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Evaluation of corn husk fibers reinforced recycled low density polyethylene composites

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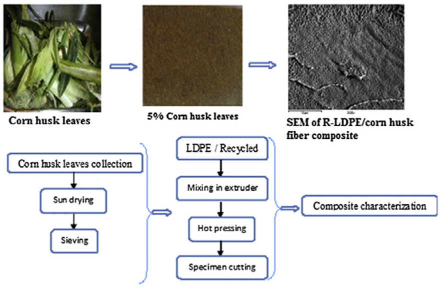
HIGHLIGHTS

- New composite based on recycled LDPE and corn husk fibers has been prepared.
- The prepared composite has a benefit of minimizing solid waste problem.
- The prepared composites were characterized using XRD, FTIR and DSC.
- Crystallization behaviors, mechanical and swilling properties of the prepared composites were investigated.

GRAPHICAL ABSTRACT



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ABSTRACT

Responding to the community demand for disposal of environmental problematic agricultural and polymer waste, composite sheets using recycled low-density polyethylene (R-LDPE) and corn husk fibers were prepared by melt compounding and compression molding. These composites were prepared in different concentrations (5, 10, 15, and 20%) of powder corn husk with 125 μ particle size based on R-LDPE matrix. Beside the importance of property improvement, an additional incentive was responding to the social demand for the disposal of environmental problematic agricultural waste. The influence of loading rate on R-LDPE crystallization behavior, mechanical, and swilling properties were investigated. Increasing in fiber loading led to increased moduli and tensile strength while hardness was decreased. X-ray diffraction (XRD) examinations indicated that introducing fiber to R-LDPE matrix did not change characteristic peak position. The thermal stability of the prepared composites was evaluated using differential scanning calorimetry (DSC) which displayed that the R-LDPE had significantly larger peak heat flow during cooling run than the blank R-LDPE, indicating higher crystallization rates for R-LDPE. The prepared composites materials can be used in packaging applications.

1. Introduction

With growing production and consumption, plastics worldwide is currently resulting in a significant contribution to the municipal solid waste. Recycling of the waste plastics has benefits of minimizing solid waste disposal problem, reducing the virgin plastics consumption and lowering the production costs [1]. In wood plastic composite virgin plastics such as high and low density polyethylene, polypropylene and poly vinyl chloride are commonly used. In a similar way as for the virgin plastics and wood any recycled plastics that can melt and be processed under below the degradation point of the cellulosic waste can be used in manufacturing composites. Low Density Polyethylene (LDPE) was originally prepared some fifty years ago by the high pressure

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polymerization of ethylene. Its comparatively low density arises from the presence of a small amount of branching in the chain (on about 2% of the carbon atoms). This gives a more open structure. LDPE is defined by a density range of 0.910–0.940 g/cm^3 and a specific gravity of 0.92 [2]. Recently, due to their excellent properties the linear LDPE has become a very popular type of polyolefin. In scientific literature, one can find data about linear LDPE and natural fiber containing composites [3].

A pressing issue in developing countries today, is the recycling of waste products and other agricultural by-products suitable for the invention and characterization of new materials [4,5]. In addition, an increased awareness that non-renewable resources are becoming scarce and our inevitable dependence on renewable resources has arisen. This century could be called the cellulosic century, because more and more renewable plant resources for products are being discovered [6]. In order to reduce ecological problems arising from the use of non-biodegradable products such as plastics, novel alternatives have been invented. As example, one can cite green composite materials [7–13] such as fiber-reinforced composites which are a hybrid material composed of natural and synthetic polymer. Once the materials are mixed together to achieve a relatively thick consistency, they are extruded or molded. These composites are environmentally friendly innovative materials, and their application is defined by a low cost and density [14,15]. Moreover, they are unlimited sources with the ability to reproduce quickly. Technological properties of these composites allow processing materials with traditional polymer processing methods. Recently the utilization of fillers (bio-fibers or powders) derived from agricultural sources such as banana, sisal, hemp, jute, pineapple, rubber wood powder, waste rubber particles, palm oil fruit bunch, bamboo, bagasse, wood chips flax, and rice husk (RH) has become a subject of interest in polymer composites and has become a strong competitor to inorganic fillers [16–19]. This is mainly due to their low densities, very low cost, non-abrasiveness, high filling levels, recyclability, biodegradability, and renewable nature [20].

Natural fibers have gained a lot of interests as reinforcement for the production of composite materials due to their attractive features of abundance, low cost, lightweight, renewability, and biodegradability. These qualities make them superior to glass fiber. Natural fibers are claimed to be capable of being part of everything from cars to golf clubs [21]. The natural fibers used to reinforce thermoplastics mainly include wood, cotton, flax, hemp, jute, sisal, and sugarcane fibers [22–25].

A Large number of publications and patents in recent years have been devoted to investigate the benefits of using annual plants or/and agricultural wastes in cellulosic derivatives, paper-making, fiber reinforced composite materials, packaging, low-cost housing and structures and the use of agricultural crop residues could boost rural agriculture based economy [26–32]. Since they are waste, the utilization of natural fibers as reinforcement for polymer composite is considered as available eco-reusing technique. The higher strength and aspect ratio of natural fibers offers good reinforcing potential in composite matrix compared to the artificial fibers [33]. Environmentally friendly alternatives to the wood plastic composites include products that use polyethylene resins, which can help reduce or eliminate the formaldehyde that otherwise would be emitted into the air. With the current high interest in recycling, Researchers decided to make composites using a post-consumer plastic granulated LDPE [34]. Additives can also be added to improve the quality of the composites by eliminating the off-putting properties. The thermoplastics which are used as matrix for fiber reinforced composites are high density polyethylene (HDPE) [35], low density polyethylene (LDPE) [36], chlorinated (CPE) polyethylene, polypropylene (PP) [37], normal polystyrene (PS) [38], impact-modified PS [39], polyaniline [40], and polyvinylchloride (PVC) [41].

The objective of this study is to investigate the suitability of using corn husk fibers in recycled low density polyethylene (R-LDPE) board manufacturing without any treatment for both R-LDPE as well as corn husk fibers and to investigate the influence of fiber components on mechanical, thermal, water absorption, and crystalline properties of the reinforced R-LDPE composites. Besides the importance of property improvement, an additional incentive was responding to the social demands for the disposal of environmentally problematic agricultural waste (Scheme 1).

2. Experimental

2.1. Materials

Corn husk fibers (surrounding the ear of corn/maize) were obtained from a local farmer market in El-Menoufyia Province, Egypt. The corn husk was dried, grounded and sieved to be in part size (125 μ). The Chemical constituents of corn husk fibers were found to be (cellulose 43%, hemi-cellulose 31%, lignin 22%, and ash 1.9%). Recycled LDPE (Indothene 16 MA 400), used as a polymeric matrix, was procured from M/s Indian Petrochemical Corp., Ltd. (Baroda, India), and it had a melt index of 2 g/10 min and a density of 0.92 g/cm^3.

2.2. Methods

2.2.1. Compounding and compression molding

Prior to blending, all fibers were dried to 1–2% moisture content at 80 °C. R-LDPE was first added to the mixer at 160 °C for 10 min. The blending was made at 165 °C with a rotor speed of 60 rpm (Haake RheomexTW100, twin screw extruder with intermeshing screws, USA). Each blend was removed from mixing chamber, cooled, and cut into small pieces suitable for feeding four-piece stainless steel compression molds to make 3–4 mm thick test sample plates. After the thermoplastic matrix melted, the fiber powders were added and the mixing maintained for additional 10 min. Compression molding was done using compression molding at 175 °C and 5 MPa for 5 min. Each sample was then cooled to room temperature under the pressure before being removed from the press (Scheme 2).

2.2.2. Composite property testing

Three replicates were tested for each property under each formulation.

Thickness was measured using a dial micrometer.

2.2.2.1. Swelling. For water absorption a small sample of composite was immersed in water at room temperature for different times. After that, the sample was dried between two sheets of filter paper and then the weights as well as the dimension of the samples were measured. The percentage weight gain (PWG) was calculated as:

$$\mathrm{PWG}\left(\%\right) = \left(W_f - W_o\right)\Big/W_o \times 100$$

Where W_o is the weight of the sample before the impregnation and W_f is the weight of the sample after the impregnation.

The percentage of swellability was calculated as:

$$\mathrm{Swellability}\ (\%) = (x - y)/y \times 100$$

Where x is the volume of the sample after the impregnation and y is the volume of the sample before the impregnation.