RECYCLING AND REUSE FACILITIES OF LIGNOCELLULOSIC MATERIAL FILLED ECO-COMPOSITES

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ABSTRACT

The increased ecological consciousness has generated the concept of sustainable development of environmental resources with improved economic activities. Also, the International Community and waste legislation are influencing the composite industry, such as EU directives, End of Life Vehicles (ELV) and Waste Electrical and Electronic Equipment (WEEE), increased the pressure on solving fibre reinforced polymer waste management through recycling and reuse [1,2].

The aim of this work is to show the possibilities of recycling and reuse of thermoplastic polymer matrices with rice hulls (RH) and kenaf fibres (KF) using the conventional techniques, extrusion and compression moulding.The investigation have been performed in three steps: i) investigation of the recycling ability of the polymer matrix, ii) application of the recycled matrix for production of the rice hulls composites and kenaf eco-composites, iii) investigation of the recycling ability of the rice straw and kenaf fibre composites. Characterization of all the recycled composites includes mechanical, morphological and thermo-gravimetrical analysis.

The obtained results have shown that both polymer matrices (biodegradable and non-degradable) could be recycled with acceptable mechanical properties and they can be successfully used for production of eco-composites. Increased modulus have been measured for both tensile and flexural, from 12 to 32 %, while tensile and flexural strength were slightly decreased. The same tendency was obtained and for the mechanical properties of the recycled composites. SEM analysis has shown that the agricultural fillers are covered by the recycled polymer matrix, indicated on the satisfied durability of the recycled polymer matrices.

1. INTRODUCTION

To assist in the transition from disposal in landfill to recycling, the Fibre Reinforced Polymer industry needs to consider designing materials and components for easier deconstruction, reuse and recycling at the end of the product life. Current and impending waste management legislation will put more pressure on the industry to address the options for dealing with FRP waste through the waste hierarchy and will therefore put more pressure on solving FRP waste management through recycling and reuse.

From eco-compatible polymer composites, special attention have been given to the polypropylene composites due to their added advantage of recyclability [3,4]. Yang *et al.* have studied the possibility of using lignocellulosic rice-husk flour (RHF) as the reinforcing filler in thermoplastic polymer composites. They have designed RHF/Polypropylene composites with four levels of filler loading (10, 20, 30 and 40 wt %). The results of tensile test performed at six levels of temperatures and various crosshead speed have shown that tensile strength of the composites slightly decreased as the filler loading increased. Tensile modulus was improved by increasing the filler loading. Notched and unnotched Izod impact strengths were lowered by the addition of rice-husk flour. The composite became brittle at higher crosshead speed, and it has shown plastic deformation with increasing test temperatures [4].

Kim *et al.* have analysed the thermal degradation and thermal stability of RHF filled PP and HDPE composites [5]. They have found that as the RHF content increased, the thermal stability of the composites decreased and the ash content increased as a logical consequence of the lower thermal stability of the RHF. Also, as the thermal decomposition proceeded in the studied RHF/PP composites, the activation energy increased slowly in the initial stages until degradation conversion (α) of α=0.3. Finding that activation energy of the composites depend on the dispersion and interfacial adhesion of RHF in the PP and HDPE matrix polymers they have recommended addition of a compatibilizing agent.
The aim of this work is to show the possibilities of recycling and reuse of thermoplastic polymer matrices, PP and PLA, with rice straw (RS) and kenaf fibres (KF) using the conventional techniques, extrusion and compression moulding.

2. EXPERIMENTS

Eco-composites based on recycled PP and PLA matrix reinforced with kenaf and rice straw, as well as based on recycled composites, have been prepared.
PP based composites were prepared by the following procedure: the recycled PP matrix was mixed in a Brabender together with the copuling agent (PP-g-MA) and with Rice Straw and Kenaf fibers (reactive blending) (melt mixing in Brabender at 180^{o}C, time 10 min by the following scheme:

PP; dry rice straw;
PPx1; } + CA (3 min) + { dry kenaf fibers; (7 min)
PPx2;

The obtained composites were cut in pellet form to perform the sheets and they have been molded by thermo compression at T= 185^{o}C, t=10 min with continuous adding a pressure up to 10 000 pounds.
PLA recycled based composites (PLA/RH/CA 65/30/5 wt/wt, PLA x1/RH/CA 65/30/5 wt/wt) were prepared by the described procedure
melt mixing in Brabender at 170^{o}C, time 10 min:

PP; dry rice straw;
PLAx1; } + CA (3 min) + { dry kenaf fibers; (7 min)

The obtained composites were cut in pellet form to perform the sheets and they have molded by thermo compression at T= 185^{o}C, t=10 min with continuous adding a pressure up to 10 000 pounds.
Characterization protocol of the these composites includes flexural test, TGA and SEM. The flexural tests were performed on unnotched samples (60x10x2mm), with a Universal Instron Machine (Model 4301) using three-point test. The tests were performed at crosshead speed of 2 mm/min, span 48 mm, at room temperature. Morphology of fracture surfaces of composites after the flexural test was analyzed using a JEOL SEM (vacuum Au/Pd alloy deposition of the samples in a Polaron Sputtering apparatus was performed previously). The thermal stability of the samples was measured using a Perkin Elmer Pyris Diamond Thermogravimetric/Differential Thermal Analyzer. About 12 mg of the composite samples were heated from 40 ^{o}C to 800 ^{o}C at a heating rate of 20 ^{o}C/min in nitrogen atmosphere.

3. EXPERIMENTAL RESULTS

3.1. Mechanical behavior

After the end life of a product the material that is composed of can be recycled or reused for other application. When reusing it is essential to know the mechanical behavior of the material after several transformation steps. Usually, for reusing the products are re-extruded in order to obtain pellets ready for transformation. So this work will let us know the effect of reprocessing on the mechanical properties of the final eco-composites.

Mechanical properties i.e. flexural data of the studied eco-composites are reported in Table 1 for recycled polymer matrices with rice straw, and in Table 2 for eco-composites composites based on recycled polymer matrix and kenaf fibers. Flexural properties of the rice straw composites based on recycled PLA remarkably decreased, while the data obtained for composites based on recycled PP are in acceptable range.

Flexural data measurements for the completely recycled eco-composites (x1, x2) are presented in Table 3. Evidently, the mechanical properties of the recycled composites decreased but in acceptable level.

Table 1. Flexural modulus of the composites based on recycled PP and PLA matrices with rice straw

SAMPLE	Stress at peak [MPa]	Flexural Modulus [MPa]
PP x1	52,8	1305
PPx1/RS/CA (60/30/10)	42,2	1825
PP x 2	49,5	1341
PPx2/RS/CA (60/30/10)	39,6	1842
PLAx1	32,0	2431
PLAx1/RS/CA (65/30/5)	14,8	2275

Table 2. Flexural modulus of the composites based on recycled PP and kenaf fibers

SAMPLE	Stress at peak [MPa]	Flexural Modulus [MPa]
PP x1	52,8	1305
PPx1/Kenaf/CA (60/30/10)	51,1	2346
PP/Kenaf/CA (60/30/10)	51,3	2106

Table 3. Flexural and impact resistance of recycled rice straw based composites

SAMPLE	Stress at peak [MPa]	Flexural Modulus [MPa]	Kc [MN-3/2m]	Gc [kJ/mm2]
PP / RS / CA 60/30/10 wt/wt	42,6	1941		
PP / RS / CA (x1) 60/30/10 wt/wt	44,8	1884		
PP / RS / CA (x2) 60/30/10 wt/wt	38,5	1910		
PLA / RS / CA 65/30/5 wt/wt	26,8	3031	1,05	0,42
PLA / RS / CA (x1) 65/30/5 wt/wt	12,1	3211	0,53	0,12
PLA / RS / CA (x2) 65/30/5 wt/wt	10,7	3307	0,45	0,11

3.2. Thermal properties of the Polymer mortars

Thermal properties have been followed by TGA. The obtained parameters for eco-composites based on recycled PP and recycled PLA, are presented in Table 4. TGA has confirmed that there is no remarkable changes in the thermal stability of the recycled eco-composites.

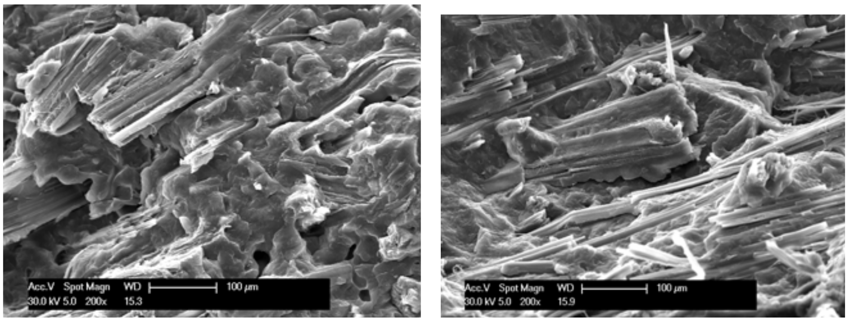
Table 4. TGA of PP recycled eco-composites with rice straw and kenaf fibers

	Td [oC] 90 %	*Td* [oC] 50 %	*Td* [oC] 10 %
PP / RH / CA	344,43 (89,74 %)	411,21 (49,74 %)	452,17 (9,74 %)
PP x1/RH/CA	309,09 (87,51 %)	385,22 (47,51 %)	458,82 (12,.51 %)
PP x2/RH/CA	343,53 (86,82 %)	405,97 (46,82 %)	475,27 (11,82 %)
PP /Kenaf /CA	340,57 (90,94 %)	408,94 (50,94 %)	441,96 (10,94 %)
PPx1/Kenaf/CA	338,43 (91,98 %)	412,35 (51,98 %)	443,77 (11,98 %)
PLA x1/ RH / CA	299,42 (88,41 %)	341,70 (48,41 %)	529,70 (13,41 %)

3.3. Fracture morphology

Some of the SEM microphotographs with the characteristic morphology obtained at the fracture place during the flexural test of the recycled eco-composites are presented on Fig.

1 and 2. Fig. 1 represents the fracture morphology of kenaf based composites with recycled and raw PP. PP has shown good durability and kenaf fibres are well covered by the polymer matrix. Fig. 2 represents the fracture morphology of composites based on PP-recycled with rice straw.



a) PP/Kenaf/CA (x200)   b) PPx1/Kenaf/CA (x200)

Fig. 1 SEM microphotographs of kenaf based composites with recycled and raw PP

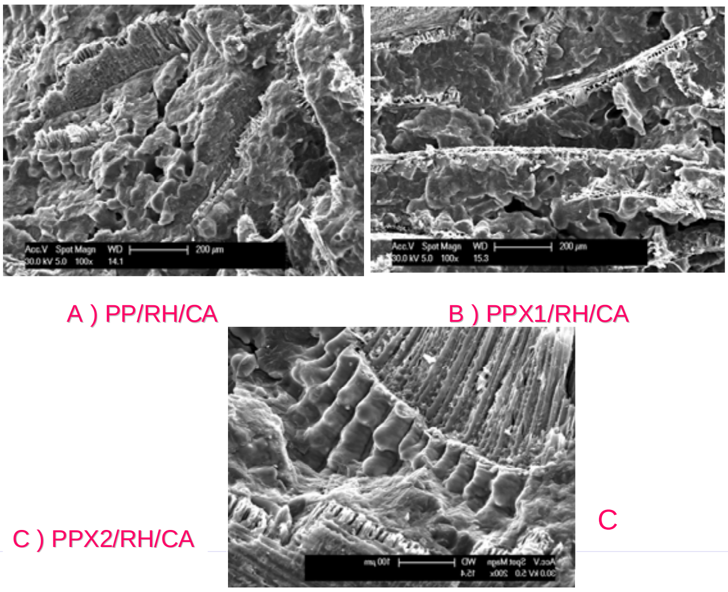


Fig. 2 SEM microphotographs of composites based on recycled PP

4. CONCLUSIONS

Investigation performed in this work have confirmed the recycling ability of the PP and PLA matrix. Also, it was reported the possible application of the recycled matrix for production of the Rice Straw - composites and Kenaf – composites, as well as the recycling ability of the obtained eco-composites. Flexural test measurements have shown that mechanical properties of the recycled composites decreased but in acceptable level.

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