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EFFECT OF *IMPERATA CYLINDRICA* REINFORCEMENT FORM ON THE TENSILE AND IMPACT PROPERTIES OF ITS COMPOSITES WITH RECYCLED LOW DENSITY POLYETHYLENE

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Abstract. Composites of recycled low-density polyethylene obtained from waste water-sachets and imperata cylindrica were produced with particulate and long-fibre unidirectional mat reinforcements. Comparison was made of the tensile and impact properties resulting from the use of the different reinforcement forms at 10 wt% ratio in the matrix. The results obtained from the tests carried out revealed that tensile strength, tensile modulus, elongation at break and impact strength of the composite with the long-fibre mat reinforcement were better than those of the one composite with the particulate reinforcement. The better performance observed in the long-fibre mat reinforcement could be attributed to the retention of the toughness and stiffness of the imperata cylindrica stem in this form of reinforcement, which is lost after the stem strands are pulverized into particles. Imperata cylindrica stem, as a natural fibre reinforcement for polymetric material is, therefore, recommended in the long-fibre mat form. The combination of these otherwise challenging resources in composite materials development will add economic value to them and help to reduce the environmental menace they present.

Keywords: tensile properties; impact strength; imperata cylindrica (IC); water-sachets; composites; particulate; long-fibre mat.

1. Introduction

Effective resource utilization as well as concern for the environment are among the reasons many researchers and industries are adopting the use of renewable natural fibres as replacement for synthetic fibres in a polymer reinforcement for the development of composites [1–3]. The composites produced with the natural fibre reinforcement of polymetric material have shown the potential of application in many engineering applications [4] due their excellent properties (mechanical, physical, electrical, etc). One natural fibrous plant is imperata cylindrical, which is a perennial, with basal leaves 3–100 cm long, 2–20 mm wide [5]. It is an aggressive and difficult weed to control due to its short growth cycle. It is abundant, yet unsuitable for grazing animals and lacks good commercial value [6]. When fully mature, its overall nutrient decline and its sharp pointed seeds and tangled awns may injure animals and humans [7]. They also act as a collateral host for pathogens that affect the yield of some food crops [8]. However, imperata cylindrica is stiff and tough [5, 9]. These properties make it promising as a fibre reinforcement for polymers, particularly recycled water-sachets, to produce thermoplastic composites. This will give economic importance to the fibre and reduce the environmental challenges posed by plastics wastes to human and aquatic lives. However, several factors affect the properties of composite materials, they include: fibre ratio in the matrix [2], production technique, chemical modification, fibre orientation or direction, fibre type and reinforcement form [10]. There are many types and forms of reinforcement, such as fibre, powder, and bulk. Compared to the other types of fibre form, the powder form has the smallest volume. According to El-Shekeil et al. [11], the mechanical properties of kenaf fibre reinforced polyurethane composites were influenced by the size of the kenaf fibre. Different fibre size showed a significant influence on the tensile and flexural properties and impact strength. Agarwal et al., [12] reported that a substantial improvement in the mechanical properties can be envisaged through an addition of fillers (either short fibre or particulate) into a nitrile rubber. However, the addition of short fibres has been found to be more effective. Vijay and Singha [13] reported that with a particle reinforcement, the compressive strength increases to a greater extent than with the short and long fibre reinforcement. It was also reported that the composite with a particle reinforcement has a higher load bearing capacity and lower wear rate than those with the short and long fibre reinforcement. This study, therefore, made a comparative examination of the tensile and impact properties of polymer composites produced with imperata cylindrica (IC) in the particulate form and long-fibre mat form at 10 wt% ratio in the matrix.

Figure 1. IC Mat.

Figure 2. Pulverized waste water-sachets.

2. Materials and method

The part of the imperata cylindrica that was used for this study is the stem and these were obtained from Pilla village in Makurdi area of Benue State. The growth environment of the imperata cylindrica is tropical with an average temperature of 27 °C and relative humidity of 82 %. The water-sachets made from low density polyethylene (LDPE) were handpicked from the environment within Makurdi area of Benue State.

2.1. Processing of the materials

The imperata cylindrica stems were harvested in February during the dry season, which is one of the two major season in the tropics. Subsequently, the finer strands of the stems were handpicked and arranged into a unidirectional mat (see Figure 1). The average diameter across the length of the strands selected to form the mat was 3 mm. This was measured with a digital micrometre screw gauge. Tiny threads were used to hold the IC strands together at three different positions along the breadth of the mat to ease its transfer into the mould without scattering. The dimension of the woven IC mat is $285 \times 200 \times 3$ mm. Some of the IC strands were also ground into smaller particles. The waste water-sachets were thoroughly washed and pulverized at Goshen Plastics Industry, Makurdi (see Figure 2). These pulverized waste water-sachets will be referred to as recycled low density polyethylene (RLDPE) henceforth.

2.2. Preparation and characterization of the composites

The equipment used and methods adopted for producing and characterizing the composites were as described by Olusunmade et al. [3]. The weight of the IC (particulate, mat) and the RLDPE were measured using an electronic weighing balance such that the weight ratio of the mat in the matrix was 1:9. The thickness of the mat (which is the diameter of the individual strand of the IC stem) and the expected thickness of the test specimens were responsible for the weight ratio in this study. Both reinforcement forms of the imperata cylindrica were used to produce the sheets. Figures 3–5 show one of the composite sheets produced and the test specimens. The test specimens for the tensile test have a dumb-bell shape with a gauge length of 30 mm, grip width of 15 mm and thickness of 5 mm. The dimensions of the impact test specimens are $100 \times 10 \times 5$ mm. Three specimens were used for each of the tests. The temperature and relative humidity of the test environment is 22 °C and 50 %.

3. Results and discussion

3.1. Tensile properties

3.1.1. Tensile strength of the composite

Table 1 shows the average tensile strength of the composites produced with the long-fibre mat and particulate IC compared to the RLDPE. It was observed that there was an increase of 57.27 % in the average tensile strength of the RLDPE/IC mat composite when compared to the RLDPE and an increase of 81.23 % when compared to the RLDPE/IC particulate composite. The higher value of tensile strength observed for the RLDPE/IC mat composite when compared to that of the neat RLDPE and RLDPE/IC particulate composite was due to the transfer of stress to the IC long-fibre. A physical examination showed that the IC stem offers great resistance to the force pulling it along its length, due to its stiff nature, thereby increasing the tensile load bearing capacity of the composite material before fracture.

3.1.2. Tensile modulus of the composite

Table 1 shows the average tensile modulus of the composites produced with the long-fibre mat and particulate IC compared to the RLDPE. It was observed that there was an increase of 327.50 % in the average tensile modulus of the RLDPE/IC mat composite when compared to the RLDPE and an increase of 278.05 % when compared to the RLDPE/IC particulate composite. The increment in the modulus can be attributed to the decreased deformability of the rigid interface between the IC mat/particulate and the matrix material, which cause a reduced strain. The enhancement in the

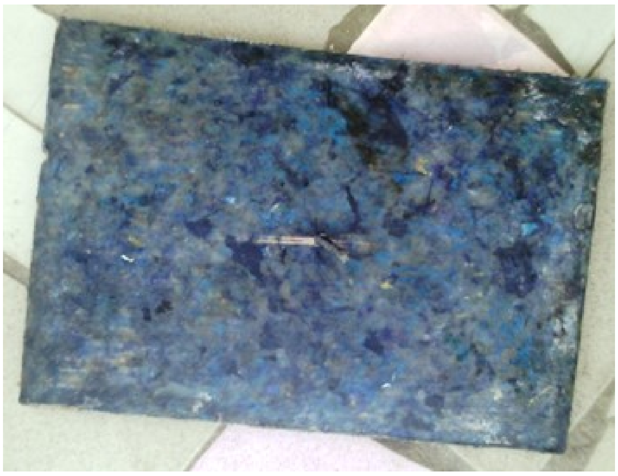

Figure 3. Finished Composite Sheet.

Figure 4. Tensile Test Specimens.

Figure 5. Impact Test Specimens.

tensile modulus is also due to the fibres itself, which have a higher stiffness than the polymer [2, 3, 14]. The IC stem is more rigid in its original form than when pulverized into particulate, hence, there is a more rigid polymer/IC interface in the long-fibre mat form resulting in a higher value for the average tensile modulus recorded for the RLDPE/IC mat composite over the RLDPE/IC particulate composite.

3.1.3. Percentage elongation at break of the composite

It was observed in Table 1 that there was a decrease of 35.24 % in the average percentage elongation of the RLDPE/IC mat composite when compared to the RLDPE and an increase of 28.74 % when compared to the RLDPE/IC particulate composite. With the incorporation of the IC mat/particulate in the polymer, the elasticity of the composite is suppressed. The reduction is attributed to the decreased deformability of the rigid interface between the IC mat/particulate and the matrix material [2, 3]. The decrease in elongation at break is due to the destruction of the structural integrity of the polymer by the fibres and the rigid structure of the fibres [15]. The higher value of the average percentage elongation recorded for the RLDPE/IC mat composite over the RLDPE/IC particulate composite was as a result of the mat's long-fibres being able to stretch a little further while been pulled by tensile forces before fracture due to their length unlike the particles, which easily separate under a load in the matrix. The IC stem is slightly more elastic in the long-fibre mat form than in the particulate form.

3.2. Impact strength of the composite

Figure 6 illustrates the average impact strength of the composites produced with the long-fibre mat and particulate IC compared to the RLDPE. It was observed that there was an increase of 44.14 % in the average impact strength of the RLDPE/IC mat composite when compared to the RLDPE and an increase of 151.74 % when compared to the RLDPE/IC particulate composite. The IC stem has a foam-like inner layer, which makes it tough and able to absorb more impact energy before fracture. This is responsible for the higher value of the impact strength obtained for the RLDPE/IC mat composite. In the particulate form, the structure is destroyed, leading to a reduction in the toughness and hence a lesser value of the impact strength of the RLDPE/IC particulate composite.

	RLDPE	RLDPE/IC Mat	RLDPE/IC Particulate
Tensile Strength (MPa)	10.86 ± 0.86	17.09 ± 1.50	9.43 ± 0.62
Tensile Modulus (MPa)	116.44 ± 14.86	497.78 ± 33.34	131.67 ± 15.46
Elongation at Break (%)	54.93 ± 16.57	35.57 ± 8.43	27.63 ± 2.3

Table 1. Tensile properties of RLDPE, RLDPE/IC Mat and RLDPE/IC Particulate.

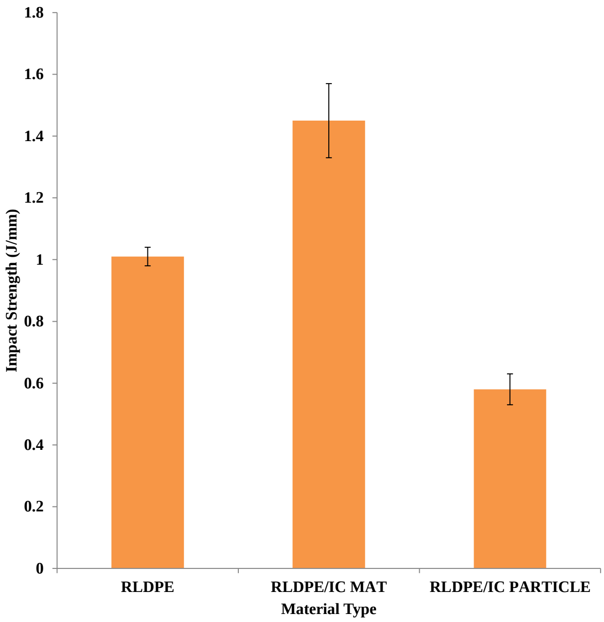

Figure 6. Comparison of Impact Strength of RLDPE, RLDPE/IC Mat and RLDPE/IC Particulate.

4. Conclusion

In this study, composites of recycled low-density polyethylene obtained from waste water-sachets and imperata cylindrica were produced with particulate and long-fiber unidirectional mat reinforcements. Comparison was made of the tensile and impact properties resulting from the use of the different reinforcement forms at 10 wt% ratio in the matrix. The results from the tests carried out revealed that tensile strength, tensile modulus, elongation at break and impact strength of the composite with the long-fibre mat reinforcement were better than that of the composite with the particulate reinforcement. The better performance observed in the long-fibre mat reinforcement could be attributed to the retention of the toughness and stiffness of the imperata cylindrica stem in this form of reinforcement, which is lost after the stem strands are pulverized into particles. Imperata cylindrica stem, as a natural fibre reinforcement for polymetric material is, therefore, recommended in the long-fibre mat form.

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