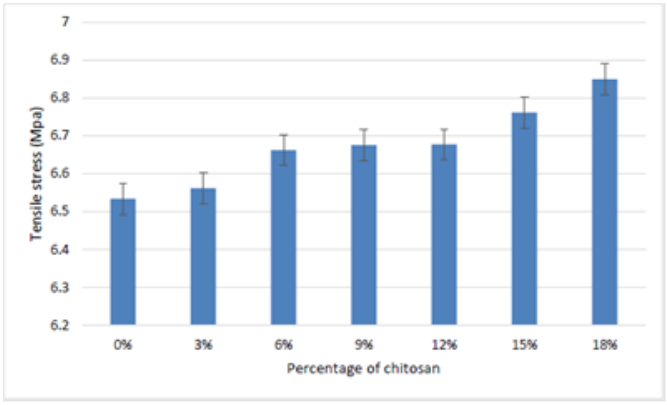

Figure 3: Tensile stress of the LDPE/KCF biocomposites with different percentage of chitosan

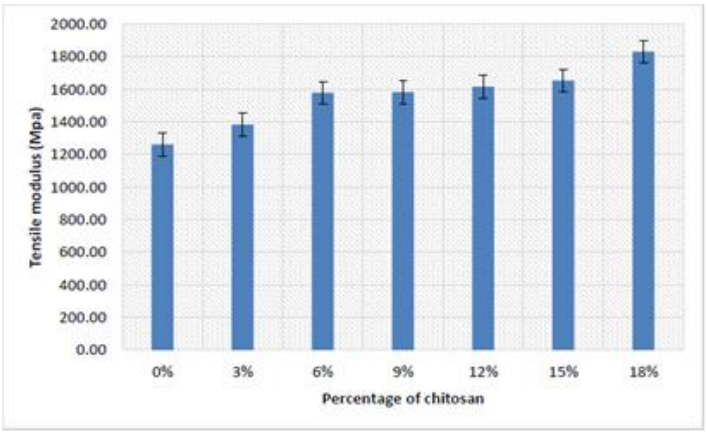

Figure 4: Tensile modulus of the LDPE/KCF biocomposites with different percentage of chitosan

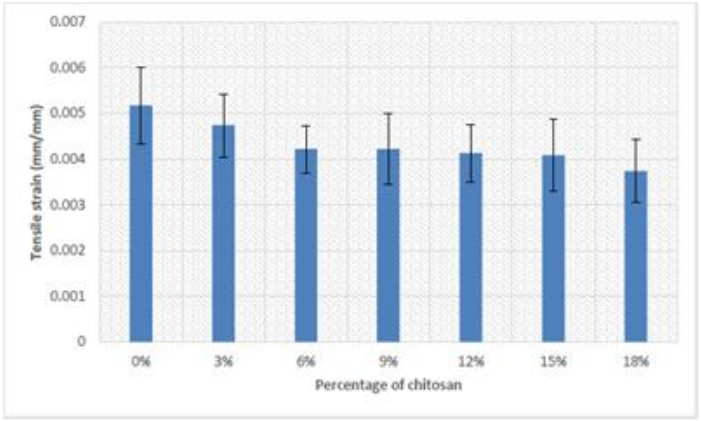

Figure 5: Tensile strain of the LDPE/KCF biocomposites with different percentage of chitosan

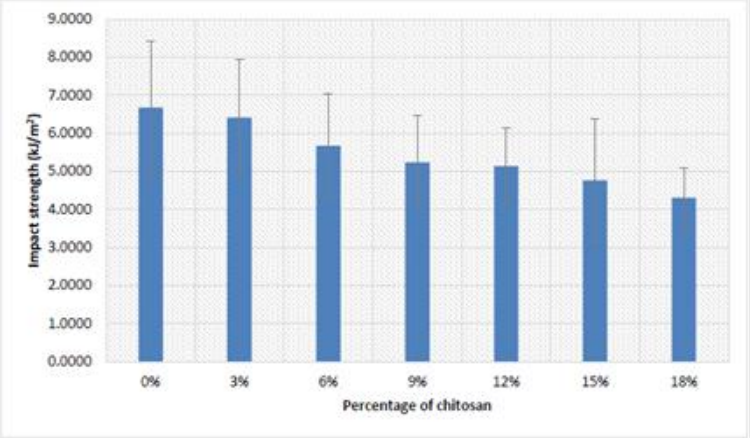

Figure 6: Impact strength of the LDPE/KCF biocomposites with different percentage of chitosan

4. Conclusion

From this research, the LDPE/KCF biocomposites with chitosan added as secondary filler were successfully processed. It can be seen that the processing torque and stabilization torque increased after chitosan added to the biocomposites. This is due to the fact that the addition of chitosan has exerted some amounts of friction on the molten biocomposites. Thus, with the addition of chitosan, it enhanced the melt viscosity of the biocomposites. Moreover, the tensile strength and tensile modulus of the LDPE/KCF biocomposites added with chitosan increased due to their high stiffness and rigidity properties. In contrast, the tensile strain and impact strength of the chitosan-added biocomposites displayed decreasing trend instead of increasing trend as the tensile strength and tensile modulus due to their low elasticity and ductility properties. This concluded that the LDPE/KCF biocomposites with chitosan added as secondary filler can potentially develop stiffer products that able to withstand applied load before failure as compared to the one without chitosan.

Acknowledgements

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