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Sustainable Use of Recycled Polymer and Biomass Materials in the Preparation of Composites for Possible Applications

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ABSTRACT

In the study, cost-effective and environment-friendly composites were prepared from recycled polymer i.e., waste expanded polystyrene (EPS) and biomass (rice husk) by using compression moulding method. The impact of process variables such as raw material loading, compression moulding pressure, and polymer quantity on physico-mechanical properties of the composites was investigated. The physico-mechanical properties of the in-house prepared composites, such as, tensile strength, tensile modulus, %elongation, flexural strength, compressive strength and water absorption were estimated as per the standard procedures. According to the findings, recycled EPS and biomass offer a lot of potential for making cost-effective and environment-friendly composites. According to the findings, the physico-mechanical characteristics of the composites improved when raw material quantity, compression moulding pressure, and EPS loading increased. Water absorption of the composites reduced as compression moulding pressure and polymer loading increased. The obtained tensile strength values of the in-house prepared composites were in the range of 4-18 MPa, whereas the flexural strength values were in the range of 10-33 MPa. The obtained water absorption values ranged from 4-12 wt.%. The prepared composites can be used in various possible applications.

KEYWORDS: Sustainability; Recycled polymer; Rice husk; Composites; Properties.

1. INTRODUCTION

Polymers / plastics are well-known for being high-molecular-weight materials made from simple molecules known as monomers. Currently, a wide range of polymers are produced commercially for a number of purposes around the world; and a wide range of polymer products are employed in our daily lives for a wide range of purposes [1-3]. Plastic materials are preferred because of their superior properties such as physico-chemical and biological inertness, low density, durability, and low cost, which have made their processing / production efficient and effective, despite their disadvantages such as environmental pollution, toxic material accumulation, non-renewable nature, and difficulty in degradation, which arise in their release into the environment [4].

Sustainable management has become the focus of research around the world in recent years. It entails, among other things, the development of environment-friendly processes and products. The goal of this study is to produce an environment-friendly and cost-effective composite material from recycled plastic (waste expanded polystyrene) and biomass (rice husk) for potential uses. Reusing / recycling of waste materials will reduce pollution caused by their disposal, resulting in a cleaner and greener environment, as well as provide value-added products for a variety of applications (sustainable management perspective).

The commercial name for expanded polystyrene (EPS), which is made up of pre-expanded polystyrene beads, is thermocol. EPS has a wide range of applications due to its good attributes such as lightweight, rigidity, and formability properties, such as manufacturing plates, trays, boxes, bowls, insulation, packing materials, building walls and roofing, and so on [5]. The global production of EPS is estimated to be beyond 15 million metric tonnes (MMT) per year, and majority of it ending up in landfills. EPS is classified as a substantial solid waste because of its widespread use and low recycling rate [6]. Since 2008, polystyrene has contributed roughly 10% of the total plastic garbage produced annually [7]. The recycling of synthetic polymers has received more attention in recent years. Due to a lack of safe disposal facilities, especially in developing countries, the problem of plastic waste cannot be solved by landfilling. Plastic trash incineration adds to hazardous and greenhouse gas emissions, which promote climate change and produce carcinogens [8].

From the literature, it is found that, waste EPS can be recycled to prepare value added chemicals and fuels [7, 9-16], building materials [17-22], value added and economical light weight composites [23-27], carbonaceous materials [28-30], and adhesive materials [31-35] for a sustainable environment.

Wood-plastic composites (WPC) have been extended into a variety of applications in recent years, including interior décor, door and window manufacturing, flooring, and vehicle interior design. Natural fibers and thermoplastics such as polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), and polylactic acid (PLA) can be used to make WPC materials [26]. Particle boards are typically made from bonded wood particles and synthetic adhesives or binders. Binders including urea formaldehyde (UF), melamine formaldehyde (MUF), phenol formaldehyde (PF), isocyanides, and others are commonly used to bind wood particles. In general, binder costs account for roughly 30% of the total cost of manufacturing a particleboard [23]. The fabrication of composite materials using synthetic resin derived from municipal and industrial solid wastes can be a cost-effective procedure. Few research groups have looked at the use of discarded EPS to make wood-plastic composites.

According to the literature, recycled EPS has the potential to be used in the production of light weight wood-plastic composites for a variety of applications. To the best of our knowledge, specific studies relevant to the synthesis of wood-plastic composites from recycled EPS and biomass are scarce, based on the literature. In addition, to the best of our knowledge, the preparation of wood-plastic composites from recycled EPS and rice husk biomass is not reported in the literature. Therefore, preparation of composites from recycled EPS and rice husk, as well as characterization of the obtained composites, are the goals of this work. Rice husk, which is considered as abundantly available agricultural waste, and is comes out from rice mills around the world. More items / products will be provided to our society, and environmental pollution will be considerably decreased, if this agricultural waste product can be appropriately converted into valuable products [36].

2. MATERIALS AND METHODS

2.1 Materials

Recycled EPS was obtained from the scrap yard at the B V Raju Institute of Technology (BVRIT), Narsapur campus; and the biomass (rice husk) was collected from a neighbouring rice mill to the preparation of the wood-plastic composites.

2.2 Preparedness of recycled EPS and rice husk materials

Prior to the preparation of composites, the recycled EPS was cleaned and cut into small pieces (≅ 10 cm ×10 cm). The EPS material was then dried in the sun for two days to remove the moisture; and stored in sealed bags. The degassing (volume reduction) of EPS material was done using dissolution method at room temperature. In the dissolution method, the EPS was dissolved in a solvent till saturation stage in a container using a mechanical stirrer. Then the wet material was dried in hot air oven to remove solvent; and then the dried material was crushed into required size using pulveriser. The crushed material was stored in air-tight covers. The collected biomass (rice husk) was cleaned and dried in a hot air oven to remove moisture. The dried rice husk was crushed using domestic mixer grinder and sieved for its particle size distribution. Various fractions of the rice husk materials were stored separately in air-tight covers.

2.3 Experimental Procedure and analytical methods

In the study, the prepared EPS and rice husk materials were used to make the wood-plastic composites. The experimental procedure which was mentioned in our previous work [37] was followed in the present study to prepare the composites. The prepared composite was used to estimate various physico-mechanical properties such as tensile strength, tensile modulus, %elongation, flexural strength, compression strength and water absorption etc. The analytical methods which were mentioned in our previous work [37] were followed in the present study.

3. RESULTS AND DISCUSSIONS

In the study, the EPS-Rice husk composites were prepared using recycled EPS and rice husk. The effect of various parameters such as EPS-Rice husk mixer quantity, compression moulding pressure and EPS quantity on the properties of the composites was studied. In the study, EPS-Rice husk mixture quantity was varied from 140-200 grs, compression pressure was varied from 25-100 kg/cm^2 and the EPS loading was varied from 20-70% by weight.

3.1 Effect of EPS-Rice husk mixture quantity on the properties of the composite products

Various amounts of EPS-Rice husk mixture were used to investigate the effect of EPS-Rice husk mixture quantity on the physico-mechanical properties of composites. The experiments were conducted with 50 wt.% EPS and 50 wt.% rice husk with a fixed compression pressure of 50 kg/cm^2. The composite properties that were determined are shown in Figure 1. As per the findings, the composite sheet thickness grew as the material quantity increased. Under identical testing settings, an improved tendency for mechanical characteristics is found as the material quantity raised up to nearly 170 grs. Around 1.52 fold increase in tensile strength, 1.44 fold increase in tensile modulus, and 1.21 fold increase in flexural strength are observed for the composites up to 170 grs. When the material quantity raised further from 170-200 grs, however, a negative trend in composite characteristics is noticed. Poor material packing in the composite due to insufficient compression pressure is a likely cause of negative composite qualities, which is also supported by thickness data.

3.2 Effect of compression moulding pressure on the properties of the composite products

To study the effect of compression moulding pressure on the physico-mechanical properties of the composites, the experiments were carried out at four different compression pressures under identical experimental conditions. To prepare the composite, the EPS and rice husk materials were mixed at 50:50 wt.%, and 155 grs of EPS-Rice husk mixture was taken. The estimated properties of the composites are shown in Figure 2. From the obtained data, it can be said that as the compression pressure increased, the thickness of the composite sheet decreased due to close packing of material. The composite properties improved dramatically with the increase in compression pressure up to 75 kg/cm^2. However, the improvement in product properties is insignificant when the compression pressure increased further from 75-100 kg/cm^2. Further it is noticed from the data that around 1.36 times and 1.79 times increment is observed in tensile strength and tensile modulus respectively of the composite with the increase of pressure from 25-100 kg/cm^2. It is furthermore observed that the increment in

%elongation and flexural strength are around 2.01 times and 1.44 times respectively with the increase of pressure from 25-100 kg/cm². From the results, it can be concluded that compression pressure plays an important role to enhance the composite properties.

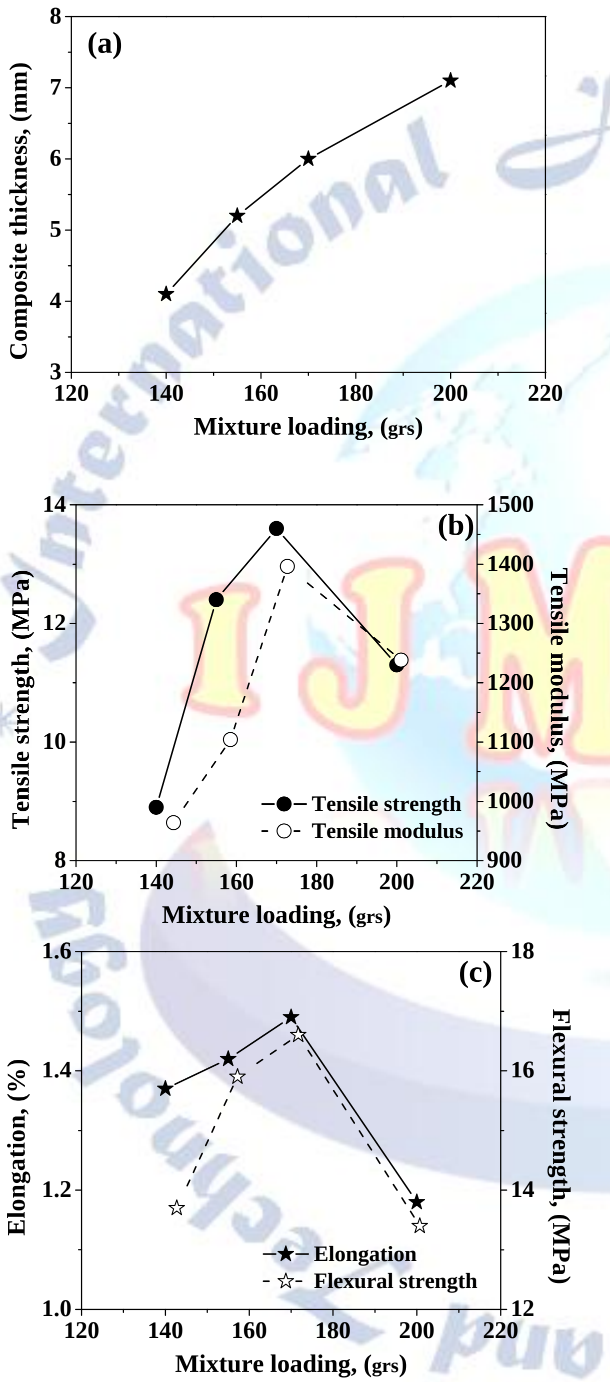

Figure 1. Effect of EPS-Rice husk mixture loading on the composite properties

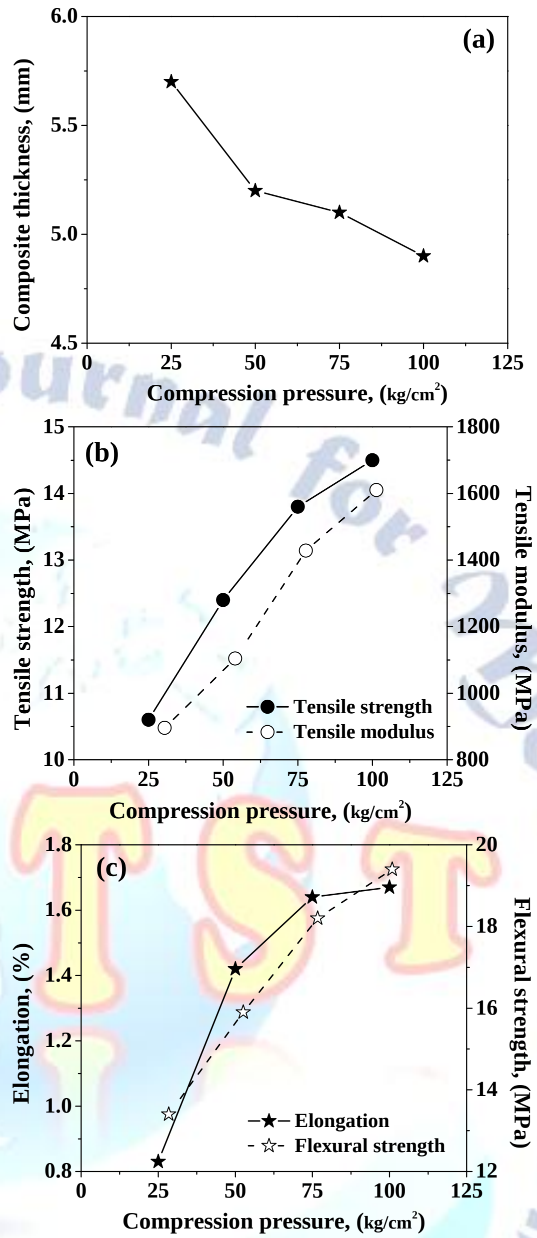

Figure 2. Impact of compression pressure on the composite properties

3.3 Influence of recycled EPS quantity on the properties of the composite products

In the work, to investigate the impact of EPS quantity on the composite properties, the EPS loading was varied from 20-70 wt.% by taking around 155 grs of EPS-Rice husk mixture at a compression pressure of 75 kg/cm². The impact of EPS loading on composite properties are shown in Figure 3. According to the data, it is observed that the characteristics of the composites improved as the amount of EPS rose. Around 4.56 fold increase in tensile strength and 2.72 fold increase in %elongation is obtained with the increase of EPS quantity from 40-70 wt.%. It is also noticed that around 3.92 fold improvement in tensile modulus, 3.22 fold improvement in flexural, and 2.65 fold increase in compression strengths are obtained with the increase of EPS quantity under present experimental conditions. A decreased trend is observed for water absorption with the increase of EPS quantity. The analysis was not performed to the prepared composites at 20 and 30 wt.% of EPS loading as the composite sheets were broken during the ejection from the cavity of compression moulding machine due to poor binding (packing) of EPS and rice husk. The in-house prepared composite using EPS and rice husk are shown in Figure 4. From the composite sheet image, it can be said that the EPS and rice husk materials were nicely bound together and offered rigid composite.

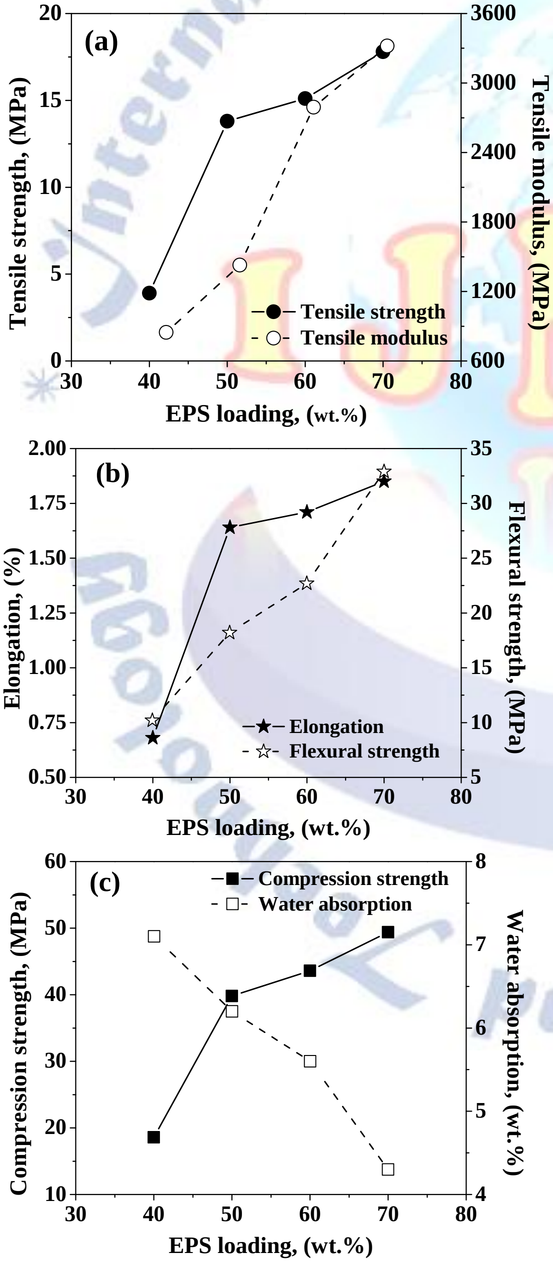

Figure 3. Influence of EPS quantity on the physico-mechanical properties of the composites

Figure 4. EPS-Rice husk based in-house prepared composite sheet.

4. CONCLUSIONS

In the study, cost-effective and environment-friendly composites were prepared from recycled polymer i.e., waste expanded polystyrene (EPS) and biomass (rice husk) by using compression moulding method. The impact of process variables such raw material loading, compression moulding pressure, and polymer quantity on physico-mechanical properties of the composites was investigated. The physico-mechanical properties of the in-house prepared composites, such as, tensile strength, tensile modulus, %elongation, flexural strength, compressive strength and water absorption were estimated as per the standard procedures. According to the findings, recycled EPS and biomass offer a lot of potential for making cost-effective and environment-friendly composites. According to the findings, the physico-mechanical characteristics of the composites improved when raw material quantity, compression moulding pressure, and EPS loading increased. Water absorption of the composites reduced as compression moulding pressure and polymer loading increased. The obtained tensile strength values of the in-house prepared composites were in the range of 4-18 MPa, whereas the flexural strength values were in the range of 10-33 MPa. The obtained water absorption values ranged from 4-12 wt.%. The prepared composites can be used in various possible applications. We believe that the findings of this study will assist corporate visionaries / analysts in developing a suitable process for addressing global issues related to trash development and its proper management.

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Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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