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Can bamboo fibres be an alternative to flax fibres as materials for plastic reinforcement? A comparative life cycle study on polypropylene/flax/bamboo laminates

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ABSTRACT

Although flax fibres are largely used to reinforce plastic, the quality of these fibres depends on the cultivation conditions, moreover, the global production volume of these fibres is also limited. The main aim of this current work was to investigate the feasibility of replacing flax fibres with bamboo fibres for reinforcing thermoplastics in terms of mechanical and environmental performance of both fibres. Two types of bamboo fibres, bamboo original fibres (BOF) and bamboo viscose fibres (BVF) and flax fibres as reference were used to reinforce polypropylene (PP). The composites were fabricated into laminates using manual stacking and hot pressing and the mechanical properties (tensile, flexural and impact) of the composites were evaluated. In order to evaluate the environmental performance of these composites life cycle assessment approach was conducted which showed that the composites reinforced with bamboo fibres were eco-friendlier as compared to the composites with flax fibres. However, the flax fibre-reinforced composite showed better mechanical performance. The BOF/PP composites showed better life cycle environmental performance as compared to both flax/PP and BVF/PP composites. Finally, a compatibilizer, i.e., maleic anhydride grafted polypropylene, was added which resulted in better mechanical and environmental performance of the bamboo fibre reinforced composites. Comparison between the environmental impacts of different disposal routes for the composites demonstrated that incineration and recycling are more environmental friendly disposal practises than placing waste in a landfill.

1. Introduction

Due to the high specific stiffness, low cost, renewability, sustainability and eco-efficiency, bio-fibres, or organic fibres, are becoming popular in industrial applications as plastic fillers and/or reinforcements (Faruk et al., 2012; Sam-Brew and Smith, 2015; Pickering et al., 2016). Compared to their inorganic, synthetic counterparts, such as glass fibres, bio-fibres generally exhibit a much lower density (Pickering et al., 2016) with a comparable mechanical performance (Khan et al., 2011; Shah et al., 2013; Delgado-Aguilar et al., 2017) and are thereby more suitable for fabricating lightweight composites. Adopting lightweight composites in industrial applications, such as automobile production, can significantly reduce such applications' life cycle energy consumption and emissions (Li et al., 2016). The energy consumption required for producing bio-fibres is only 20–40% of that for producing most synthetic fibres, and the emissions that occur when bio-fibres are produced are also significantly less than those that occur when synthetic fibres are produced (Dittenber and GangaRao, 2012). Moreover, the manufacturing and handling of bio-fibres poses minor threats and/or hazards to workers (Pickering et al., 2016). In addition, due to their prolonged life durations and bio-degradability, bio-fibres do not negatively impact the environment through over-accumulation of landfill sites as synthetic fibres (Assamoi and Lawryshyn, 2012).

Among the commonly used bio-fibres, flax (*Linum usitatissimum*) has drawn the most attention due to its excellent mechanical properties (Pillin et al., 2011; Pickering et al., 2016). According to Baley and Bourmaud (2014), flax fibres demonstrate specific, reproducible mechanical properties that are similar to those of glass fibres. In both

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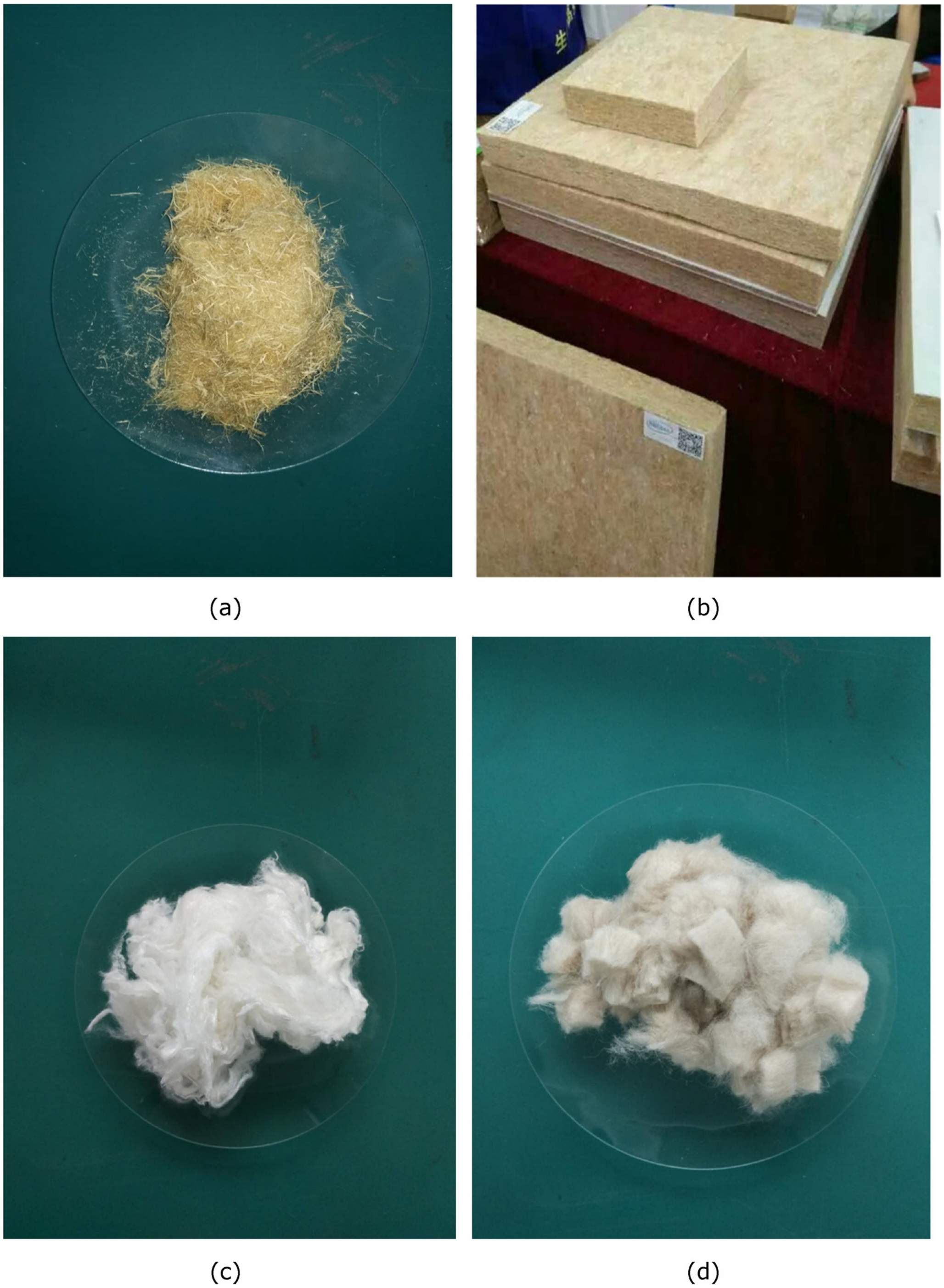

Fig. 1. Photos of the fibres used in this study: (a) the BOF; (b) mats made of the BOF; (c) the BVF; (d) the flax.

tension and bending directions, flax fibre composites exhibit higher specific stiffness than glass fibre composites, and the performance of flax fibre composites is comparable to that of carbon fibre composites (Pil et al., 2016). Due to these properties, flax fibres are promising alternative to glass fibres for reinforcing composites in engineering applications, such as automobile production and construction (Kulma et al., 2015; Sam-Brew and Smith, 2015). Flax fibres are also an excellent candidate for sports and musical applications due to their high vibration damping capacity (Pil et al., 2016). Flax-reinforced composites also show better recyclability (Bensadoun et al., 2016). However, because flax fibres are assembled in bundles (Bourmaud et al., 2013), their mechanical properties are highly anisotropic (Baley et al., 2006) due to plant growth (Gorshkova et al., 2003). The quality of these natural fibres is heavily affected by cultivating parameters, such as seed density, soil, location, climate and harvesting time (Dittenber and GangaRao, 2012). Moreover, flax fibres have a limited cultivating area (Bourmaud et al., 2015); thus, the global production of flax fibres is limited (Faruk et al., 2012) and can barely satisfy the demands of the textile and apparel industries (Kulma et al., 2015).

The main aim of this study was to investigate the feasibility of replacing flax fibres with bamboo fibres by comparing the mechanical and environmental properties of the composites prepared by reinforcing by these fibres. Widely cultivated in the Asia-Pacific region (Bystriakova et al., 2003), bamboo has an abundant global production of 30,000 kt each year. While, the annual global production of flax is only 830 kt (Faruk et al., 2012). The strength and stiffness of bamboo