J. Trop. Agric. and Fd. Sc. 42(2)(2014): 169 – 174

Effect of fibre loading on mechanical properties of durian skin fibre composite

W.B. Wan Nazri[1], Z. Nurzam Ezdiani[1], M. Mohd Romainor[1], K. Syarajatul Erma[1], J. Jurina[1] and I.Z.A. Noor Fadzlina[1]

[1]Food Technology Research Centre, MARDI Headquarters, P.O. Box 12301, 50774 Kuala Lumpur, Malaysia

Abstract

The study investigated the effect of durian skin fibre loading on the mechanical properties of durian skin fibre (DSF) composites. DSF are cellulose-based fibres extracted from durian skin. The fibre content in the composites in this study was varied from 10 to 70 vol % of fibre loading. Increasing DSF content in the matrix (LLDPE-Eco) has reduced the tensile strength and impact of the composites meanwhile the flexural modulus increased up to 60% fibre loading. Morphological study observed by Scanning Electron Microscope showed that the interaction between DSF and matrix was poor which contributed to the reduction in the composite properties.

Keywords: durian skin fibre, polymer composites, mechanical properties

Introduction

Research in replacing glass fibre composites with natural fibre composites in various applications began in 1990. Natural fibre reinforced composite such as hemp-epoxy and flax-PP are widely used in automotive industry because of low price and density. Natural fibre composites have an advantage over the glass fibre composite due to more environmental friendly and also reduction of environmental problems due to the biodegradable property (Joshi et al. 2004). The attractive features of natural fibres over the traditional counterparts include relatively low cost, low weight, high specific modulus, less hazards, abundant and renewable resources.

However, natural fibres have a few disadvantages when used in composites, such as lower impact strength and higher moisture absorption which brings about dimensional changes thus leading to micro-cracking and poor thermal stability. However, by choice of the fibre and matrix, the fabrication method and manufacturing procedures, the final application envisaged and the fibre surface treatment have resulted in the applications of natural fibre reinforced composites. Natural fibres can be classified into three types, namely, vegetable fibre, animal fibre and mineral fibre. The vegetable fibres are further categorised into stem or bast fibre, leaf fibre, seed fibre and fruit fibre (Alsaeed et al. 2012).

Durio zibethinus Murray, commonly known as durian, is one of the most important seasonal fruits in tropical Asia. Widely known as the ‘King of fruits’, durian is a dicotyledonous tropical seasonal plant species belonging to the Bombacaceae family (Voon 2006). About 50 – 65% of durian fruit is made up of skin which is considered as waste. This means that 1,500,000 tonnes of durian skin is generated

Article history
Received: 1.11.2012
Accepted: 20.5.2014

Authors’ full names: Wan Nazri Wan Busu, Nurzam Ezdiani Zakaria, Mohd Romainor Manshor, Syarajatul Erma Khalid, Jurina Jaafar and Noor Fadzlina Inche Zainal Abidin
E-mail: wannazri@mardi.gov.my

every year. Durian skin has potential as reinforcing filler for polymer composites. However, it must be processed to obtain durian skin short fibres. The use of natural fibre to replace the inorganic substances and synthetic fibres in plastics would be highly beneficial in environmental protection (Yang et al. 2007).

The current management and utilisation of durian fruit waste are not enviromental friendly, therefore, the utilisation of durian skin fibre in composite is one of the most promising methods to utilise and manage durian fruit waste. Durian skin fibre (DSF) can be fabricated into composite by using various techniques including resin transfer moulding, compression moulding, injection moulding, direct extrusion and vacuum infusion like any other natural fibre such as kenaf and flax (Ho et al. 2011). Durian skin fibres are the newly explored fibre as reinforcement for thermoset and thermoplastic to produce composite products. It is important to understand their properties so that it be can used in many applications.

This study is part of the project to develop biodegradable food packaging materials. The objective of the study was to derive the optimum fibre loading into composite materials. This paper focuses on the effect of fibre loading on the mechanical properties of durian skin fibre composites.

Materials and methods

Durian skin was obtained from local market and processed at the laboratory of Food Research Technology Centre, MARDI to produce durian skin fibre (DSF). The density of DSF is 1.436 g/cm^3, measured by using densitometer. Low linear density polyethylene (LLDPE) was supplied by Exxon Mobil Chemical Asia Pacific with density 0.92 g/cm^3 and Eco-degradant PD 04 at density 0.934 g/cm^3 was obtained from Behn Mayer Polymers Sdn. Bhd.

The fresh durian skins were washed thoroughly with tap water to remove any adhering particles and dusk. The durian skin was then sliced into small pieces (±3 mm) by using slicer machine and dried in the cabinet dryer at 70 °C for 24 h. The dried durian skin was then pulverised to produce durian skin fibre. The fibres were sieved using sieve shaker to obtain fibres at 300 – 500 mm in size (Retch AH2000). The density of DSF was measured by using densitometer (AccuPyc). The length of the durian skin fibre was measured using Image Analyser and was found to be between 0.839 and 2.379 mm and the average length was 1.475 mm. Thus, the average aspect ratio (L/D) was 5.531 with range 1.952 to 10.300.

Durian skin fibre composite (DSFC) was prepared using LLDPE by adding 10% ECO matrix to assess the reinforcing of DSF. The DSF was compounded with matrix by using internal mixer (Haake Rheomix 600p, Germany) at 135 °C with speed 50 rpm for 12 min of processing time. Composites samples were prepared with seven different percentage volumes of fibre (10, 20, 30, 40, 50, 60 and 70%). Finally, the compound was transferred into a test piece shape by using compression-moulding (Lab Tech Engineering LTD, Sweden).

Tensile properties were measured using a Testometric 350 according to ASTM D638 at crosshead speed of 50 mm/min. The gauge length was kept at 70 mm. Flexural strength was measured under a three-point bending approach with a Testometric 350 instrument (Lancashire, UK) according to ASTM D 790. The distance between the spans was 100 mm, and the strain rate was 5 mm/min. Five test specimens were used for each composition. Impact test was carried out using Dynisco Polymer Test Machine according to ASTM D 256. The velocity and weight of the hammer were 3.5 m/s and 0.898 kg respectively. All samples were notched before testing. The density of composites was determined using Electronic Densitimeter MD200S (Mirage) according to ASTM D792.

The tensile fractured surfaces of the composite were examined under FEI Quanta

200 Scanning Electron Microscope. The fracture ends of the samples were mounted on an aluminium stub and coated with a thin layer of gold to avoid electrostatic charging during examination. The objective was to obtain some information regarding the fibre dispersion and the bonding quality between fibre and matrix.

Results and discussion

Mechanical properties

The tensile strength and strain at break decreased with increasing DSF content (*Figure 1*). Similar trend was also reported by Lee and Wang (2006). Tensile strength of the sample without DSF was 24.2 MPa and reduced to less than 9.27 MPa when DSF was added. The strength of composites depends on the fibre loading, which is determined by the adhesion at the fibre-matrix interface. DSF is a hydrophilic natured meanwhile the matrix is hydrophobic. By adding natural fibre into matrix, poor interfacial adhesion between the polymer matrix and DSF may occur and this will lead to reduction in strength. This is also a general phenomenon in incompatible composites with different characteristics, such as hydrophobicity of the polymer matrix and hydrophilicity of the filler (Lee and Wang 2006). The reduction in the strain at break of the composites is also due to the poor interfacial adhesion between DSF and matrix.

It can be seen that increasing the DSF content increased the tensile modulus (*Figure 2*). This is common in composites reinforced with hard filler (Lee and Wang 2006). The tensile modulus of the composite containing 60% DSF is five times of that pure matrix. This shows that DSF has imparted its stiffness to the matrix up to 60 vol %.

The flexural strength of the sample with 0 vol % of fibre is used as the control. Flexural strength is the ability of material to withstand bending forces applied perpendicular to its longitudinal axis. Results showed that flexural strength at DSFC increased up to 30% of DSF loading and reduced when more than 30% of DSF was loaded (*Figure 3*). This reduction is due to the problem of interaction between the matrix and fibre, arrangement of the fibres in the matrix, existing of voids as well as problem with fibre arrangement within the matrix as explained by Anuar et al. (2008). Incompatibility is another factor which affects flexural strength since DSF is hydrophilic and the matrix is hydrophobic. The reduction in the flexural strength was also reported by Arbelaiz et al. (2005) where they observed that flexural strength is affected by fibre-fibre intraction, the alignment of the fibre with the matrix, the presence of voids, dispersion and the location of resin-rich areas.

Flexural modulus increase with DSF loading up to 60% fibre loading (*Figure 3*). An increase in flexural modulus is influenced by the modulus of fibre used. The arrangement of DSF in the matrix also plays an important role in determining the compressive modulus of the composite system.

Impact strength of DSF composites is a measure of the ability of the composites to resist the fracture failure under stress applied at high speed and is directly related to the toughness of the composites. It is generally accepted that the toughness of a fibre composite is mainly dependent on the stress–strain behaviour of fibre. Matrix (LLDPE-Eco) possesses higher impact strength than the DSF composites (*Figure 4*). Impact strength increased from 10 to 30 vol % of fibre and the highest impact strength recorded was about 93 kJ/m^2. Fibres play an important role in the impact resistance of composites as they interact with the crack formation and act as stress transferring medium (Ruhul et al. 2010). The reduction in impact strength with DSF fibre loading is due to incompatibility problem as explained earlier for tensile and flexural strength.

The performance of composite material reinforced fibre depends on various factors

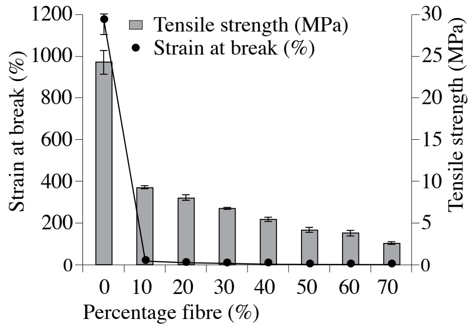

Figure 1. Tensile strength (MPa) and strain at break (%) of DSF composites with different fibre loading

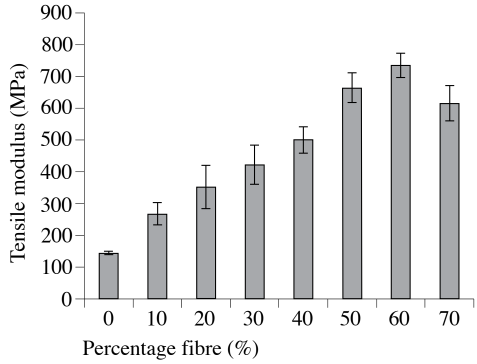

Figure 2. Tensile modulus (MPa) DSF composites with different fibre loading

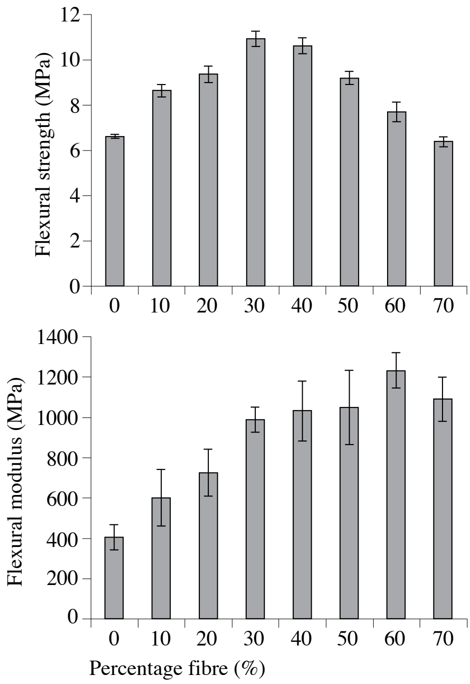

Figure 3. Flexural strength (MPa) and flexural modulus (MPa) DSF composites with different fibre loading

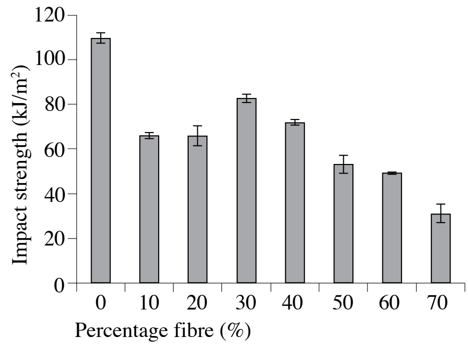

Figure 4. Impact strength (kJ/m^2) DSF composites with different fibre loading

including the section's condition, surface of fibre and matrix, technique of producing sample and geometric of the composite as well as types of testing performed on the samples produced (Joseph et al. 2002). As load or force is transferred exceeding the bond strength between the surface of the fibre and matrix, breaking of bonding will happen to the composite system. Furthermore, as stress applied exceeds the fibre strength, stress at break will occur on the fibre. The breaking fibre might be pulled out of the matrix thus resulting in energy separation.

Morphological observation

The SEM micrograph of the tensile fracture surface of the composites is shown in *Figure 5*. It showed the poor interfacial bonding and adhesion between fibre and matrix for 40 – 60% volume of DSF. The presence of void and uncoated fibre on fibre surface demonstrate poor adhesion between fibre and matrix. It is evidenced in *Figure 5* that fibre pull-out is the major failure during tensile tests. Similarly to other natural fibres, DSF has inconsistency in dimension. Adhesion between the surface of

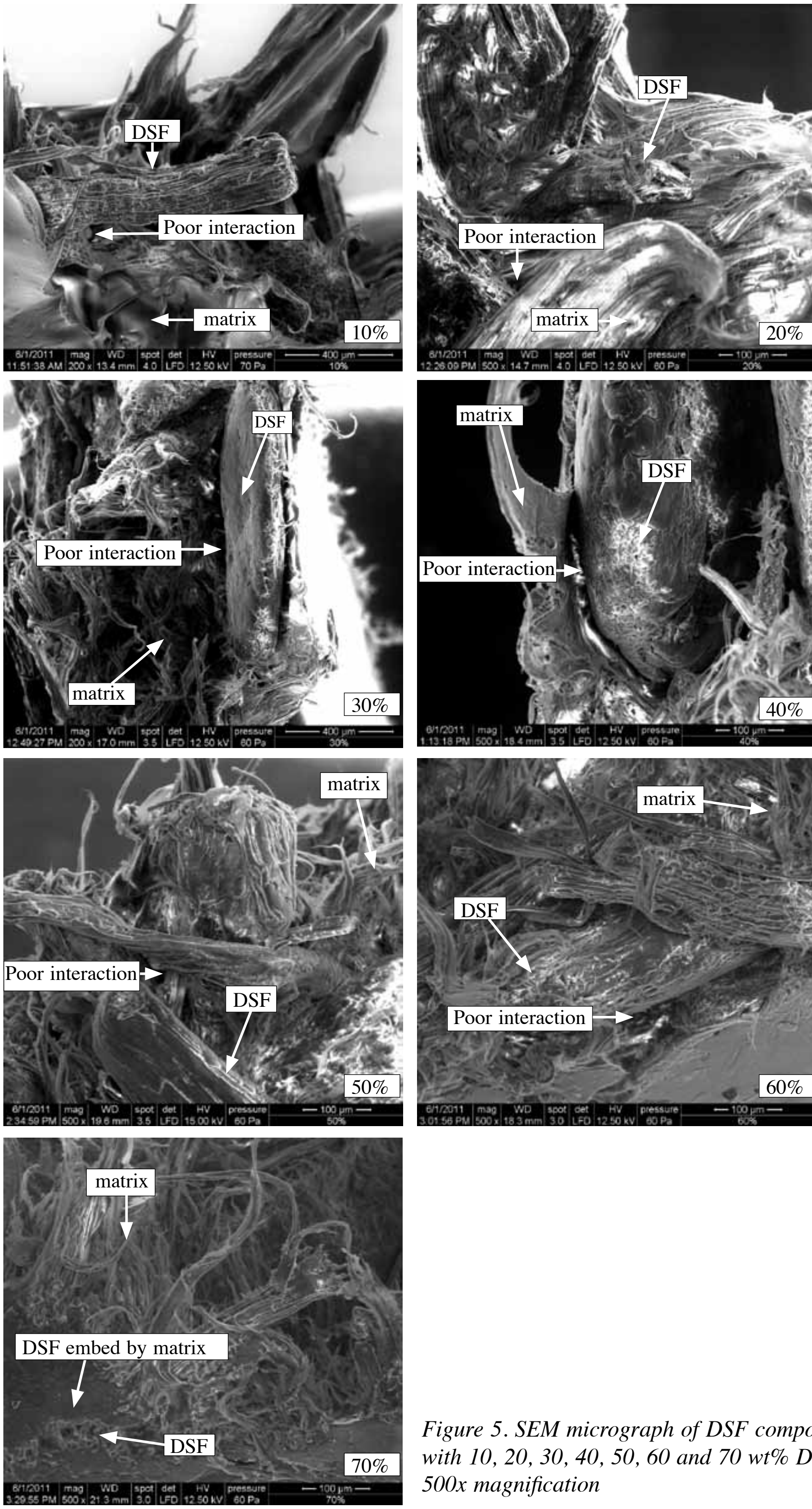

Figure 5. SEM micrograph of DSF composite with 10, 20, 30, 40, 50, 60 and 70 wt% DSF at 500x magnification

fibre and the matrix plays an important role in improving the property of a material. It is found that different polarities of the fibre and matrix will also affect the adhesion between these surfaces.

Conclusion

Tensile strength, strain at break and impact strength composite reduced with increasing DSF content. Tensile and flexural modulus increased with increasing fibre loading. From the tensile fracture surface, scanning electron micrographs showed poor interaction between DSF and matrix. This poor interaction contributed to the reduction in properties with increasing DSF loading.

Acknowledgment

The authors acknowledge the assistance of Mr Muhammad Ramdhan Adman, Mr Mohamad Saifudin Omar, Ms Ashahida Amran and supporting staff at Food Packaging and Handling Programme, MARDI.

References

Alsaeed T., Yousif B.F. and Ku, H. (2012). The potential of using date palm fibres as reinforcement for polymeric composites. *Materials & Design* 43: 177 – 184

Anuar, H., Ahmad, S.H., Rasid, R. and Wan Busu, W.N. (2008). Reinforced thermoplastic natural rubber hybrid composites with *Hibiscus cannabinus*, L and short glass fibre – Part I: Processing parameters and tensile properties. *Journal Composite Material* 42: 1075 – 1087

Arbelaiz, A., Fernandez, G., Cantero, R., Llano-Ponte, L.-P., Valea, A. and Mondragon, I. (2005). Mechanical properties of flax fibres/polypropylene composites –Influence of fibre/matrix modification and glass fibre hybrization. *Composites: Part A*: 36: 1637 – 1644

Ho, M.P., Wang, H., Lee, J.H., Ho, C.K., Lau, K.T., Leng, J. and Hui, D. (2012). Critical factors on manufacturing processes of natural fibre composites. *Composites: Part B:* 3549 – 3562

Joseph, S., Sreekala, M.S., Oommen, Z., Koshy, P. and Thomas, S. (2002) A comparison of the mechanical properties of phenol formaldehyde composites reinforced with banana fibres and glass fibres. *Compos. Sci. Technol.* 62: 1857 – 1868

Joshi, S.V., Drzal, L.T, Mohanty, A.K and Arora, S. (2004). Are natural fibre composites environmentally superior to glass fibre reinforced composites? *Composites* part A 35: 371 – 376

Lee, S.H. and Wang, S. (2006) Biodegradable polymer/bamboo fibre biocomposite with bio-based coupling agent. *Composites Part A: applied science and manufacturing*. Part A 37: 80 – 91

Ruhul, K.A., Mubarak, A.K., Haydar, U.Z., Shamim, P., Nuruzzaman, K. and Sabrina, S. (2010). Comparative studies of mechanical and interfacial properties between jute and E-glass fibres reinforced polypropylene composites. *Journal Reinforced Plastic Composites* 29(7): 1078 – 1088

Voon, Y.Y. (2006). Physicochemical, microbial and sensory changes of minimally processed durian (*Durio zibethinus* cv. D24) during storage at 4 and 28 °C. *Postharvest Biology and Technology* 42: 168 – 175

Yang, H.S., Wolcott, M.P., Kim, H.S., Kim, S. and Kim, H.J. (2007). Effect of different compatibilizing agents on the mechanical properties of lignocellulosic material filled polyethylene bio-composites, *Composite Structures* 79: 369 – 375

Abstrak

Kajian dilakukan untuk mengenal pasti kesan kandungan gentian kulit durian terhadap sifat mekanik komposit gentian kulit durian (DSF). DSF adalah gentian selulosa yang peroleh daripada kulit durian. Kandungan gentian di dalam komposit untuk kajian diubah daripada 10 kepada 70% isi padu gentian. Penambahan DSF ke dalam matriks (LLDPE-Eco) telah mengurangkan kekuatan regangan dan kekuatan terikan komposit di mana kekuatan lenturan meningkat sehingga 60% gentian. Kajian morfologi dilakukan dengan menggunakan Mikroskop Imbasan Elektron (SEM) dan menunjukkan interaksi antara DSF dengan matriks adalah rendah dan menyebabkan pengurangan sifat mekanik komposit.