PREPARATION OF POPLAR WOOD PLASTIC REINFORCED COMPOSITES: INFLUENCE OF TENSION AND NORMAL WOOD FIBRES ON DEFIBRIZATION AND MECHANICAL PROPERTIES

BEAUGRAND Johnny[1], DOBOSZ Simon[1], CLAIR Bruno[2]

[1]INRA, UMR 614 - Fractionation of Agricultural Resources and Environment, Reims, France

[2]CNRS, UMR 5508 - Laboratoire de Mécanique et Génie Civil (LMGC), Université Montpellier 2, France

Introduction

Wood Polymer Composites (WPCs) are mixtures of a polymer matrix with a wood filler fraction, like sawdust. However, the reinforcement given to the matrix is negligible in almost every end-use product. The biological and mechanical properties of tension wood[1] are currently explored, notably in poplar[2], and may lead to WPC with enhanced mechanical properties. In this study, we focused on mechanical properties of composites made of PolyCaproLactone (PCL) filled with 20%w Normal Wood (NW) or Tension Wood (TW) fraction, either in a sawdust condition (fibre bundles) or fibre units individualized thanks to a thermochemical treatment (Kraft pulping). We also studied fibres characteristics such as aspect ratio (L/D for Length/Diameter) and the surface free energy that modulates the adhesion with the matrix. Finally, we used the Hirsch Model to estimate the intrinsic Young's Modulus of the fibres in composites, which can not be determined experimentally.

Experimental

-Fibres: Poplar Normal Wood (NW) and Tension Wood (TW).

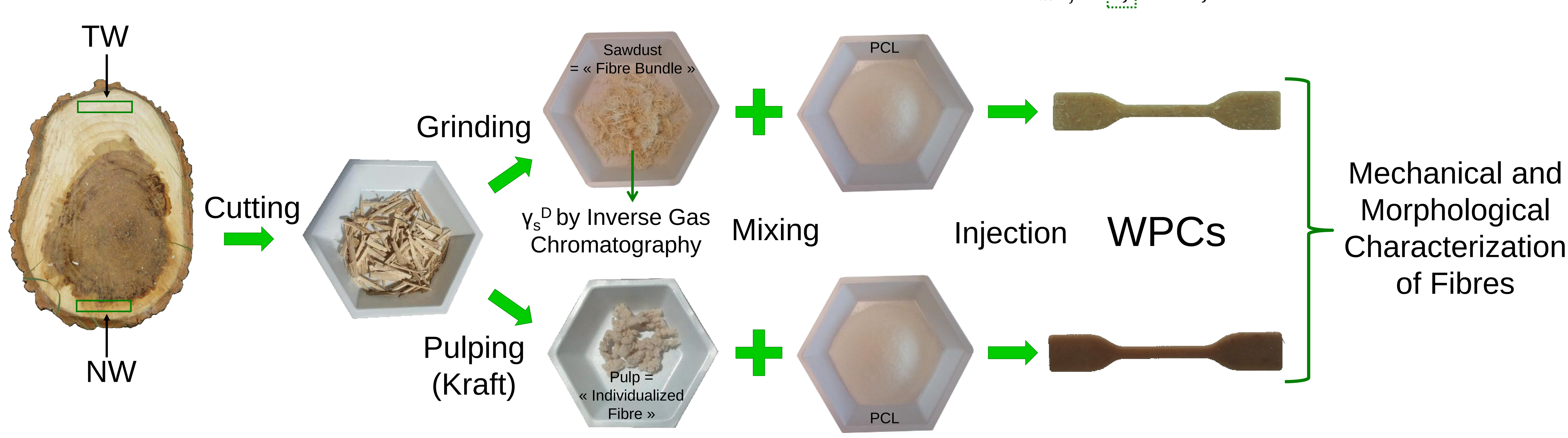
-Matrix: PolyCaproLactone (PCL) was selected to ensure a satisfactory compatibility with the hydrophilic fibres.

-Process: Fibre bundles (sawdust obtained from dry-grinding) or individualized fibres (Kraft pulped) were mixed (20%w) with PCL using a laboratory scale single screw extruder. The extruded compound produced has been then injected into standard dumbbell specimens.

-Characterizations: Tensile properties in uniaxial extension were measured on PCL/Wood fillers (sawdust or individualized) dumbbell specimens; Inverse Gas Chromatography was only done on sawdust samples, the Kraft pulping method preventing reliable measurement on individualized fibres.

-Hirsch Model[3]: The Young's Modulus of the fibres in composite can be predicted using a micro-mechanics approach and based on the Rule of Mixture. Here E_f = Young's Modulus of the fibres used.

$$E_c = \beta\left(\boxed{E_f} V_f + E_m(1-V_f)\right) + (1-\beta) * \frac{\boxed{E_f} E_m}{E_m V_f + \boxed{E_f}(1-V_f)}$$



Results

Legend :

- NW Bundle of fibres
- TW Bundle of fibres
- NW Individualized fibres
- TW Individualized fibres

Means not sharing a common letter within the same graph are significantly different (Student Test, p=95%), a>b>c>d

Fig. 1 a

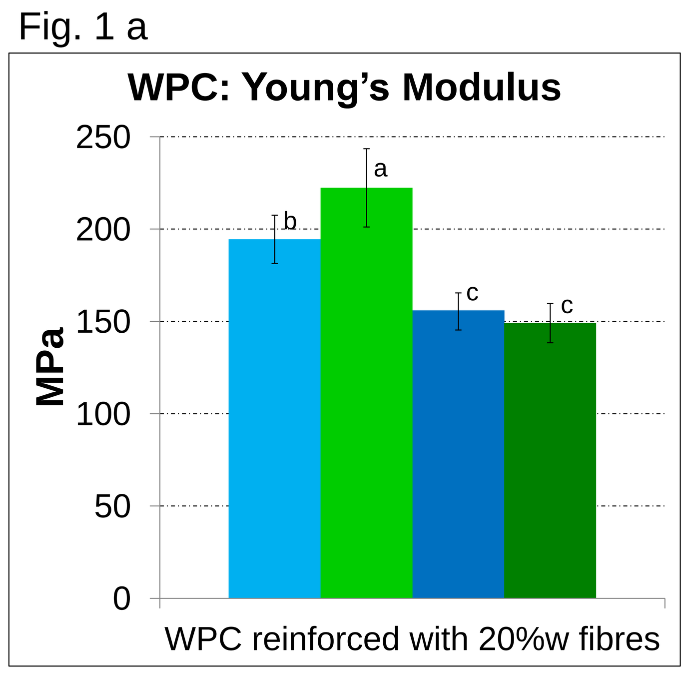


Table 1

	State	NW Bundles	TW Bundles	NW Indiv. Fibres	TW Indiv. Fibres
L (µm)	Raw	2486	5175	712	772
	WPC	316	465	589	594
D (µm)	Raw	102	82	17.3	17.1
	WPC	46	35	16.7	19.3
L/D	Raw	24.4	63.1	41.2	45.1
	WPC	**6.9**	**13.3**	**35.3**	**30.8**

Fig. 3

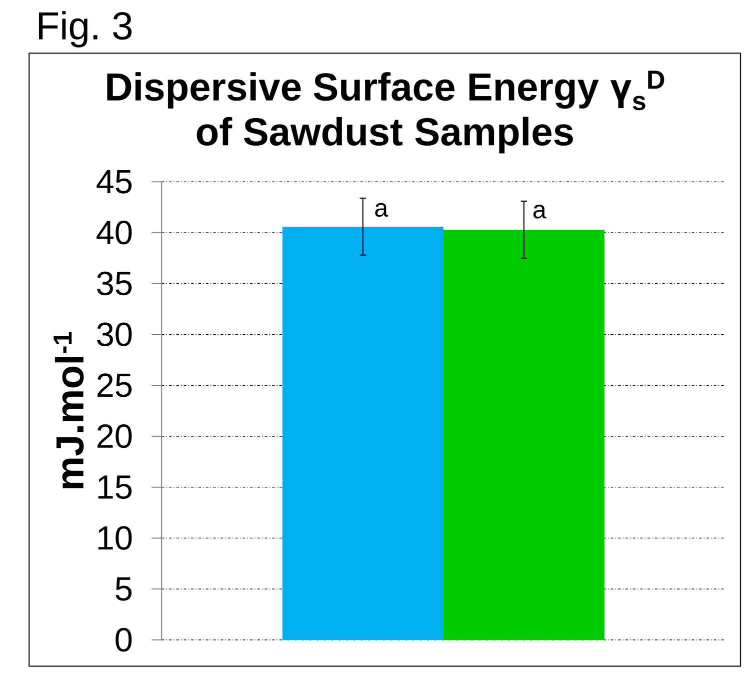


Fig. 1 b

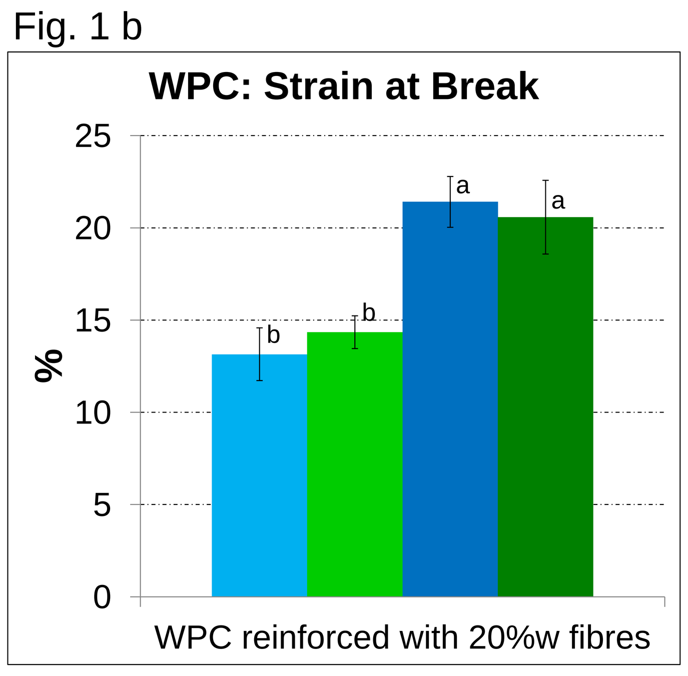


Fig. 1 c

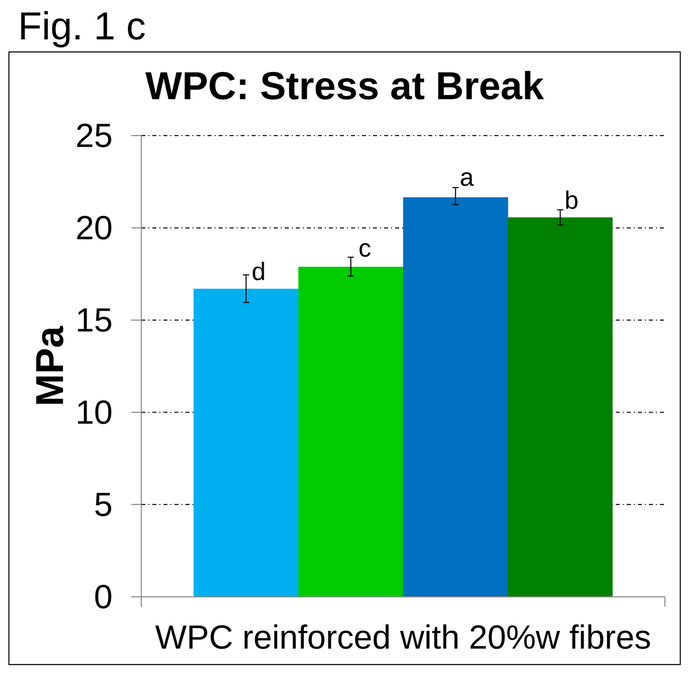


Fig. 2

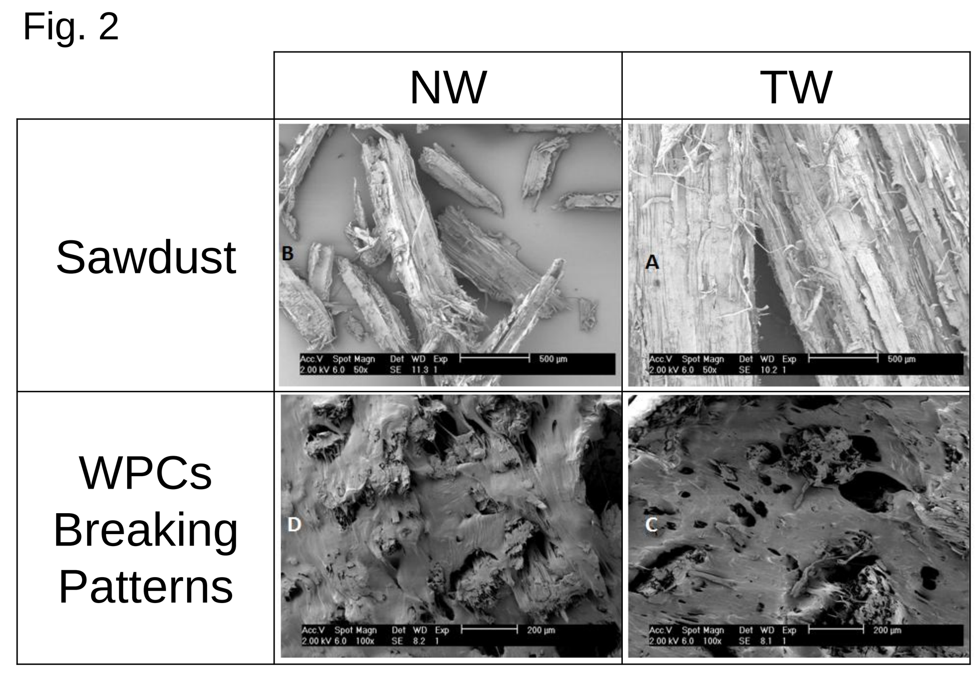
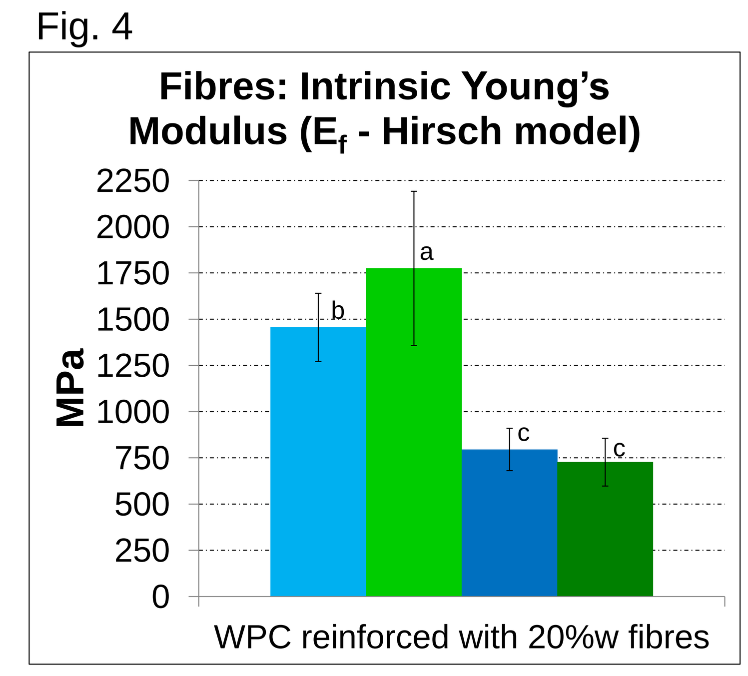


Fig. 4



Conclusions

The main factor explaining the higher Young's modulus and Stress at break (Fig. 1) brought by TW is its aspect ratio (L/D)[4] which is twice as high as the one of NW (Table 1). TW sawdust tends to be more fibrous whereas NW tends to be more powdery (in accordance with SEM observations, Fig. 2), suggesting a different defibrization mechanism or rupture pathway. Regarding the surface properties of sawdust samples, no differences that could suggest a better adhesion of TW with the matrix were determined (neither by measuring the dispersive surface energy by IGC Fig.3, nor by observing the breaking patterns on SEM, Fig. 2). Finally, the results obtained from modeling (Hirsch model) show that bundles of fibres have a better intrinsic Young's Modulus (Fig. 4) in composites compared to individualized fibres, moreover TW bundles seem to be higher than NW bundles. This is arguably a second factor, with the higher L/D ratio aforementioned, explaining the reinforcement observed in WPC made of TW sawdust.

[1]Clair B., Ruelle J., Thibaut B. Relationship between growth stresses, mechano-physical properties and proportion of fibres with gelatinous layer in chestnut (Castanea Sativa Mill.). Holzforschung, 57(2), 189-195.
[2]Fang C.H., Guibal D., Clair B., Gril J., Liu Y.M. & Liu S.Q. Relationships between growth stress and wood properties in Poplar I-69 (Populus deltoides Bartr. cv."Lux" ex I-69/55). Annals of Forest Science, 65, 307.
[3]López J.P., Méndez J.A., El Mansouri N.-E., Mutjé P. & Vilalesca F. Mean intrinsic tensile properties of stone groundwood fibers from softwood. BioResources, 6(4), 5037-5049.
[4]Beaugrand J. & Berzin F. Lignocellulosic fiber reinforced composites: influence of compounding conditions on defibrization and mechanical properties. Journal of Applied Polymer Science, published online ,DOI: 10.1002/app.38468i