



# Kenaf-fiber-reinforced copolyester biocomposites

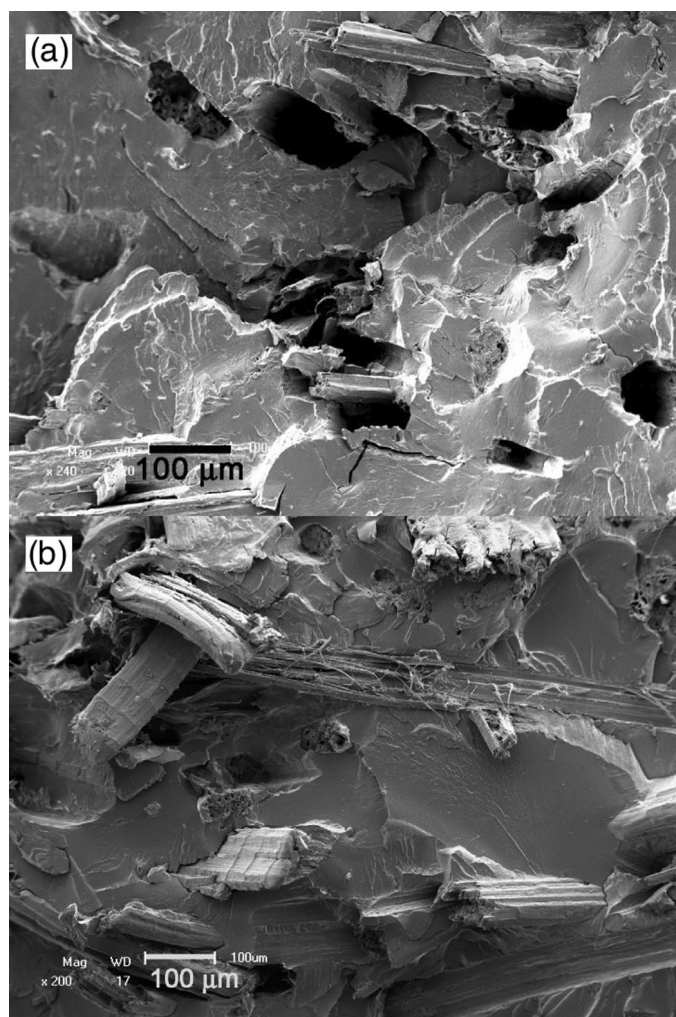
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*Alkali-treated kenaf fibers improve the thermal and mechanical properties of an aliphatic-aromatic copolyester resin.*

Biodegradable polyesters are one family of polymers that have been considered as replacements for conventional plastic resins. Aliphatic polyesters, such as the naturally occurring polyhydroxyalkanoate family of materials and the synthetic polycaprolactone, have been investigated as possible alternatives to traditional plastics. However, their material properties seriously affect the versatility of these materials.<sup>1</sup> A more promising alternative is an aliphatic-aromatic copolyester of 1,4-butanediol, adipic acid and terephthalic acid, which has been commercialized under the trade name Ecoflex. The copolyester is produced from the random polymerization of the diether oligomers of adipic acid/butanediol and terephthalic acid/butanediol.

Fiber from the kenaf plant has recently gained attention as a biomass-based additive. Kenaf fixes carbon dioxide (CO<sub>2</sub>), and its photosynthesis speed is at least three times higher than that of usual plants.<sup>2</sup> It can absorb 1.4 times its own weight in CO<sub>2</sub>, and its carbon content is about 43%.<sup>3</sup> Kenaf has been used mainly for textiles, paper, and animal food, but composites of kenaf fiber and poly(lactic acid), known as PLA,<sup>1</sup> or composites of kenaf fiber and petroleum-based plastics<sup>4</sup> have been studied recently. Huda *et al.*<sup>5</sup> investigated the effect of modifying the kenaf fiber by alkalization and silane treatment on the mechanical and thermal properties of kenaf-fiber-reinforced PLA laminated composites. They reported that the silane coupling agent improved the compatibility between the kenaf fiber and PLA.

We studied biocomposites of kenaf fiber in an aliphatic-aromatic copolyester resin (Ecoflex F BX 7011), where the fiber was treated with either sodium hydroxide (NaOH) alone or with NaOH followed by a phenyltrimethoxysilane coupling agent. We measured their thermal and mechanical properties, as well as biodegradability. We refer to the aliphatic-aromatic copolyester resin as CP, to the composite with unmodified fibers as CP/kenaf, to the composite with NaOH-treated fibers as CP/NaOH-kenaf, and to the composites where the fibers were first treated with NaOH, followed by silane treatment, as CP/NaOH-silane-kenaf.



**Figure 1.** Scanning electron microscopy images for (a) 90/10 w/w aliphatic-aromatic copolyester resin/kenaf and (b) 90/10 w/w CP/sodium-hydroxide-modified kenaf.

Reinforcing the CP matrix with unmodified kenaf fiber showed poor fiber-matrix interaction as seen by scanning electron microscopy (see Figure 1a). However, adding kenaf fiber stiffened the CP matrix. The

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storage and Young's moduli of the CP/kenaf composite were also higher than that of CP. Including kenaf in the CP/kenaf composite did not significantly change the melting temperature or melting enthalpy of CP, which shows that the crystallization of the polymer was unaffected. The thermal stability of the CP was reduced by the introduction of unmodified fiber. The CP/kenaf showed a higher biodegradability than CP, but the mass loss percentages were very small for all the samples, so statistically there was very little difference between the different samples.

The CP/NaOH-kenaf composite showed much better interfacial adhesion between the matrix and the fibers (see Figure 1b) and better tensile properties than the CP/kenaf composite. It had a higher Young's modulus and larger elongation at break than the CP/kenaf composite. The tensile results are in line with the DMA results where a high modulus was also observed. The improved fiber-matrix adhesion as a result of the fiber treatment with NaOH probably contributed to the increased modulus of the CP/NaOH-kenaf composite. The NaOH treated fibers also did not significantly influence the melting temperature or crystallinity of the CP. The CP/NaOH-kenaf composite showed better thermal stability than the CP/kenaf composite. This was probably because the alkali treatment brought about an increased surface roughness in the fiber, which resulted in better mechanical interlocking between the filler and the matrix. The biodegradability of the CP/NaOH-kenaf was very similar to that of CP/kenaf.

The CP/NaOH-silane-kenaf composites showed improved fiber-matrix interaction due to grafting, which we confirmed through gel content determination. The silane treatment of the CP/NaOH-kenaf composite caused a slight shift in the melting peaks to higher temperatures, but the melting and crystallization enthalpies were too scattered to draw any firm conclusions from the differential scanning calorimetry results. The CP/NaOH-silane-kenaf composites showed lower thermal stabilities than the CP/NaOH-kenaf composite. Silane treatment of the fibers resulted in a reduction of the storage modulus of the composites. The tensile results of the CP/NaOH-silane-kenaf composites also showed a reduced modulus value, but the stress and strain at break were of the same order of magnitude as those of CP/NaOH-kenaf. The biodegradability results did not differ significantly from that of CP/NaOH-kenaf, and statistically there were no real differences between the different samples.

In summary, we observed the best balance of properties for the CP/NaOH-kenaf composite, which showed improved thermal, thermo-mechanical, and mechanical properties. The introduction of alkali treatment caused increased surface roughness in the fiber, which resulted in mechanical interlocking between the filler and the matrix, while silane treatment slightly reduced the properties. We are now working on other kinds of biocomposites based on poly(lactic acid), polycaprolactam and poly(hydroxybuterate-co-valerate), reinforced with sisal nanofibers (whiskers).

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#### References

1. M. S. Huda, L. T. Drzal, A. K. Mohanty, and M. Misra, *Effect of fiber surface-treatments on the properties of laminated biocomposites from poly(lactic acid) (PLA) and kenaf fibers*, **Compos. Sci. Tech.** **68**, pp. 424–432, 2008. doi:10.1016/j.compscitech.2007.06.022
2. M. Itävaara and M. Vikaman, *An overview of methods for biodegradability testing of biopolymers and packaging materials*, **J. Polym. Env.** **4**, pp. 29–36, 1996. doi:10.1007/BF02083880
3. L. Liu, J. Yu, L. Cheng, and X. Yang, *Biodegradability of poly(butylene succinate) (PBS) composite reinforced with jute fibre*, **Polym. Degrad. Stabil.** **94**, pp. 90–94, 2009. doi:10.1016/j.polymdegradstab.2008.10.013
4. W. Liu, A. K. Mohanty, P. Askeland, L. T. Drzal, and M. Misra, *Influence of fibre surface treatment on properties of Indian grass fiber reinforced soy protein based biocomposites*, **Polymer**, pp. 7589–7596, 2004. doi:10.1016/j.polymer.2004.09.009
5. N. E. Marcovich and M. A. Villar, *Thermal and mechanical characterization of linear low-density polyethylene/wood flour composites*, **J. Appl. Polym. Sci.** **90**, pp. 2775–2784, 2003.