# Progress and challenges in valorisation of biomass waste from ornamental trees pruning through pyrolysis processes. Prospects in the bioenergy sector

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## Introduction

The increase in the world population as well as the better quality of life have caused an increase in energy demand. Currently, the energy industry is responsible for approximately three quarters of greenhouse gas emissions, so it holds the key to limiting the most serious effects of climate change (Sokołowski, 2022). Therefore, it is necessary to look for more sustainable alternatives for energy production. In this context, a greater interest in the energy use of forest, agricultural or urban lignocellulosic residues was favoured as renewable sources of energy and raw materials that can replace fossil fuels (coal, gas and oil).

The objective of this work is to investigate the possibilities of energy and environmental recovery of biomass residues from the forestry sector from the pruning of ornamental trees in the north of Spain. The valorisation of these wastes will be carried out through conventional and flash pyrolysis at high temperature (PC and PF, respectively), being an alternative to its incineration or accumulation in landfills. The tree pruning residues and bioproducts obtained after the pyrolysis process (bio-char, bio-oil and gas) will be characterized, and their possible use as fuel, raw material in the chemical industry or precursors of adsorbent materials will be evaluated.

## Methodology

Two lignocellulosic residues from spring pruning of ornamental trees were selected (Horse Chestnut (CI) and False Acacia (FA)). The collection of lignocellulosic waste was carried out by random sampling to guarantee its representativeness. The residues were characterized by proximate and ultimate analysis, inorganic composition, calorific value, morphological and thermogravimetric analysis in order to know their physical-chemical properties.

The pyrolysis experiences were carried out in an electric, cylindrical and horizontal oven of original design. In PC, the sample was introduced into the oven at room temperature; after inerting the interior atmosphere of the reactor, the furnace programming began: heating ramp of 25°C/min, pyrolysis temperature of 750°C or 850°C and 1 hour stay at the pyrolysis temperature. In PF, the sample was instantly introduced into the oven when it reached working temperature (750 °C or 850 °C). In both pyrolysis processes, a $N_2$ flow of 100 ml/min was maintained.

After the pyrolysis process, three fractions were obtained: solid fraction (bio-char), liquid fraction (bio-oil) and gas fraction (gas). Bio-char, bio-oil and gas were characterised with different analysis techniques in order to study their possible energy uses, as raw material in the chemical industry or as adsorbent precursor.

## Results

The pruning residues presented moderate moisture content (7.96-7.52%), high carbon content (≈ 49%) and low ash content (2.85-1.81%). The composition of its ashes is constituted mainly by calcium (CaO>50%), which is characteristic of tree species and there is no presence of heavy metals.

The yield of bio-char, bio-oil and gas obtained in the pyrolysis processes, can be seen in **Figure 1**. The gas yield was always the highest, regardless of the biomass or the type of pyrolysis, reaching values of up to 70% in the FP of the Horse Chestnut.

Biochars have high heating values (HHV) (28.4-29.8 MJ/kg) so they could be used as fuels. They could also be used as adsorbent precursor or as additives to fertilize the soil, given their high carbon content, low ash content, and absence of heavy metals. A similar behavior was found in the biochars obtained from PC and PF from pomegranate (Punica granatum L.) peel wastes (Saadi, 2019). The SEM images taken of the bio-char obtained from flash pyrolysis at 750°C of FA is shown in **Figure 2**.

All pyrolysis bio-oils contain aromatic organic compounds (≥80%). PC bio-oils contain mainly simple aromatic hydrocarbons, with phenols being the most abundant (≥ 60 %) and the presence of PAHs is almost non-existent (≤ 0.25 %). PF bio-oils contain up to 95% PAHs (naphthalene, fluorene, anthracene, etc). These Bio-oils have great potential for the synthesis of organic compounds.

FP gases contain a high volume (%) of combustible gases (CO, $CH_4$, $H_2$) and low amounts of $CO_2$, which is why they reach HHV up to 18.06 MJ/kg. PC gases have very high concentrations of $CO_2$. Similar behaviour was found in the gases obtained of the PC and PF of the invasive species Cortaderia selloana (Pérez, 2021).

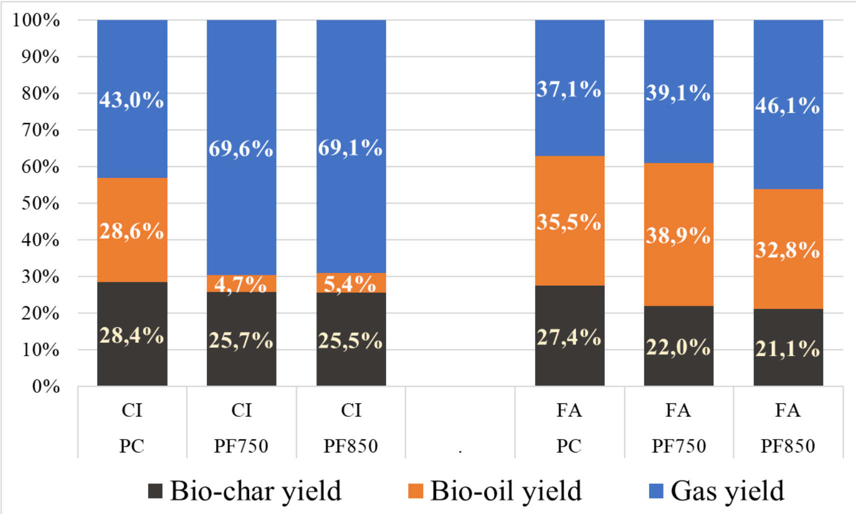


***Fig. 1.*** *Yield of bio-char, bio-oil and gas fractions in the different pyrolytic processes of CI and FA.*

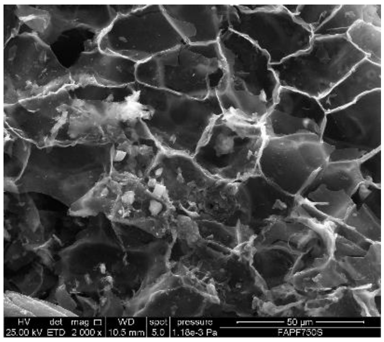

***Fig. 2.*** *Bio-char obtained from flash pyrolysis at 750°C of FA*

## Conclusions

The chemical properties of pruning residues make them appropriate to be used as raw material in pyrolysis processes and to obtain biofuels. Pyrolysis will be highlighted as a sustainable process for the energy use of biomass residues from the forestry sector from the pruning of ornamental trees, avoiding environmental problems derived from residues and using them as raw material to obtain products with high added value (biofuels, biomaterials). All this framed in a more respectful scenario with the environment. PF is the most pyrolysis technology easily scalable method at an industrial level.

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