Composites: Part B 43 (2012) 2230–2236

Contents lists available at SciVerse ScienceDirect

Composites: Part B

journal homepage: www.elsevier.com/locate/compositesb

Morphological and mechanical properties of carbonized waste maize stalk as reinforcement for eco-composites

S.B. Hassan, J.E. Oghenevweta *, V.S. Aigbodion

Department of Metallurgical and Materials Engineering, Ahmadu Bello University, Zaria, Nigeria

ARTICLE INFO

Article history:
Received 19 September 2011
Received in revised form 4 January 2012
Accepted 1 February 2012
Available online 10 February 2012

Keywords:
A. Polymer matrix composites
B. Mechanical properties
B. Microstructure
C. Mechanical testing
Electron microscope

ABSTRACT

The morphology and the mechanical properties of carbonized waste maize stalk reinforce polyester composites with the aim of producing an eco-friendly composite material showing enhanced properties for engineering applications has been investigated. Carbonized maize stalk ash particles (MSAps) were added in different weight fractions into a polyester matrix at 5%, 10%, 15% and 20% respectively. Composites samples were produced from these mixtures and the effect of the carbonized maize stalk ash content on the mechanical properties of the composites was investigated and analyzed. Results from the scanning electron microscope (SEM) of the composites show a good and gradual interfacial bonding as the MSAp content increases while the Energy Dispersive spectrometer (EDS) and X-ray diffraction (XRD) show the various compounds/elements present in the reinforcement. The tensile strength, tensile modulus and compressive strength value increases as the carbonized maize stalk ash content increases but there is a gradual decrease for the impact strength. These results showed that the carbonized maize stalk ash can be used to improve the strength of polymer matrix composites for use in automobile and building applications.

1. Introduction

Development of polymer composites using agro-wastes or lignocellulosic materials as reinforcements for eco-friendly composites is currently the focus of attention. Rice husk is one of such major agro-waste products and natural reinforcement, which contain cellulose, hemicellulose, lignin and ash. This natural reinforcement has been utilized in the manufacture of composite panels. Use of other agricultural residues such as corn cob fibers, flax straw fibers, wheat fibers and bagasse as reinforcement in the production of plastic composites has alleviated the shortage of wood resources. These low cost lignocellulosic sources (agro-fibers) when combined with polymer matrices decrease overall manufacturing costs and increase stiffness of the composite materials [1].

Many researchers have investigated on the use of rice husk and rice husk ash as reinforcement in thermoplastic composites. The use of rice husk and rice husk ash as reinforcement in polypropylene composites and influence of coupling agents on their mechanical properties has been studied. They found that the flexural modulus and tensile modulus increased with reinforcement content while elongation at break and Izod impact strength showed a minimal decrease [2].

The microstructure, thermal and mechanical properties of flax and wheat straw as reinforcing additives in thermoplastics has been carried out. In their study, addition of flax and wheat straw caused a significant increase in tensile modulus, particularly, in the case of flax fibers, which also gave higher tensile yield strength and Charpy toughness [3].

The effect of rice husk content in polypropylene matrix has been studied. In terms of mechanical properties, Young's modulus and flexural modulus increased, whereas yield strength and elongation at break decreased with increase in reinforcement content [4]. The study of the mechanical and physical properties of polyurethane composites produced with rice husk and polyethylene glycol has been carried out. It was found that flexural, impact and tensile properties increased as the percentage of rice husk or rice husk hydroxyl groups was increased. Smaller size of rice husk was found to produce composites with higher strength. They also reported that water absorption and thickness of swelling increased with increasing percentage of rice husk [5].

It was also reported that improved mechanical properties and water resistance of wheat straw–soy flour particleboard composites can be obtained [6]. The utilization of lignocellulosic fraction from wheat straw as natural reinforcement in composites with polyolefin (a copolymer of polyethylene and polypropylene) and biodegradable polyester [poly(butylene adipate-co-terephthalate)] has been carried out. They reported good mechanical properties of the composites [7].

* Corresponding author. Tel.: +234 805159193.
E-mail addresses: hassbolaji@yahoo.com (S.B. Hassan), jojolinto@yahoo.com (J.E. Oghenevweta), aigbodionv@yahoo.com (V.S. Aigbodion).

1359-8368/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.compositesb.2012.02.003

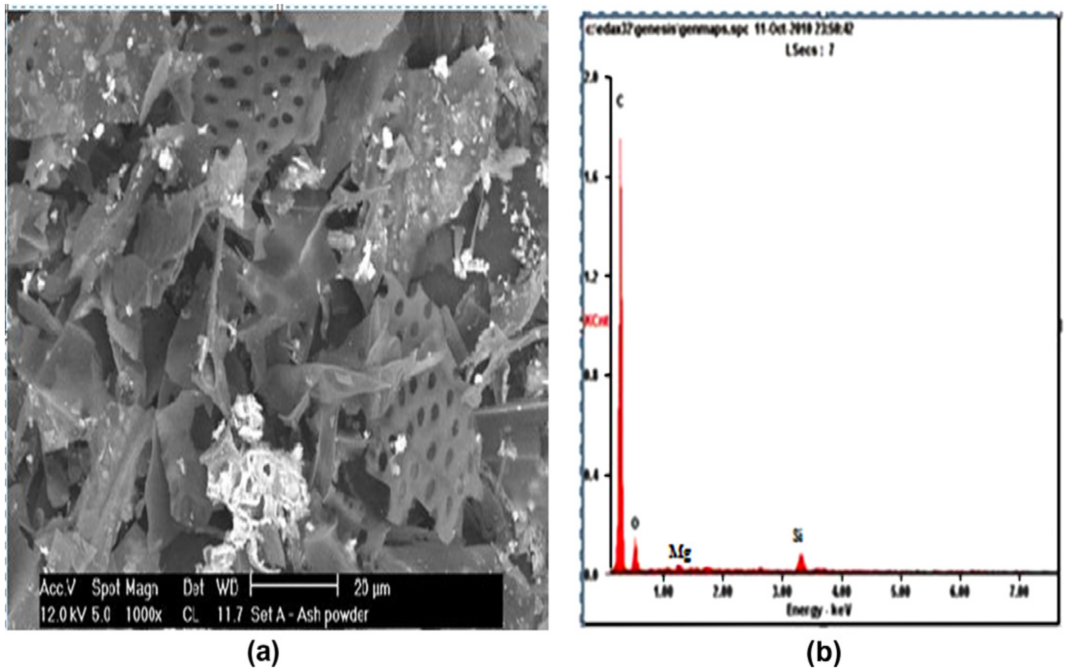

Plate 1. (a) SEM microstructure of the carbonized maize stalk ash particles (1000×) and (b) EDS of the carbonized maize stalk ash particles.

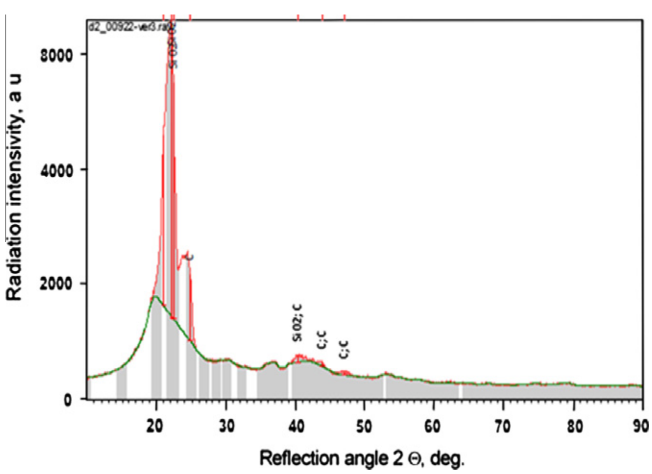

Plate 2. X-ray diffraction (XRD) pattern of MSAp.

Maize stalk is commonly found in abundance and readily available in large quantity as waste after harvesting and other processing operations. They are non-toxic, environmentally friendly, fully biodegradable, abundantly available, and renewable and are quite cheap. Therefore, reinforcing polymer with maize stalk ash will have tremendous impact on the environment since polyester/maize stalk ash particulate composites will be partially biodegradable since the maize stalk ash is fully biodegradable.

The aim of this study is to investigate the microstructure and mechanical properties of carbonized maize stalk ash particles reinforced polyester composites in order to develop an engineering material for novel configurations in automotive industries such as car bumper and in the building sectors such as house tiles.

2. Materials

The maize stalk that was used was obtained from a harvested agricultural farm in Samaru, Zaria-Kaduna State, Nigeria. The base polyester resin, accelerator (Cobalt Octoate) and catalyst (Methyl Ethyl Ketone Peroxide (MEKP)) was obtained from Steve Moore Chemicals, Zaria-Kaduna State, Nigeria.

3. Methods

The collected maize stalk tegument was dried in the sun and ground to a fine powder using electrical milling machine. The fine powder was carbonized at a temperature of 1200 °C in an electric resistance furnace in order to form the maize stalk ash.

The maize stalk ash was then sieved unto a set of sieves arranged in descending order of fineness and particle size analysis was carried out in accordance with BS 1377:1990. A particle size of 53 μm was selected and used.

In producing the reinforced polyester composites, the unsaturated polyester was measured into a 400 ml beaker and heated to 150 °C and the maize stalk ash was added and then stirs until even dispersion was achieved. Addition of 1% weight of catalyst was made and stirred for 3 min, after which 2% weight of accelerator was added and stirred for another 3 min before casting the sample into a mold. The mold was cleaned with acetone and coated with polyvinyl alcohol (PVA) and allowed to dry before the sample were cast. This procedure was repeated for all samples produced with changes in the percentage of the maize stalk ash particles.

The microstructures of the maize stalk ash particles, polyester resin matrix and the composites developed were carried out using SEM and EDAX equipment, model Leica Cambridge S-360. The impact strengths of the composite developed (120 × 10 × 4 mm sample) were determined using Charpy impact tester (Changteh China, Model JC-25 4 J). The tensile strengths and tensile modulus of the polyester/maize stalk ash particulate developed specimen with dimension 60 × 6 × 3 mm were determined using the Instron machine (model 5564) with cross-head speed of 5 mm/min, at room temperature, according to ASTM D 638-90.

4. Results and discussion

The results of test conducted on the control and the developed composites are presented as follows: The simultaneous SEM