Green wastes of urban parks and gardens as sustainable fillers for biocomposite materials.

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Due to environment and sustainability issues, there is an expanding search in the field of materials science focused on eco-friendly materials. Biocomposites, whose fillers are produced from lignocellulosic residues, are a solution to the current demands in terms of valorisation of lignocellulosic solid wastes, reduction of our dependence on fossil resource, reduction of environmental pollution generated by non-biodegradable and/or non-recyclable plastics, and eco-design of high performance materials (Faruk, 2012, and Mohanty, 2002).

Lignocellulosic residues stemming from urban parks and gardens constitutes a highly available resource. Today, the two main ways of recycling green waste from urban parks and gardens are the organic valorization comprising composting and anaerobic digestion and the energy recovery with biogas production by methanation.

The objective of the present work was to assess the potential of using this lignocellulosic resource for the production of reinforcing fillers. Such a resource is very heterogeneous, consisting mainly in organic (such as leaves, branches or grass clippings) and inorganic (soil and stones) compounds, and also includes foreign objects such as plastic bags, glasses or papers. Its reinforcing effect has thus to be investigated by taking into account this heterogeneity. For that purpose, different fractions have been identified and used for the production micrometric size fillers by dry fractionation. The polymer matrix used for this study was a bacterial polyester, i.e. a polyhydroxy-butyrate-co-valerate (PHBV), allowing to obtain fully biobased and biodegradable biocomposites (Berthet, 2015 and 2016, Lammi, 2018).

Experimental

A commercial polyhydroxy-butyrate-co-valerate, PHBV was purchased from Natureplast (PHI 002, injection molding grade) and the studied lignocellulosic fibers were derived from Copenhagen urban park and garden wastes (sent by the Technical University of Denmark, as project partner). Five valuable fractions were identified and sorted (Figure 1), i.e. fractions containing (1) large pieces of branches, (2) large pieces of leaves, (3) large pieces of grass, (4) a mixture of medium particles of branches, leaves and grass, and (5) a mixture of fine particles of branches, leaves and grass with a large amount of soil. Micrometric size fillers were obtained exclusively by dry fractionation, which consisted in a combination of sorting and grinding processes (Figure 1). The obtained fillers were characterized in terms of biochemical composition, size, morphology, density, color and thermal stability.

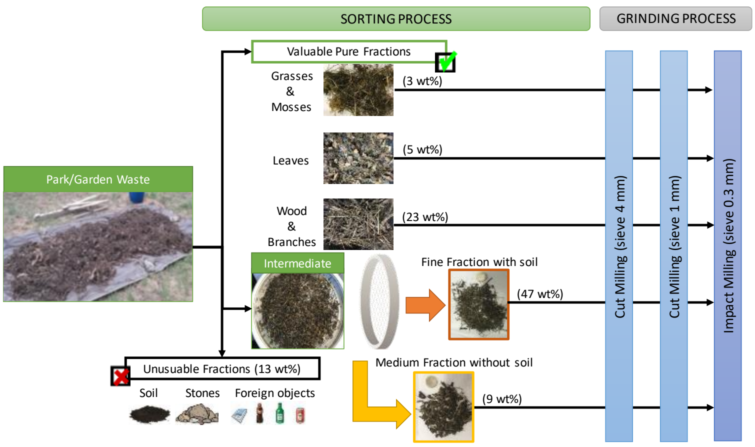

Figure 1. Sorting and Grinding processes of lignocellulosic fillers derived from Park and Garden wastes

Fillers were introduced up to 40 wt% into the PHBV matrix using a corotative lab-scale twin-screw extruder. The PHBV-based formulations were molded by injection to produce tensile test specimens (ISO 527-2 1BA). The mechanical properties of biocomposites were evaluated by tensile tests performed with a static materials testing machine; the strength at break (σ_b), the elongation at break (ε_b) and the Young's modulus (E) were determined from stress-strain curves. The morphological observations at break were carried out using SEM. The thermal stability of materials was evaluated by TGA. The phase transition temperatures of materials, as well as their crystallinity (χ_c), were measured by DSC

Results & Discussion

The reinforcing effect of each fraction was evaluated and discussed in relation to the structure of PHA-based biocomposite materials. In terms of thermal stability and crystallinity (χ), the addition of any filler slightly impaired these properties (Table 1), even at high loadings (from 5wt% up to 30wt%). This trend was verified with regard to the mechanical properties. The strength at break (σ), the strain at break (ε) and the Young's modulus (E) values for pure PHBV were 38.3 ± 1.3 MPa, 4.5 ± 0.5 % and 2.1 ± 0.04 GPa respectively (Table 1). The incorporation of any filler resulted in a slightly decrease of these properties (Table 1). The branches-filled biocomposites presented the best mechanical properties, even better than biocomposites filled with a commercial grade of wood flour. Biocomposites filled with leaves or branches showed a slightly decrease of the strength at break at 5 wt% of fillers but their strain at break were not impacted.

Table 1. Thermal and mechanical properties of PHA-based biocomposite materials.

Formulations	$T_{onset\ 2\%}$ (°C)	$T_{max\ deg}$ (°C)	T_{melt} (°C)	χ (%)	σ (MPa)	ε (%)	E (GPa)
PHBV	274.5±0.5	298±0	175.1	66.4	38.3±1.3	4.5±0.5	2.1±0.04
PHBV+5wt%Branches	271.5±1.5	296±0	174.5	67.4	38.0±0.7	3.4±0.5	2.7±0.1
PHBV+15wt%Branches	260±0	277±0	174.4	69.6	36.7±1.8	3.3±1.1	2.8±0.1
PHBV+30wt%Branches	253±0	270±0	174.7	67.4	38.7±0.3	3.5±0.4	3.0±0.1
PHBV+15wt%Leaves	256±0	272±0	174.2	69.9	32.8±1.3	3.8±1.1	2.7±0.0
PHBV+15wt%Grass	247±5	265.5±2.5	172.2	67.7	33.5±1.6	3.5±0.3	2.2±0.1
PHBV+15wt%FF	261±0	277±0	174.0	69.3	33.5±1.0	3.1±0.1	2.6±0.1

Conclusions

This study demonstrated that lignocellulosic fractions produced from parks and gardens wastes could be rather considered as filling agents rather than reinforcing fillers, by a preservation of PHBV thermal and mechanical properties, even at high loadings. The best results were obtained by keeping only the fraction constituted of branches, representing 23 wt% of the considered resource. According to results, the chemical composition of fillers seems not to impair the material properties. The use of such filling agents could be thus be interesting to decrease the overall cost pf PHBV-based materials, while giving added value to this lignocellulosic residue.

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References

Faruk, 2012: O. Faruk, A. K. Bledzki, H.P. Fink & M. Sain, Prog. Polym. Sci., **37** (11), 1552-1596 (2012).

Mohanty, 2002: A. K. Mohanty, M. Misra, L. T. Drzal, J. Polym. Environ., **10** (1-2), 19-26 (2002).

Berthet, 2015: M. A. Berthet, H. Angellier-Coussy, D. Machado, L. Hilliou, A. Staebler, A. Vicente & N. Gontard, Ind. Crop. Prod., 69, 110-122 (2015).

Berthet, 2016 : M. A. Berthet, H. Angellier-Coussy, V. Guillard & N. Gontard, J. Appl. Polym. Sci., 42528, 1-18 (2016).

Lammi, 2018: S. Lammi, N. Le Moigne, D. Djenane, N. Gontard & H. Angellier-Coussy, Ind. Crop. Prod., 120, 250-261 (2018).