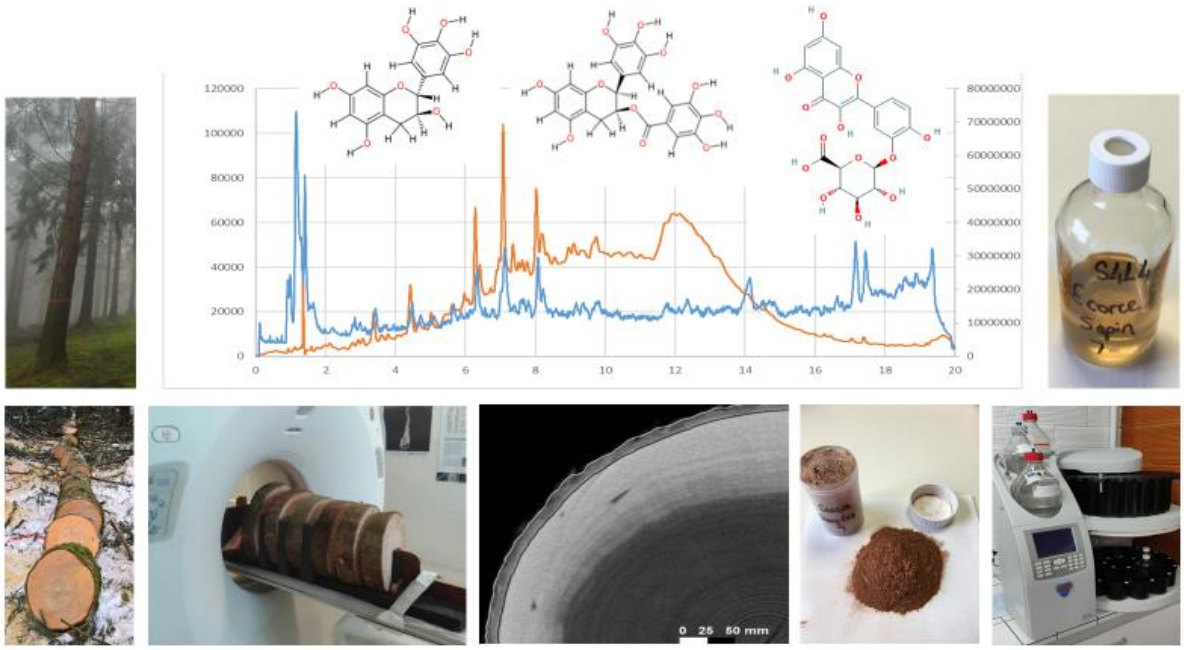
Bark-Tan-Bio



Within- and between- tree biodiversity of softwood bark tannins

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Context — With an annual harvest of softwood bark biomass in Europe estimated to be 25 million m^3 from round wood softwood production (EUROSTAT, 2015), there are potentially ways to use a part of this bark for producing bio-materials and bio-molecules, rather than in energy or horticultural growing media as it is currently. The large chemical biodiversity found in these forest resources however, must first be determined in order to identify the bark fractions richest in marketable bio-molecules. This chemical biodiversity occurs between species, between trees, or even within bark such as between the tree top and stump, and depends finally on the genotype, stand silviculture and climatic factors (Laasasenaho et al., 2005; Li and Weiskittel, 2011; Kohnle et al., 2012).

Objectives — The project aimed to quantify the biodiversity in bark bio-molecules, especially for detecting the fractions richest in amount, and in condensed tannins suitable for producing insulating foams, adhesives and epoxy resins.

Approach — Norway spruce, silver fir and Douglas fir were selected as particularly representative of the regional forest resources, and which processed in regional wood industries, producing local sources of bark by-products. Eight trees of each species were sampled in experimental stands of National Forest Service (ONF) within two treatments (control and heavy thinning). Trunk slices with or without branches attached were recovered at given heights below or above crown base. Bark thickness, tree bark volume, bark basic density, bark biomass, extractive yields at different heights with "green" solvent (hot water + ethanol (50/50)), and extractive quantities in tree bark were analysed or estimated.

Key results — The average and maximal yield of extractives (in % of the dry bark biomass) reach surprisingly large values, larger than those referenced in the literature: 21.5% and 34.4% on Silver fir, 20.4% and 44.5% on spruce, 22.2% and 38.4% on douglas fir. We observed a general yield decrease with relative distance from tree top (RDT) but conversely a general increase of polyphenols. This probably reflects a significant quantity of sugars at the tree top. In the extracts recovered, the main components are the quinic acid (up to 2.8% of the extracts) and

the gallocatechin (up to 1.5%) on Silver fir, the piceatannol-3-O-glucoside (up to 8%) and a not yet identified component (up to 1%) on spruce, the taxifolin (10% on average up to 60% at tree base) and the eriodictyol (up to 2,5%) on douglas fir. Tannins are present with percentages (of the extracts) between 70 & 90%; their precise composition is under analysis. Calibration relationships between NIRS and bark extracts have been established by CRITTBois.

On average, bark densities were larger than knot-free wood densities for the three species: Norway spruce (453 vs 353 kg/m3); silver fir (514 versus 374), Douglas fir (443 versus 429); bark densities decrease slightly with RDT in silver fir, whereas in spruce we conversely observed a slight general increase starting at 10% of RDT and a short decrease before this 10%. In Douglas fir a general sigmoidal increase in bark density; under 25% of RDT bark densities were observed under the knot-free wood density. In Douglas fir, the proportion of taxifolin increases with RDT.

Main conclusions including key points of discussion — We have quantified the biodiversity of global yield, composition of bio-molecules present, quantities of global extractives or of certain chemical families, between species, between trees in the same species and within trees between the upper and lower bark fractions. There are obviously specific bark fractions that are richer than others for specific compounds e.g.taxifolin in Douglas fir tree bases. This highlights the need for carefully identifying and sourcing the bark fractions which are richest for in the most suitable molecules for the chemical industries. Only these fractions should be prioritised for use in the chemical industries rather than as fuel or horticultural media. Bark by-products must be then collected in specific industrial plants that would have to eventually sort the bark of the different species processed (e.g. silver fir and spruce barks which are generally mixed so far).

Future perspectives — In ExtraFor_Est which included Bark-Tan-Bio up to 31 December 2019, bark of oak and beech is currently analysed as well as other fractions as knots, sapwood, heartwood and branch wood of all the above-mentioned species. Thanks to the national bark thickness database compiled and managed by FCBA, which is a partner in the project, statistical relationships have been established that provide the trunk bark volume (BV) as a function of D130 and H the tree height, with or without bark thickness at 1.30 m (BTBH) introduced, which was found to be dependent on elevation (alt). silver fir and Norway spruce: $BV=a\cdot D130\cdot BTBH\cdot H$ with $BTBH=(d.alt+e).D130^{f}$; Douglas fir: $BV=a\cdot DBH\cdot BTBH\cdot H+b$ with $BTBH=(d.alt+e)\cdot DBH^{(f.(g.alt+h)+i)}$. Such relationships are also in preparation for oak and beech.

ExtraForEst is currently making it possible to move from the tree to the regional resource in extractives, thanks to collaboration with the IGN. On the basis of the figures given above and data from the National Forest Inventory, the annual harvest estimates are as follows (2014-2018 period). In Burgundy Franche-Comté, for each of the 3 species, the 51 to 55,000 T of bark harvested can provide about 11,000 T of total extractives, while in Grand Est, the values are more contrasted: for Douglas fir, the 15,000 T bark biomass harvested can provide 3,000 T of extractives; for Silver fir: 54,000 T → 12,000 T; for Norway spruce: 70,000 T → 14,000 T. We then examine the forest-wood chains with the CAT (Carbon accounting Tool [Pichancourt et al., 2018]) software and its conversion to Chat (Chemicals accounting tool), simulating the by-product flows.

Valorization —

Presentations

La conférence internationale WoodChem (2017 et 2019), la conférence IUFRO WoodQC les 12-17 juin 2016 au Québec, les journées du GDR Bois (Cluny 2018, Epinal 2019), les journées du réseau EFPA « CaQsis » (2016 au CNRS CEFE, Montpellier 5-7 avril ; 2018 PIAF de Clermont Ferrand 27-29 mars ; 2019 IRSTEA Aix en Provence 26-28 mars) ; 21st International Nondestructive Testing and Evaluation of Wood Symposium» 24-27 septembre 2019 à Freiburg ; journée du Labex Arbre en 2018 et février 2020

Publications

Pichancourt JB et al., 2020. Supporting decision-making for the sustainable supply of species-based molecular products: the case of the Silver Fir bioeconomy in the French Grand-Est region (in preparation)

Rodolphe Bauer, Fleur Longuetaud, Frédéric Mothe, Alain Bouvet, Antoine Billard, Francis Colin, 2020. Models of bark volume and biomass for French ressource of Norway spruce, Silver fir and Douglas fir (in preparation for Biomass & Bioenergy)

Antoine Billard, Rodolphe Bauer, Frédéric Mothe, Mathieu Jonard, Francis Colin, Fleur Longuetaud, 2020. Taking into account within-tree density variations helps to improve biomass estimates by reducing biases (in preparation for Biomasse & Bioenergy)

Maree Brennan, Clément Fritsch, Sylvain Cosgun, Stéphane Dumarcay, Francis Colin, Philippe Gérardin, 2020. Yield and compositions of bark phenolic extractives from three commercially significant softwoods show intra- and inter-specific variation (redaction completed for submission to Forest Ecology & Management)

Maree Brennan; David Hentges; Sylvain Cosgun; Stephane Dumarcay; Francis Colin; Christine Gerardin; Philippe Gerardin Pichancourt JB et al., 2020. Intra- and inter-specific variability of extractive composition of knotwood from three industrially important softwood species (submitted)

Maree Brennan, Clément Fritsch, Sylvain Cosgun, Stéphane Dumarcay, Francis Colin, Philippe Gérardin, 2019. Quantitative and qualitative composition of *Abies alba* bark polyphenols according to longitudinal position, Annals of Forest Science (accepted).