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The Tensile Evaluation of the Epoxy/ Keratin Short Fibre as New Composites

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ABSTRACT

Production of bio-composites using biodegradable filler/fibre or matrix has been increasing steadily for the past decade. In the case of fibre reinforced polymer composites, natural fibres such as jute, hemp and kenaf have been widely reported. Apart from cellulosic based natural fibre, there are other potential fillers from animal based by-products such as keratin from chicken feathers. In this study, an epoxy/keratin composite has been produced using a pressure assisted hand lay-up technique to form flat homogenized board. The percentage feather content by weight was varied accordingly (i.e. 10, 20, 30, 40 and 50 %). The board underwent standard tensile strength testing at 5mm.min^{-1} and elucidated that the ultimate tensile strength and strain decreases as the feather composition percentage increases. The Young's modulus indicated little effect with increasing feather composition percentage. A fractured piece of sample produced from the tensile testing was evaluated with respect to fracture behaviour using scanning electron microscopy (SEM). The tensile testing indicates that the composite with the maximum feather composition percentage (50 %) has the potential to be used in non-structural applications.

Keywords: *Chicken feather, epoxy, tensile test, scanning electron microscope (SEM)*

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Introduction

The usage of agricultural or bio-resources to produce short fibre composites is an area of growing interest for many researchers globally. The shift towards bio-based fillers / fibres is due to their desirable properties, such as strength, lightweight, durability, water resistance and flame resistance, but their application would be even more advantageous if the new materials are cheaper [1, 2]. Most research incorporate plant based fillers such as kenaf, jute and hemp and the matrix used in this applications is mostly thermoplastic [3-6]. The advantages of using such fillers are their low densities, good thermal properties and biodegradability [7] and this has to researchers continuing to perfect the inclusion and combination of bio-based fibers with polymers to form new materials.

Chicken feathers have distinctive structures and properties that make them differ from synthetic fibres. The feather is formed from keratin, which contains ordered α- and β-helix structures [8-10]. The feathers have low density, excellent compressibility and resilience, ability to dampen sound and warmth retention [11,12]. The bulk density of the chicken feather is approximately 0.8 g/cm^3 compared to 1.5 g/cm^3 and 1.3 g/cm^3 for cellulose fibre and wool, respectively [11]. These outstanding properties would have greater value if it can be transformed / combined into a new material/bio-composite, which could be used to benefit people as an alternative or substitution for some semi-structural material, such as gypsum board or compressed wood.

The chicken feather consist primarily of keratin, which can be found in nails, wool, claws and horn [7]. In Malaysia, the chicken feather is just another solid poultry waste that poses no economic value to the poultry owner. Most chicken feathers are either buried, burned or dumped. In 2003 a statistical report produced by the Malaysian Government a stated that on average, each Malaysian aged from 18-59 years old consumes approximately 31.66 grams of chicken per day [13]. If the chicken feather comprises 5-7 % of the chicken's mass [7] then each Malaysian wastes between 1.6-2.2 grams of chicken feathers per day and between 48-66 grams per month (assuming 30 days per month). Considering the number of Malaysians and on the consequent quantity of chicken feathers being wasted, it would be pertinent if these chicken feathers could be utilized to their fullest thereby reducing poultry waste.

Objectives

The objectives of this project are:

- To analyse the tensile properties of epoxy/feather composites composed of various weight percentages of chicken feather.
- To quantify the factors affecting the tensile properties using Scanning Electron Microscope (SEM) fractography images.

Methodology

Epoxy/feather bio-composite samples were fabricated using a three platen mould and the pressure assisted hand lay-up technique. The mould was designed with an air ventilation system to minimize the quantity of air trapped inside the epoxy/ keratin short fibre bio-composites. The epoxy (Morcote BJC-29) used in this research was obtained from a local supplier. The ratio of the epoxy to the hardener is 3.5:1.5 for which the epoxy gelling time is approximately 18 minutes. The chicken feathers and epoxy mixtures for this research were formulated according to those shown in Table 1.

Table 1: Labelling for the Composite Samples Prepared for This Research According to Their Formulations

Samples	% Chicken Feather
Ep0F	0
Ep10F	10
Ep20F	20
Ep30F	30
Ep40F	40
Ep50F	50

Tensile tests were performed according to the ASTM D638-03 method for which the overall sample length is 120mm, a gauge length of 80 mm and a sample thickness of 3 mm. Both ends of the tensile sample were covered with tape to ensure secure attachment to the tensile test jigs and minimize the possibility of sample slippage. Tensile tests were performed using a Shimadzu AG-X Series with a 20 kN load cell at test speed of 5 $mm.min^{-1}$. The results obtained were analyzed using a Trapezium X Version 1.1.2.

The fractured samples from the tensile testing were then analyzed to elucidate mechanistic detail of the fracture behaviour using a FEI Phenom Scanning Electron Microscope (SEM). The samples were shortened to within 2 cm from the fractured surface and mounted on a standard SEM tub.

Results and Discussions

Three primary results were considered in determining the effect of incorporating chicken feathers into the epoxy; these were the ultimate tensile strength (UTS), the strain at maximum stress value and the Young's modulus.

Ultimate Tensile Strength (UTS)

There are three phenomena of interest evident in the UTS behaviour as the quantity of chicken feathers incorporated increases, Graph 1. The first phenomena is the significant difference in UTS value between unfilled epoxy (virgin) and the minimum filled epoxy bio-composite; the incorporation of chicken feathers into the epoxy decreases the UTS value to less than half of its virgin epoxy value. This drop may be attributed to the fibre pullout phenomenon, which is evident in Figure 1. Even though

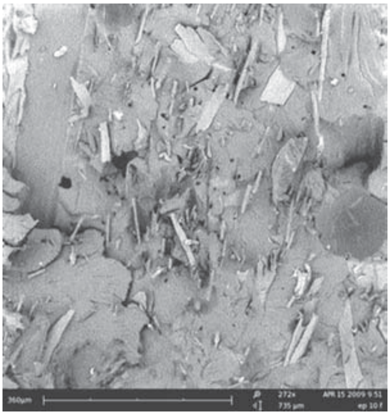


Figure 1: Fractography Images of the Ep10f Samples Viewed Using Sem at 272x This Fractography Images Showed the Fibre Pullout and Fibre Fracture During the Tensile Test

the amount of fibre pullout is extensive with 10 % chicken feather incorporation, there is evidence of fibre fracture in the fractography image. The fibre fracture shows that there is some interphase bonding between the chicken feathers and epoxy.

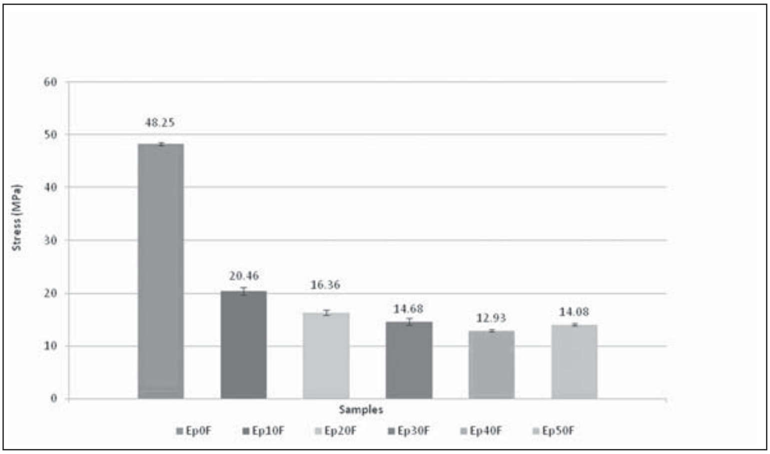
The large decreasing of the UTS value might also be due to the distortion of the polymer network as the chicken feathers pack between the complex chains of the polymer network. Having said this, validation for this argument requires additional testing such as Differential Scanning Calorimetry (DSC) or Dynamic Mechanical Thermal Analysis (DMTA) in order to visualize a shift in the transition temperatures, which would indicate a change in epoxy morphology thus validating the polymer network distortion theory [14].

The second phenomena corresponds to the marked reduction in decreasing UTS values between the 10 % (Ep10F) and 40 % (Ep40F) chicken feather composites. Although there is still a decrease in UTS value, the quantity is small, between 2-4 MPa. This gradual decrement in the UTS value may be attributed to the increasing percentage of the chicken feather in the bio-composite, but the further addition does not appear to cause the composites to lose all mechanical strength. Evidence of feather fracture occurred during the catastrophic failure of the composite, which indicates a constructive contribution to composite mechanical strength, can be seen in Figure 1. Distortion of the polymer networks is believed to occur in all composite samples at all weight percentages of chicken feather loading, thus the effect of incorporating chicken feathers and the respective quantities thereof corresponds directly to the ultimate tensile strength of the bio-composites.

The final phenomena is the increase in UTS value as the feather weight percentage loading increases from 40 % (Ep40F) to 50 % (Ep50F), Graph 1. This unexpected increase contradicts the reasoning for a decreasing UTS value in the previous paragraph. However the improved UTS value may be attributed to the epoxy resins being forced to fill and penetrate parts of the chicken feather by the fixed volume of the mould, Figure 2. This phenomenon has improved the bonding between the chicken feathers and the epoxy.

Strain at Ultimate Stress Value

With respect to Graph 2, there are two obvious phenomena; the first is the obvious reduction in strain from Ep0F to Ep20F and the second is the steady increase in strain from Ep20F to Ep50F. The first phenomena



Graph 1: Ultimate Tensile Strength (UTS) of the Epoxy/Feather Composites at Various Percentages

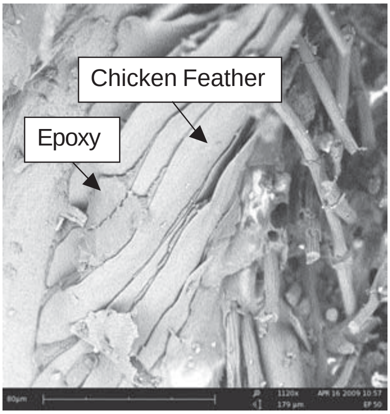
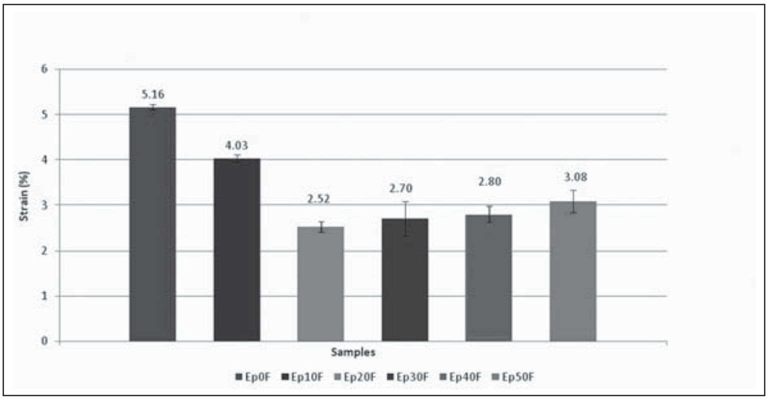


Figure 2: The Scanning Electron Micrograph Image Showing the Maximum Filling and Penetration of the Epoxy Matrix in Between the Chicken Feather as a Result of High Loading of the Chicken Feather (Sample Ep50f at 1120 × Magnification)

may be attributed to the distortion of the epoxy complex network due to the presence of the chicken feathers and the loss of epoxy penetration between the chicken feather, thus lowering the effective loads being transferred from the matrix to the chicken feather, which corresponds to an as yet not optimised bio-composite formulation. This is evident in the

SEM fractography image, Figure 3, where fibre pullout and the distribution of the chicken feather inside the epoxy can be clearly seen.

The second phenomenon is the gradually increasing strain values from Ep20F to Ep50F. The increasing trend is relatively small, since the values under consideration are in terms of strain percentage. Nevertheless this phenomenon indicates an increase in the distribution of the load throughout the bio-composite; the chicken feathers are able to stretch due to the complex structure of the alpha and beta helical keratin thus



Graph 2: Maximum Strain Results from the Tensile Test at Various Percentages of Feathers Inside the Epoxy / Feather Composites

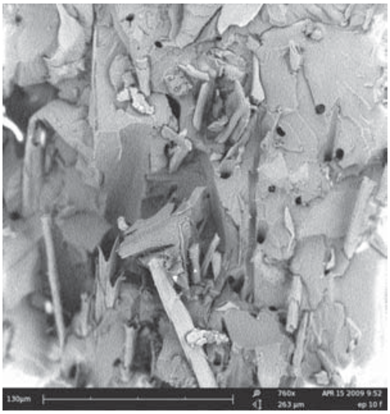


Figure 3: Fractography Image Observed Using SEM at 760x Magnification Showing the Fibre Pull Out and Fibre Fracture (Sample Ep10f)

improving load distribution [11, 15]. Evidence of this stretching capability is presented in the fractography images in Figure 4. In the fractography images it can be clearly seen that the percentage of fibre breakage increases compared to the quantity of fibre pullout as the weight percentage of chicken feathers increases. The images in Figure 4 also show improvement in the inter-phase between the chicken feathers and the epoxy.

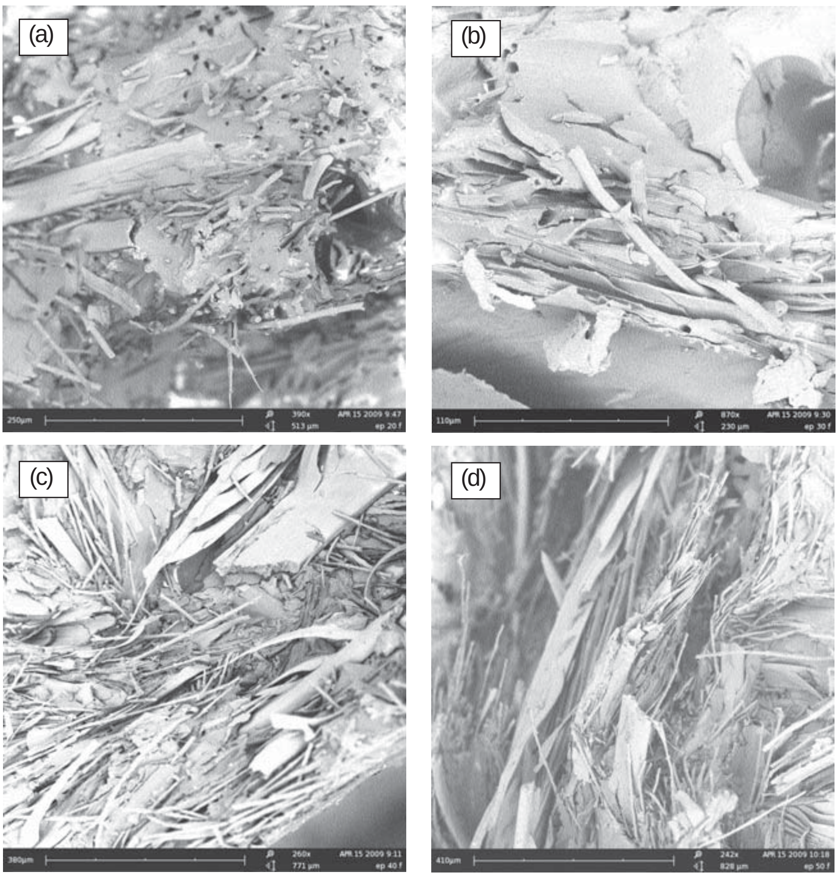
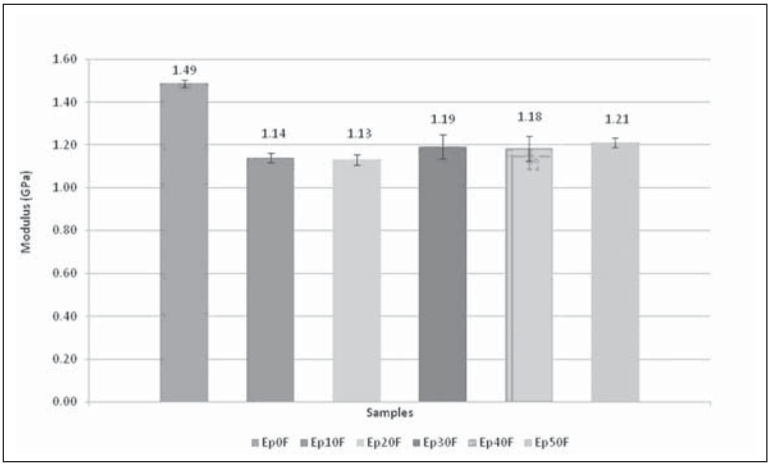


Figure 4: The Fractography Images of Epoxy/ Feather Bio-composites; (a) The Observation of the Fibre Pull Out in Ep20f Sample, (b), (c) and (d) Fibre Fracture in the Tested Sample of Ep30f, Ep40f and Ep50f Consecutively

Young's Modulus

The Young's modulus decreases from the blank (EP0F) to the first bio-composite sample (EP10F), Graph 3. The Young's modulus was taken over a range of 10-110N. It is of note that the Young's modulus value does not change significantly with increasing weight percentage of chicken feathers. This phenomenon is interesting since there are not many known fillers capable of maintaining the same Young's modulus as the weight percentage of filler increases. The lack of significant change in the modulus indicates that the toughness of the epoxy/feather bio-composite is essentially consistent for the tested percentages; 10 % -50 %.



Graph 3: Young's Modulus (at 10N to 110N) of the Epoxy/Feather Composites at Various Percentages

The reason of such behaviour is probably due to the good load transfer from the epoxy to the chicken feather. The load exerted by the polymer matrix, due to the force exerted by the motion of the cross head, is evenly transferred to the chicken feathers forcing the chicken feathers to stretch uniformly before failure.

Conclusion

The tensile test results show that the properties of the composites drop with the increasing amounts of keratin loaded into the epoxy. The factors contributing to the decreasing tensile properties, which have been evaluated using SEM, are the interfacial properties between the chicken feathers and the epoxy and that the chicken feather is most likely a semi-reinforcing type of filler.

From the results and the consequent analysis the Ep50F bio-composite would appear to be the closest optimized formulation, with respect to the minimum amount of epoxy used and the tensile property results. In conclusion the developed epoxy / keratin short from chicken feathers has the potential to be used in non-structural material applications.

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References

[1] T. Pejis, 2002. Composites Turn Green, vol. T_002 London, pp. 1-12.

[2] P. Wambua, J. Ivens and I. Verpoest, 2003. Natural Fibres: Can They Replace Glass in Fibre Reinforced Plastics, *Journal of Composites Science and Technology*, vol. 63, pp. 1259-1264.

[3] A. Leao, R. Rowell and N. Tavares, 1997. Applications of Natural Fibres in Automotive Industries in Brazil-Thermoforming Process, in *4th International Conference on Frontiers of Polymers and Advanced Materials Conference Proceedings*, Cairo, Egypt, pp. 755-760.

[4] M. Brahmakumar, C. Pavithran and R. M. Pillai, 2005. Coconut Fibre Reinforced Polyethylene Composites: Effect of Natural Waxy Surface Layer of The Fibre on Fibre/ Matrix Interfacial Bonding and Strength of Composites, *Journal of Composites Science and Technology*, vol. 65, pp. 563-569.

[5] K. John and S. V. Naidu, 2004. Effect of Fiber Content and Fiber Treatment on Flexural Properties of Sisal Fiber/ Glass Fiber Hybrid Composites, *Journal of Reinforced Plastics and Composites,* vol. 23, pp. 1601-1605.

[6] H. D. Rozman, M. J. Saad and Z. A. M. Ishak, 2003. Flexural and Impact Properties of Oil Palm Empty Fruit Bunch (EFB)-Polypropylene Composites - The Effect of Maleic Anhydride Chemical Modification of EFB, *Journal of Polymer Testing,* vol. 22, pp. 335-341.

[7] A. L. Martinez-Hernandez, C. Velasco-Santos, M. de-Icaza and V. M. Castano, 2007. Dynamical-mechanical and Thermal Analysis of Polymeric Composites Reinforced with Keratin Biofibers from Chicken Feathers, *Journal of Composites,* vol. 38, pp. 405-410.

[8] B. Edwards and J. I. Routh, 1944. Chemical studies on Powdered Keratins, *The Journal of Biological Chemistry,* pp. 593-596.

[9] B. K. Filshie and G. E. Rogers, 1962. An Electron Microscope study of the Fine Structure of Feather Keratin, *The Journal of Cell Biology,* vol. 13.

[10] I. D. Walker, and G. E. Rogers, 1976. The Structural Basis for the Heterogeneity of Chick Down Feather Keratin; The Partial Amino Acid Sequence of Down Feather Keratin, *European Journal of Biochemistry,* vol. 69, pp. 341-350.

[11] N. Reddy and Y. Yang, 2007. Structure and Properties of Chicken Feather Barbs as Natural Protien Fibers, *J Polym Environ,* vol. 15, pp. 81-87.

[12] G. J. Cameron, T. J. Wess and R. H. C. Bonser, 2003. Young's Modulus Varies with Differential Orientation of Keratin in Feathers, *Journal of Structural Biology,* vol. 143, pp. 118-123.

[13] Food Consumption Statistics of Malaysia, 2003. For Adult Population Aged 18 to 59 Years, Ministry of Health 2003.

[14] A. W. Birley, B. Haworth and J. Batchelor, 1991. *Physics of Plastics; Processing, Properties and Material Engineering*: Hanser Publishers.

[15] R. Schor and S. Krimm, 1961. Studies on the Structure of Feather Keratin II. A beta-Helix Model for the Structure of Feather Keratin, *Biophysical Journal*, vol. 1.