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Utilization of chemically treated municipal solid waste (spent coffee bean powder) as reinforcement in cellulose matrix for packaging applications

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ABSTRACT

As the annual production of the solid waste generable in the form of spent coffee bean powder (SCBP) is over 6 million tons, its utilization in the generation of green energy, waste water treatment and as a filler in biocomposites is desirable. The objective of this article is to analyze the possibilities to valorize coffee bean powder as a filler in cellulose matrix. Cellulose matrix was dissolved in the relatively safer aqueous solution mixture (8% LiOH and 15% Urea) precooled to −12.5 °C. To the cellulose solution (SCBP) was added in 5–25 wt% and the composite films were prepared by regeneration method using ethyl alcohol as a coagulant. Some SCBP was treated with aq. 5% NaOH and the composite films were also prepared using alkali treated SCBP as a filler. The films of composites were uniform with brown in color. The cellulose/SCBP films without and with alkali treated SCBP were characterized by FTIR, XRD, optical and polarized optical microscopy, thermogravimetric analysis (TGA) and tensile tests. The maximum tensile strength of the composite films with alkali treated SCBP varied between (106–149 MPa) and increased with SCBP content when compared to the composites with untreated SCBP. The thermal stability of the composite was higher at elevated temperatures when alkali treated SCBP was used. Based on the improved tensile properties and photo resistivity, the cellulose/SCBP composite films with alkali treated SCBP may be considered for packaging and wrapping of flowers and vegetables.

1. Introduction

Nowadays much debate is going on in two opposite directions regarding the development of plastic-based materials. One is utilizing the technological advancement towards increasing plastic production and the other is about to minimize the usage of plastics in industrial applications. Nevertheless, many of the established countries around the world are emphasizing more in developing recyclable products wherever it is possible as non-recyclable systems attribute to the problems like energy consumption, global warming, landfilling and more importantly harmful to animals and human safety. Hence, it requires the primary mandate to develop new green products wherever it is feasible. Accordingly, many of the industrial sectors such as automobile, food packaging, construction and even biomedical industries are turning their attention towards the implementation of environmentally friendly products. Further, discarding the used plastics is inevitable and the piled up waste causes many environmental problems, such as growth of bacteria and flies, bad odor, hindered growth of flora and fauna. At the same time, recycling process is expensive and time-consuming (Scott, 1999). Hence, it is mandatory to develop environmentally friendly systems wherever possible instead of increasing the production of non-degradable plastics.

By considering these aspects, many of the international researchers are using various bio-degradable matrix systems (Briassoulis, 2004a, 2004b; Chiellini et al., 2001; Doran, 2002). Generally, bio-resins are developed using plant proteins from soy, corn, cotton seed and wheat and studies have been carried out by making these as films and plastics (Song et al., 2008; Sun et al., 2007; Gennadios and Weller, 1990). More recently, Paul

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et al. (2013) have developed and characterized a novel bio-resin made from banana sap for low-end applications such as the interior components of motor vehicles. In the last decade, the work on completely biodegradable composite films was initiated (Tocchetto et al., 2002; Briassoulis, 2004a, 2004b; Scarascia-Mugnozza et al., 2004, 2006). Jagadeesh et al. (2011) formulated novel bio-based green films from wheat-derived proteins by a solution-casting method using propylene glycol (PG) as a plasticizer, targeted for packaging applications. However, there still is a need to develop new systems with improved properties. In this direction, recently, some systems like cellulose/turmeric powder (Li et al., 2014), polylactic acid/egg shell powder (ESP) (Ashok et al., 2014), polypropylene carbonate (PPC)/ESP (Feng et al., 2014), PPC/spent tea leaf powder (STLP) (Xia et al., 2015), cellulose/Thespesia lampas (Ashok et al., 2015) and cellulose/STLP (Duan et al., 2016) were developed.

Even though several works have prepared many biodegradable films using different fillers as reinforcement, still, there is a scope to identify some waste solid materials which can be used in biodegradable matrices. One such kind of largest day-to-day commodity is spent coffee bean powder. Due to the enormous usage of this merchandise, huge amounts of residues are generated in the coffee industry, which can cause severe environmental problems if left unutilized. Efforts have been made to utilize this solid waste for some useful purposes such as a source of green energy (Kondamudi et al., 2008), waste water treatment (Tokimoto et al., 2005) etc. Eventually, the solid waste like SCBP will have lot of scope to utilize properly in order to avoid the situation of landfilling. As SCBP has considerable amount of amorphous hemicellulose component present on the surface of the microfibrils, it offers weak interfacial bonding between the matrix and the filler. So in order to make the surface of the SCBP particles rough, alkali treatment was carried out. Hence, in this work, both untreated and alkali treated SCBP with particle size 35–40 μm were used as fillers in cellulose matrix. The biocomposites developed were characterized to study their suitability for packaging and wrapping purposes.

2. Materials and methods

2.1. Materials

Cotton linter pulp with a degree of 620 was obtained from Hubei Chemical Fiber Company Limited, Xiangfan, China. LiOH and urea were supplied by S.D. Chemicals, Mumbai, India. Ethyl alcohol manufactured by Jebsen & Jessen Company, Germany was obtained from local market. Coffee bean powder (Brooke Bond India Ltd.) was purchased from the local market. After brewing for three times, the spent coffee bean powder (SCBP) was washed thoroughly with distilled water and dried to constant weight. The dry SCBP was ground to a fine powder in a kitchen mixer and sieved. The SCBP with a particle size 35–40 μm was used as the filler.

2.2. Dissolution of cellulose

To make cellulose solution, the environmentally friendly procedure described elsewhere (Jayaramudu et al., 2013a, 2013b) was used. In brief, an aqueous solution of 8 wt% LiOH and 15 wt% Urea was prepared and cooled to −12.5 °C. To this super cooled solution, 4 wt% of cotton linter pulp was added and stirred at high speed at room temperature. A clear solution of cellulose was obtained within two minutes. This solution was centrifuged at a speed of 7200 rpm and temperature of 5 °C for 15 min to remove any insoluble cellulose and possible impurities if any. The solution was stored at 5 °C until it was used.

2.3. Preparation of cellulose/SCBP composite films

The SCBP was dried at 80 °C for 24 h prior to use. To cellulose solutions, dry SCBP was added in 5 wt% to 25 wt% by the weight of cellulose and stirred for uniform dispersion of the filler. The solutions were degassed at 5 °C. The degassed cellulose and cellulose/SCBP solutions were spread on clean glass plates using a

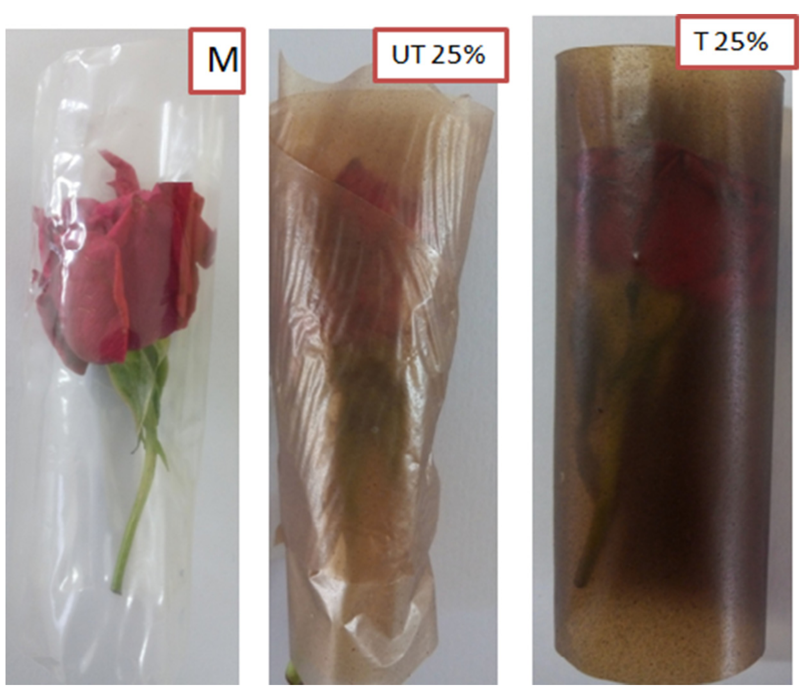

Fig. 1. Photographs of flower wrapped with matrix (M), cellulose/25 wt% untreated SCBP (untreated 25%) and cellulose/25 wt% alkali treated SCBP composite films.

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