

Performance evaluation of composites produced from mix of jute, flax, polyester, wool and LDPE wastes

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ABSTRACT: While changing textile fibres into yarns, fabrics and apparel products, considerable amounts of process wastes are generated. The amount of generated wastes is different for natural and synthetic fibres. Wastes are higher while processing natural fibres than synthetic ones. Traditionally, such textile wastes are either sold with scrap values or disposed to the environment as solid wastes. As thermoplastic materials are utilized for different holding, packaging and container purposes, they are being used till today. However, while using them, damages may occur to them and will get discarded. So, this research tries to develop an advanced and engineered composite product from the waste mixtures of jute, flax, polyester and wool as reinforcements and LDPE waste as matrix. Compression moulding machine has been used and with a melting temperature of 160⁰c & a pressure of 1.5MPa for 5 minutes, composite products have been produced. The products have been tested and characterized for; tensile, flexural, compression and impact resistance strength tests and found results of 10MPa, 7.06MPa, 10.01MPa and 35.731J respectively. These results have been compared and evaluated with other composite products made from wastes and the comparisons show the developed composite product can be a

potential candidate to be used in fencing and boarding panel application areas.

Keywords: *Textile wastes, LDPE waste, Compression moulding, Composite, Performance tests*

1. Introduction

While processing and changing both natural and synthetic textile fibres to different designs of fabrics and apparel products, waste is expected to be generated. According to the types of fibre used for such production, their damage to the environment will also vary [1]. From the synthetic fibre categorization, polyester is the most widely used due to its durability, light-weight & wicking properties and applicable from home-tech garments to different kinds of sportswear products [2]. From animal sources, different kinds of fibres are used and applied for the production of luxurious apparels including silk saree, fur sweaters and jackets, most commonly used in very cold places as the input fibres have excellent insulation properties. Wool is one of the animal fibres which is shredded from hairs of different animals. Since the fibre has better insulating property, it is used for making sweaters and suiting products. Textile fibres can also be sourced from plants. Among the many plant fibres, Jute and Flax are the most widely used because of their natural breath-ability, air and moisture management, ultraviolet, sound and heat insulation, lower thermal conduction and anti-static properties. Such properties make these fibres to be chosen in home furnishings and in high performance technical textile applications. Plastics have two categories; thermoset and thermoplastics. The thermoplastic ones can be melted and changed to different types of molds. LDPE is one of them widely used as drinking container, laundry bags, etc [3, 4, 5]. So as to reduce the negative impacts happening from improper management of the wastes generated while processing both the textile and plastic products and make use of them to produce advanced and engineered products having various technical applications, techniques like re-using and recycling can be implemented [6,7]. Neway in his works has fabricated composite panel products from jute-LDPE wastes and flax-LDPE wastes and his findings revealed that composites from flax-LDPE wastes exhibits better mechanical properties than the jute-LDPE composites and most of the performance properties are also comparable with the commonly known fencing products [8,9]. So, the current

research tries to evaluate the mechanical performances of composites made from wastes of jute, flax, wool and polyester as reinforcement and LDPE plastic waste as matrix and suggests for potential application areas.

2. Methodology

For the production and performance evaluation of the composite products, the following input waste materials, composite fabrication machine and testing facilities have been used:-

Input reinforcement and resin materials

- ✧ 100% Jute fibre and fabric wastes,
- ✧ 100% Flax fibre, roving and yarn wastes,
- ✧ 100% Polyester selvedge and fabric wastes,
- ✧ 63% polyester, 35% wool & 2% elastomer sliver, yarn and fabric wastes,
- ✧ LDPE waste

Composite fabrication machine

- ✓ Anji Yukang compression moulding machine

Testing facilities

- Computer controlled electro-mechanical Universal testing machine for tensile, compression and flexural strength testing of composite specimens,
- Pendulum impact testing machine

Fig. 1 below describes the input wastes which have been collected from local textile factories & a plastic recycling company and fabrication of composite panel products have been done in African-bamboo plc, a local bamboo decking product manufacturing company. The mechanical tests and characterizations are conducted in Addis Ababa Science and Technology University-central laboratory.



Figure 1 Collected wastes

2.1 Composite fabrication

The composite fabrication is done with 50:50 fibre volume fraction since in such fibre volume fraction, both the reinforcement and the matrix materials do have equal shares/contributions in the bonding and adhesion process and hence chances of void formations will get reduced.

Table 1 Densities of the fibres and LDPE matrix

S/no	Type of textile material	Fibre density (g/cm ³)	Type of plastic material	Matrix density (g/cm ³)
1	Polyester	1.38	LDPE	0.91
2	Wool	1.307		
3	Flax	1.52		
4	Jute	1.46		

To fabricate 1kg of composite product, the weight fractions of the fibre and matrix have been calculated using equation 1 and by considering the densities of both the reinforcement and matrix, which is described in table 1 above.

$$W_{\text{fibre}} = [1 + 1 / \{(V_f / 1 - V_f) * (\text{den}_{\text{fib}} / \text{den}_{\text{resin}})\}]^{-1} \dots\dots\dots \text{Equation (1)}$$

Where, W_{fibre} is weight fraction of the fibre,

V_f is fibre volume fraction,

den_{fib} is fibre density and

$\text{den}_{\text{resin}}$ is matrix density

So, the weight fractions have been calculated as:-

$$W_{\text{fibre}} = 0.86 \ \& \ W_{\text{matrix/plastic}} = 0.14,$$

So, to produce 1 kg sample composite product; $0.86 * 1\text{kg} = 0.86\text{ kg}$ (in total) of jute, flax, polyester & polyester-wool fibre (0.215kg for each fibres) & 0.14 kg of LDPE matrix is required.

As it is stated in fig. 2 below, the composite sample is fabricated with a melting temperature of 160°c , a pressure of 1.5MPa for 5 minutes.



Figure 2 Compression moulding process

2.2 Composite characterizations

The composite products have been tested for; Tensile, compression, flexural and impact strength tests and the procedures are described and indicated in below figures from 3 to 6:-

2.2.1 Tensile strength test:

- Test method: ASTM D 638-10
- Software used: Origin pro version 8.5,
- Specimen thickness: 14mm; width: 19mm; length: 165mm; Gauge length: 105mm
- Load rate: 2mm/min



Figure 3 Tensile strength testing

2.2.2 Compression strength test:

- ✓ Test method: ASTM D 3410
- ✓ Software used: Origin pro version 8.5,
- ✓ Specimen thickness: 14mm; width: 25mm; length: 25mm;
- ✓ Load rate: 2mm/min



Figure 4 Compression strength testing

2.2.3 Flexural strength test:

- ✓ Test method: ASTM D 790-03
- ✓ Software used: Origin pro version 8.5,

- ✓ Specimen thickness: 14mm; width: 12.7mm; length: 127mm; Gauge length: 85mm
- ✓ Load rate: 5mm/min



Figure 5 Flexural strength testing

2.2.4 Izod Impact resistance test:

- Test method: ASTM D256
- Software used: Impact star impact testing machine software version 2.0,
- Specimen thickness: 14mm; width: 12.6mm; length: 64mm



Figure 6 Impact strength testing

3. Results and discussion

For each mechanical characterizations done, numbers of specimens have been tested and results are shown along with the calculated mean values which is indicated in below tables from 2 to 6.

Table 2 Tensile strength test results

S.no	Type of composite material	Breaking load (N)	Specimen thickness (mm)	Specimen width (mm)	Cross sectional area (mm ²)	Tensile strength (MPa)	Strain (%)
1	Mix of all fibre reinforcements-LDPE	2231	14	19	266	8	6.2
2	Mix of all fibre reinforcements-LDPE	3111	14	19	266	12	12.3
3	Mix of all fibre reinforcements-LDPE	2723	14	19	266	10	8.7
Mean val.		2688.3	14	19	266	10	9.1

For characterizing the tensile strength of the composite product, 3 specimens have been tested and found a mean breaking load and tensile strength values of 2688.3N and 10MPa respectively. These values are comparable with the composites made by Neway [9] from jute-LDPE wastes and found a tensile strength of 10MPa, which is suggested to have a potential in fencing, decking and panel boarding application.

Table 3 Compression strength test results

S.no	Type of composite material	Ultimate compressive load (N)	Depth max. Compressive load is applied on (mm)	Specimen width (mm)	Cross sectional area (mm ²)	Compression strength (MPa)	Strain (%)
1	Mix of all fibre reinforcements-LDPE	2330	10	25	250	9.32	1.1
2	Mix of all fibre	2590	10	25	250	10.36	1.8

S.no	Type of composite material	Ultimate compressive load (N)	Depth max. Compressive load is applied on (mm)	Specimen width (mm)	Cross sectional area (mm ²)	Compression strength (MPa)	Strain (%)
	reinforcement s-LDPE						
3	Mix of all fibre reinforcement s-LDPE	2220	10	25	250	8.88	1.5
4	Mix of all fibre reinforcement s-LDPE	2870	10	25	250	11.48	1.6
Mean val.		2,502.5	10	25	250	10.01	1.5

For testing the compression strength of the composite product, 4 specimens have been tested and found a mean ultimate compressive load and compression strength values of 2502.5N & 10.01MPa respectively. Here, the researcher have found a mean compression strength values of 9.87MPa & 9.51MPa for composites made from jute-LDPE and flax-LDPE wastes respectively [8,9]. Thus, composites made from wastes of mixture of jute/flax/polyester/wool with LDPE wastes exhibits higher compression strength performance than the jute and flax only composites and it can be suggested for the applications of fencing and panel boarding products.

Table 4 Flexural strength test results

S.no	Type of composite material	Ultimate flexural load, F (N)	Specimen thickness, d (mm)	Specimen width, b (mm)	Support span length, L (mm)	Flexural strength, $3FL/2bd^2$ (MPa)	Strain %
1	Mix of all fibre reinforcements-LDPE	131	14	12.7	85	6.7	45
2	Mix of all fibre reinforcements-LDPE	160	14	12.7	85	8.2	36.3
3	Mix of all fibre reinforcements-LDPE	120	14	12.7	85	6.14	30
4	Mix of all fibre reinforcements-LDPE	141	14	12.7	85	7.2	10.2

S.no	Type of composite material	Ultimate flexural load, F (N)	Specimen thickness, d (mm)	Specimen width, b (mm)	Support span length, L (mm)	Flexural strength, $3FL/2bd^2$ (MPa)	Strain %
Mean val.		138	14	12.7	85	7.06	30.375

For characterizing the flexural strength performance, 4 specimens have been tested having a mean ultimate flexural load and flexural strength values of 138N & 7.06MPa respectively. Researchers like Neway have tried to develop composite product from jute-LDPE wastes and found a mean flexural strength value of only 5.07MPa [9] which is much lower than the one made with mixture of jute/flax/polyester/wool and LDPE wastes. Thus, the composite produced in this research can have the potential to be used for fencing and panel boarding application areas.

Table 5 Impact resistance strength test results

S.no	Type of composite material	Specimen thickness (mm)	Specimen width (mm)	Cross-sectional area (mm ²)	Toughness	Impact resistance energy (J)
1	Mix of all fibre reinforcements-LDPE	14	12.6	176.4	0.23	28.459
2	Mix of all fibre reinforcements-LDPE	14	12.6	176.4	0.34	41.899
3	Mix of all fibre reinforcements-LDPE	14	12.6	176.4	0.22	27.206
4	Mix of all fibre reinforcements-LDPE	14	12.6	176.4	0.37	45.36
Mean value					0.29	35.731
Std. deviation					0.08	9.243

4 composite specimens have been tested and evaluated for impact resistance strength performance. The calculated mean impact resistance energy value of 35.731J is found to be higher than the one achieved for composite product made from jute-LDPE wastes and get a mean impact resistance energy value of only 27.67J, by

which the researcher depicts the developed composite product has a potential to be used for fencing and panel boarding applications [9].

Table 6 Summarized test results

S.no	Type of product	Mechanical properties			
		Impact resistance energy (J)	Tensile strength (MPa)	Flexural strength (MPa)	Compression strength (MPa)
1	Mix of all fibre reinforcements-LDPE	35.731	10	7.06	10.01

4. Conclusions

Generally, the current research tries to develop composite products from the mixture of input waste reinforcements of flax, jute, polyester and wool with LDPE waste as a matrix. The stated wastes are collected from local textile factories and a plastic recycling company. For composite fabrication, compression moulding machine has been used and with the use of 50:50 fibre volume fraction, the weight fractions of the fibres and the matrix has been determined on the basis of their densities. The composite production is conducted with a melting temperature of 1600c & a pressure of 1.5MPa for 5 minutes. The composite specimens have been tested and their performance has also been evaluated for tensile, compression, flexural and impact strength characterizations. The results show that the product has a mean tensile, compression, flexural and impact resistance strength values of 10MPa, 10.01MPa, 7.06MPa and 35.731J respectively. The results depict the composite product has better performance properties as compared with composites made from a single type of fibre and LDPE matrix wastes, such as; jute-LDPE composites. Hence, the composite product is suggested to have a potential to be used in fencing and boarding panel application areas.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this article.

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