Scientific Research Journal,
Vol 20, No 2 (2023) 101-113
https://doi.org/10.24191/srj.v20i2.23506

Comparative Study of Mechanical and Physical Properties of Rice Husk Filled Polyethylene Waste Composites

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Received: 11 August 2023
Accepted: 20 September 2023
Online First: 21 September 2023

ABSTRACT

Polyethylene (PE), a type of plastic, is utilized extensively in many different applications and has become a significant part of our daily life. However, numerous plastic product manufactures have a significant environmental impact. As a result, several approaches have been investigated in order to reduce waste disposal issues. Rice husk (RH), on the other hand, is a form of agricultural waste that contains lignocellulosic fiber that can be used as a filler in polymer composites. As a result, combining both PE waste and RH fiber could be a viable option for saving our world. The objective of this study was to ascertain the impact of different RH fiber loadings, including 5, 10, 15, 20, and 25 %, on the mechanical and physical characteristics of composites manufactured from used HDPE and LDPE materials. Due to inadequate bonding between the hydrophilic fiber and the hydrophobic polymer matrix, it was discovered that increasing the filler loading lowered the tensile strength, elongation at break, and impact strength of the composites. In comparison to RH/HDPE, the tensile strength of RH/LDPE composites showed greater decline at 45 % at the highest loading of 25 % RH fiber. Both composites showed a 98–99 % decrease in elongation at break as a result of constrained chain elongation and mobility. Additionally, the impact strength value of RH/HDPE waste composites decreased by 43 % compared to 31 % for RH/LDPE waste composites. In contrast, the inclusion of fillers improved the modulus and density of the composites substantially. While the trends for RH/HDPE and RH/LDPE composites are similar, RH/

HDPE waste composites demonstrated superior mechanical characteristics than RH/LDPE waste composites.

Keywords: Polymer Composites; Waste Plastics; HDPE; LDPE; Rice Husk

INTRODUCTION

Numerous food packaging products, including snacks, rice, bread, drinks, and even pharmaceutical items, employ plastic. Plastics is the world's third-largest waste source, with the total volume of rising in line with global population and per capita consumption [1]. As a consequence, the globe now has an endless problem with disposing of plastic waste since we produce more garbage every day, which builds up as debris in landfills and natural environments [2]. For example, garbage from plastic bags not only clogs drainage systems but also makes the surroundings unattractive. Four significant sources of waste production include domestic, commercial, industrial, and agricultural. Plastics is widely used in the former three types for various products. PE is the simplest types of plastics which can be produced as either linear low-density PE (LLDPE), low density PE (LDPE) and high-density PE (HDPE). PE is the most frequently used and well-liked plastic due to its flexibility, making up more than half of all plastic use in Asian nations, particularly Malaysia. It was reported that 148,000 tons of plastic packaging have been used in Malaysian food industry in 2020 [3], hence generating huge plastics waste which are harmful to the environment. The third type of waste generation is agricultural waste, which generates significant volumes of biomass classed as natural fibers [4].

Examples of natural fibers that have been used to improve the mechanical qualities of plastic composites include kenaf, jute, sugarcane bagasse, coconut husk, bamboo, and corn stalks. RH is the name for a natural sheath that forms around rice grains as they grow. RH is a waste product produced by the milling of rice that is either burned or dumped. Burning the RH will release methane gas and contribute to air pollution. Because cellulose, hemicelluloses, and lignin are the main components of all plant fibers, the phrase "lignocellulosic fiber" refers to natural fiber [5]. Natural fiber filled composites have gained popularity in recent decades due to their renewability, biodegradability, at least partial recyclability, low

specific weight, and low cost of production. RH contains 52 % silica, which contributes to the mechanical and fire-retardant properties of plastics [6]. Furthermore, using lignocellulosic fibers can improve stiffness, hardness, and dimensional stability [7].

The creation of new composite materials from waste plastics as a matrix reinforced with natural fillers is a viable solution to the waste disposal problem. It will form improved chemical, physical, and mechanical qualities, increasing their combined worth and applicability in consumer goods manufacture. Meanwhile, it has the potential to lessen the environmental impact of waste materials [8]. PE waste, for example, is non-biodegradable because decomposition might take hundreds of years. This is due to the intermolecular bonds that comprise plastics, the structure of which keeps them from corroding or dissolving. Plastics are not environmentally friendly because they are unlikely to degrade indefinitely in the environment [9]. As a result, shredding, melting, and mixing plastic waste with RH are viable options for recovering a new material from plastic trash and reducing plastic pollution [9]. PE is a strong choice for use as the matrix in composites with natural fibers due to its high recycling capacity [10].

Agricultural fibers have been widely incorporated into conventional polymers such as PE [11], polypropylene (PP), and polyvinyl chloride (PVC) [7]. The literature is replete with studies on RH-filled virgin HDPE and LDPE composites. However, only 10 % are currently used as alternative raw materials in a variety of industries such as bio-composites, automotive components, biomedical, and others [4]. A few studies have recently reported using RH as a PE waste composite reinforcement [12]. Most of these works created polymers with unique mechanical characteristics. However, there were few findings in the literature comparing the mechanical and physical properties of RH-filled HDPE and LDPE waste. Therefore, the objective of this study was to create a composite material from HDPE and LDPE plastic wastes combined with RH agricultural waste fiber. Both composites' mechanical and physical properties were compared in terms of tensile strength, impact strength, hardness, and density.

EXPERIMENTAL DETAILS

Chemical Treatment of RH Fibers

Kilang Beras Dibuk Sdn. Bhd. in Perlis provided the RH fiber for this study. RH were initially cleaned with tap water and dried for 8 h in an oven set to 80 °C. The dried RH were then mechanically ground and sieved to produce fiber with an 850 μm size. The RH fiber was then exposed to 1.0 M NaOH for 24 h at room temperature before being washed with water to achieve pH 7. Another 24 h were spent for drying treated RH at 80 °C in the oven. Next, an airtight container was used to store the RH in order to reduce water absorption.

Sample Preparation

The HDPE and LDPE wastes were collected near the University Teknologi MARA, Perlis Branch, and were then cleaned with tap water to eliminate any impurities before being physically chopped into smaller sizes with scissors and dried at room temperature. To reduce variation in the results, both HDPE and LDPE wastes were collected from the same kind of grocery plastic bag. Then, as shown in Tables 1 and 2, the RH/HDPE and RH/LDPE composites were prepared using five different RH fiber loadings of 5, 10, 15, 20, and 25 %. With the processing temperature (Tm) set at 170 °C for HDPE and 150 °C for LDPE, and the rotating speed at 60 rpm, the compounding was done using a plastic internal mixer. The material was then hot-pressed into two specimens, one with dimensions of 64 mm x 10 mm and a thickness of 2 mm for an impact strength test and the other with dimensions of 150 mm x 150 mm and a thickness of 2 mm for a tensile strength test. Test specimens for the tensile strength test were cut with a plastic cutter.

Testing

Using the Instron 5567 Tensile Tester Machine, the tensile test was carried out in accordance with ASTM D3039. The test's speed was set at 50 mm per minute with a 20 kN applied stress. Young's modulus, elongation-at-break, and tensile strength were calculated from the average of the eight tested samples. The samples were hit with a hammer that had a potential

energy of 150 joules during an impact strength test that was carried out at room temperature in accordance with ASTM D 256-97 using a GT-7045-MDL Gotech Testing Machine. To create a region of concentrated stress for the beginning of a fracture, the specimens were originally notched with a depth of 0.5 mm, and the notched side was placed facing the pendulum. Five specimens were tested for each compound. The density of the samples was identified using MD-300s Digital Electronic Solid Density Tester, according to ASTM D 792-00. Three samples were tested for each compound and the mean value of density was then calculated.

Table 1: Composition of RH/HDPE composites

Compound	RH	HDPE waste
H0	0	100
H1	5	95
H2	10	90
H3	15	85
H4	20	80
H5	25	75

Table 2: Composition of RH/LDPE composites

Compound	RH	LDPE waste
L0	0	100
L1	5	95
L2	10	90
L3	15	85
L4	20	80
L5	25	75

RESULTS AND DISCUSSION

Tensile Properties

The tensile strength of waste HDPE and LDPE composites loaded with varied RH loadings is shown in Figure 1. The highest tensile strengths of the unfilled HDPE and LDPE waste matrix are 35 MPa and 22 MPa,

respectively. Similar to the findings reported by [10,13], it was demonstrated that gradually adding additional RH fibre decreased the tensile strength of the composites. The RH/HDPE and RH/LDPE composites had the lowest tensile strengths at 25 MPa (down 29 %) and 12 MPa (down 45 %), respectively, with 25 % RH fibre loadings. Poor bonding between the hydrophilic RH fiber and the hydrophobic polymer matrix, which limits stress transfer during tensile loading, was the cause of the lower tensile strength [14]. Since the fibres were not initially dried before the composites were moulded, it is possible that the presence of moisture and voids in the specimens of the composites caused the drop in tensile strength [10]. Tensile strength may also have decreased due to an increase in weak interfacial interaction between the HDPE and LDPE matrix and the RH fiber [10]. Additionally, the higher RH fiber had decreased the degree of crystallinity, which prevented the waste HDPE and LDPE from being arranged in an orderly fashion in the formed composites [15], lowering the tensile strength.

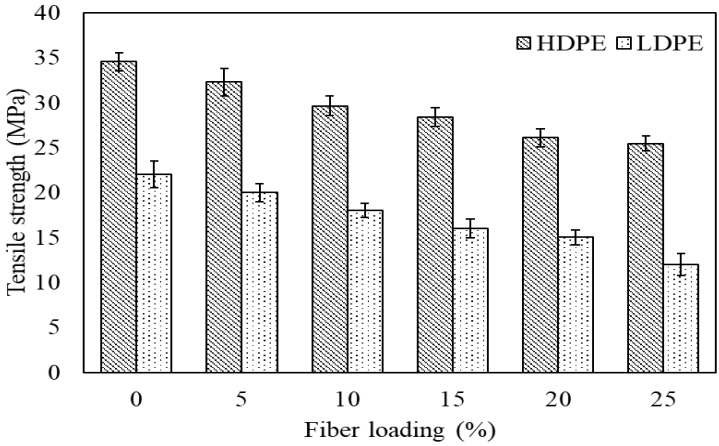

Figure 1: Tensile strength of RH/HDPE and RH/LDPE waste composites

Figure 2 depicts the correlation between the composites' percentage elongation at break and different RH fiber loadings. In comparison to HDPE waste, unfilled LDPE waste considerably exhibits higher elongation at break. The elongation at break was reduced by the addition of RH fibers from 550 % to 25 %, and further decreased by the addition of RH fibers to the lowest value of 3 %. With an increase in RH fiber loading, it was found that the elongation at break had drastically decreased for both types

of composites. This is such that the polymer matrices themselves cannot move or deform because to the presence of RH filler [14]. RH will fill in the gaps between the primary polymer's chains, which will lessen chain elongation and movement [16]. Polymeric chains that are not constrained by any limitations can move freely since the mixture is not homogeneous [7]. This includes RH's rigidity, which raises the stiffness of the polymer and lowers elongation [17]. Because RH fillers give the composite a brittle quality, they decreased the ductility of the polymer matrix. Due to weaker interfacial areas, particularly in those with RH loading above 5 wt%, the composite filled with RH fibers fractured at lower values of elongation [18].

Referring Figure 3, it was discovered that unfilled HDPE waste is significantly stiffer than LDPE waste. The RH/HDPE waste with a Young's modulus of 2019 MPa and RH/LDPE waste with a Young's modulus of 1557 MPa were the highest ever measured. The unfilled HDPE waste has a Young's modulus of 1129 MPa, which is the lowest value. It was due to the fact that the polymer composite's stiffening increased the material's Young's modulus. By placing more limits on the movement of polymer molecules, hard and stiff particle fillers like RH would raise the composites' modulus [19]. As a result, the strength and modulus of the composites will dramatically rise due to the increased filler loading.

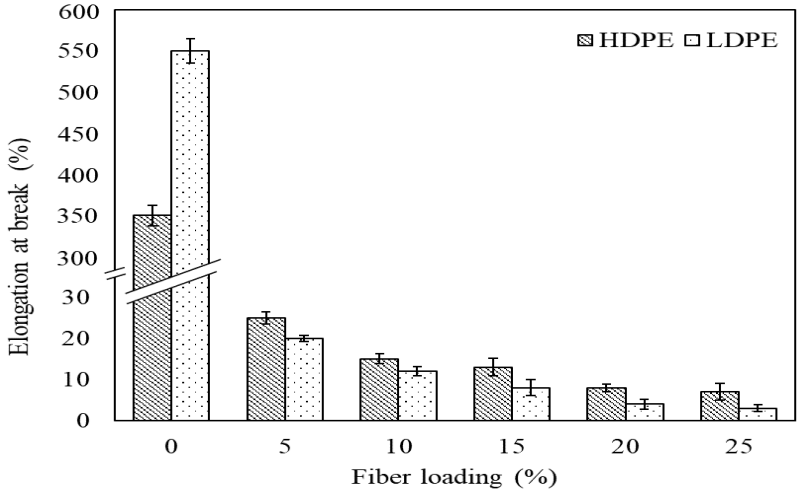

Figure 2: Elongation at break of RH/HDPE and RH/LDPE waste composites

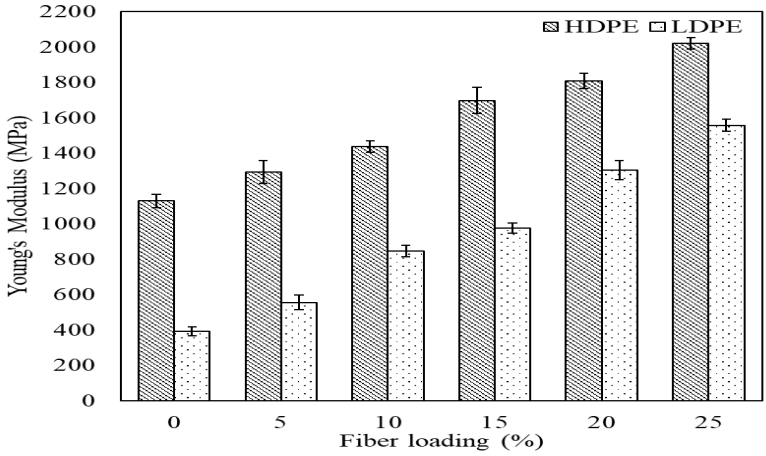

Figure 3: Young's modulus of RH/HDPE and RH/LDPE waste composites

Impact Strength

As illustrated in Figure 4, it was discovered that adding more RH fibers greatly reduced the impact strength of the composites, which from 61 x 10^3 J/m² for RH/HDPE to 35 x 10^3 J/m² and from 45 x 10^3 J/m² to 31 x 10^3 J/m² for RH/LDPE. Both HDPE and LDPE were originally flexible, but the addition of stiff lignocellulosic RH fibers caused the composites to stiffen up and become brittle and breakable. For instance, it appears that the presence of RH fibers prevents matrix flow, which causes the polymer matrix to become embrittled and lowers the impact strength of the composites. Additionally, a high fiber content in the composites enhanced the likelihood of fiber aggregation, which reduced the energy needed for fracture propagation in the areas of concentrated stress. Impact strength diminishes as fiber loading increases because more fibers weaken and reduce the capacity of the polymer matrix to absorb energy.

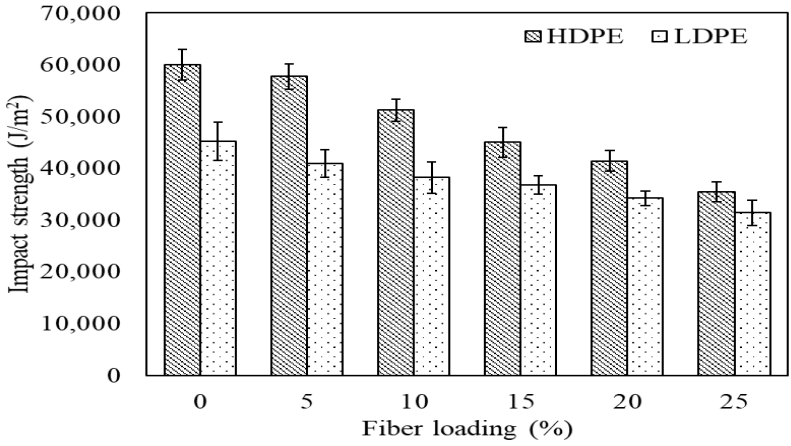

Figure 4: Impact strength of RH/HDPE and RH/LDPE waste composites

Density

Figure 5 depicts the density of composites made of RH/HDPE and RH/LDPE wastes. As filler loading was added, it was seen that the density of both polymer matrixes gradually rose. For RH/HDPE and RH/LDPE waste composites, the addition of 25 % RH filler loading enhanced the density to a maximum value of 1.09 g/cm³ and 1.02 g/cm³, respectively. When there is more fiber loading, the spaces between the fiber and the matrix are smaller, indicating that the composition is more tightly packed.

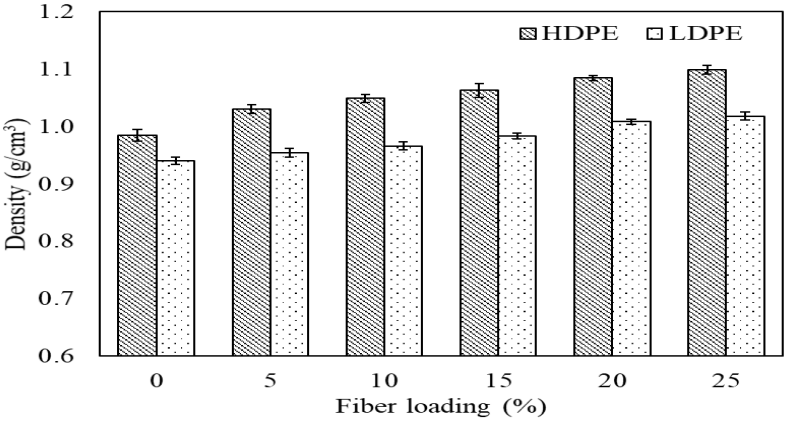

Figure 5: Density of RH/HDPE and RH/LDPE waste composites

CONCLUSION

In conclusion, the tensile strength, elongation at break, and impact strength of both RH/HDPE and RH/LDPE waste composites had drastically decreased due to the increasing RH fiber loadings. The tensile strength of RH/LDPE composites showed a larger drop at 45 % compared to RH/HDPE at the greatest loading of 25 % RH fiber. Due to restricted chain elongation and mobility, both composites displayed a 98–99 % decrease in elongation at break. Furthermore, RH/HDPE waste composites had an impact strength value that reduced by 43 % as opposed to 31 % for RH/LDPE waste composites. The stress concentrations in the polymer matrix have risen due to the presence of RH fibers. Additionally, the weak interfacial interaction between the polymer matrix and RH fiber may be to blame for the reduced mechanical capabilities. On the other hand, the composites' density and Young's modulus were dramatically affected by the higher RH fiber loadings. Furthermore, compared to RH/LDPE waste composites, RH/HDPE waste composites had better mechanical properties. Based on the results, it is strongly advised that the compatibilizing agent be used to strengthen the bond between the fibers and the matrix, hence improving the composites' mechanical properties.

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