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Effects of diammonium phosphate on the flammability and mechanical properties of bio-composites

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ABSTRACT

The flammability, thermal stability and mechanical properties of natural fiber-reinforced thermoplastic bio-composites were measured using a horizontal burning test, thermogravimetric analyzer, and universal testing machine, respectively. The composites were fabricated from film resins (Polylactic-acid, PLA and Polypropylene, PP) and natural fibers (coconut filter and jute fiber) by a hot press machine. To improve the flame retardancy of the bio-composites, various diammonium phosphates (DAP) were treated into the fibers. In general, the results indicate that increasing the percentage of DAP used to treat the fibers effectively improves the flame resistant, weight loss rate, and flexural modulus but decreases the flexural and tensile strengths of the bio-composites. Bio-composites with DAP-treated fibers showed a greater flexural modulus than those with untreated fibers, and the flexural modulus was even greater than that of neat polymers (PLA and PP). Also, increasing the percentage of DAP for treatment of the fibers in the composites decreases the temperature required for 5% weight loss and the decomposition rate, but increases the char residual at 500 °C. The best linear burning rate and weight loss rate were observed for fiber treatment with 5% DAP. The compressive and wear properties of these bio-composites were also studied.

1. Introduction

Synthetic composites that are made from non-degradable polymer and synthetic fiber have an environmental impact on the earth in terms of plastic wastes, carbon dioxide emission when they are burned, and toxic gases that are sometimes released, which contribute to climate change and pollution [1]. Synthetic polymers are made of petroleum-based polymers, for which whereas petroleum resources are finite and require hundreds or thousands of years to be renewed [1,2]. In contrast, natural plastics are made from agricultural products. Natural fibers are also agricultural products and are materially abundant. Both are environmentally friendly, inexpensive and renewable materials. Composites based on synthetic polymers filled with natural fibers (lignocellulosic) are called bio-composites, but are not fully biodegradable. Composites based on natural polymers filled with natural fibers (lignocellulosic) are also called bio-composites, but are fully biodegradable [3]. Bio-composites are developing in many fields to replace synthetic composites for the purpose of reducing the environmental impact.

Many studies performed in the field of bio-composites focus on elucidating the mechanical properties, but increasingly consider the fire behavior of materials in the design of components or structures. The use of composite materials in automotive, ship, aircraft, building interior, and insulation panels, is becoming increasingly important [4], as is attention to flammability. In fact, 80–90% of composites are used in aircraft and helicopters interior because of weight gains [4,5].

A number of flame retardants (FRs) for polymers and composites have been developed, and many of these are suitable for use in fiber composites [5]. Chemicals such as diammonium phosphate (DAP) [6,7], ammonium polyphosphate (APP) [8,9], ammonium polyphosphate with expandable graphite [10,11], boric acid with magnesium hydroxide [12], aluminium trihydroxide, and melamine cyanurate [8] are added to the molecular structure of thermoset resins or thermoplastics to improve the flame resistance of composites [5].

The flame resistance of polymers or natural fiber polymer composites can be improved by the addition of FRs. The most common method for adding FRs is blending flame retardant filler compounds into a polymer or polymer composite during processing [5]. There are other methods for improving flame resistance of composites, including fire retardant coating of the composites at the finishing stage and impregnation or modification of lignocellulosic particles or fibers with FRs before the manufacturing process [13,14].

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