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INFLUENCE OF FEEDSTOCK AND OPERATIONAL CONDITIONS ON BIO-CHARS DERIVED FROM THE PYROLYSIS OF SELECTED BIOMASSES

RE·CORD

UNIVERSITÀ DEGLI STUDI FIRENZE

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INTRODUCTION

Biochar is an excellent soil amendment due to its ability to regulate the availability of water and nutrients. A clear relationship between the nature of the biomass, pyrolysis conditions and the properties of the biochar obtained is currently missing.
In this study, biochars obtained by slow pyrolysis process were produced varying lignocellulosic feedstock typology and the process conditions.

MAIN GOALS

- To investigate (lab scale) biochar properties versus feedstocks and pyrolysis conditions
- To consider biochar porosity and CEC for use as soil amendment Feedstock

FEEDSTOCK AND PROCESS

FEEDSTOCK

The biomasses used in this study are softwood (pine) and hardwood (poplar and willow) (Figure 1).
The biomasses were collected, decortricated, chopped and characterized in terms of moisture content, ashes and volatiles.

Figure 1: Feedstock typologies

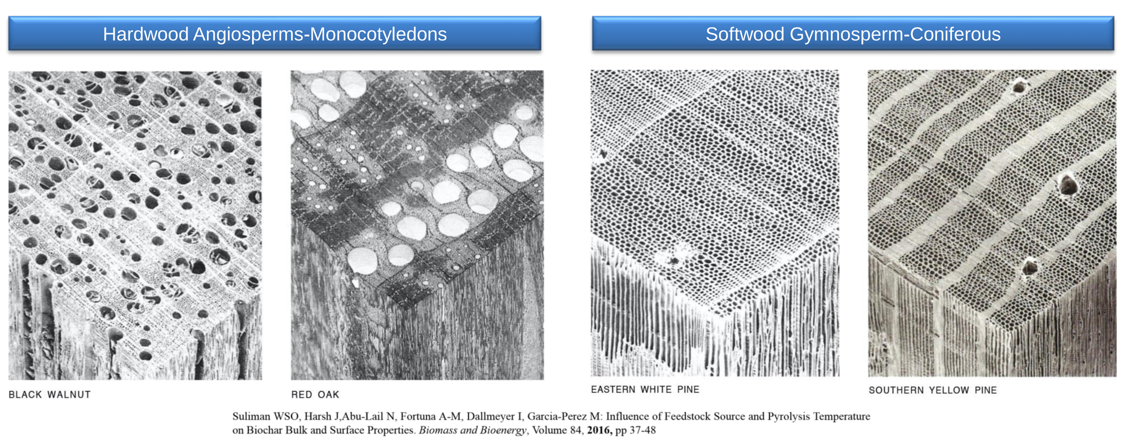


Figure 2: Structure differences in feedstock typologies

METHODOLOGY

The pyrolysis of the biomasses was carried out via macro TGA at three different temperatures: 400, 550 and 650 ° C, obtaining nine biochar samples.

Table 1: Process parameters used for production tests

Temperature [°C]	Heating rate [°C/min]	Plateau [h]	N flowrate [l/min]
400	20	2	10
550	20	2	10
650	20	2	10

The biochar was characterized in composition (CHNSO, ash), functional groups (FTIR), porosity and microstructure (BET, Hg porosimetry, SEM) and cation exchange capacity (CEC).

BIOCHAR YIELD AND ELEMENTAL ANALYSIS

Table 2: Yield in terms of % by weight d.b. for different maximum temperature parameter

	Biochar								
	Pine 400°C	Poplar 400°C	Willow 400°C	Pine 550°C	Poplar 550°C	Willow 550°C	Pine 650°C	Poplar 650°C	Willow 650°C
Yield % w/w d.b.	29,6	29,9	29,2	19,6	19,7	21,2	17,9	18,7	16,9

The H/C ratio is not influenced by the nature of the biomass and is inversely proportional to the pyrolysis temperature.

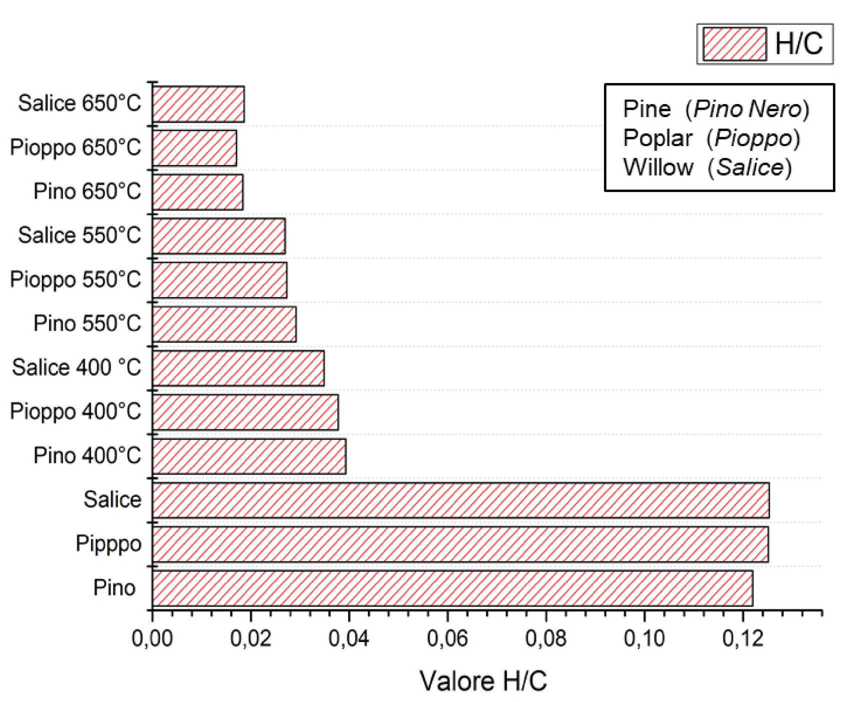


Figure 3: H/C ratio obtained by elemental analysis of feedstock and biochar

POROSITY AND MICROSTRUCTURE

BET SURFACE AREA

The surface area of biochar (BET) increases with increasing pyrolysis temperature, with a more marked effect for pine (softwood) than poplar and willow (hardwood).

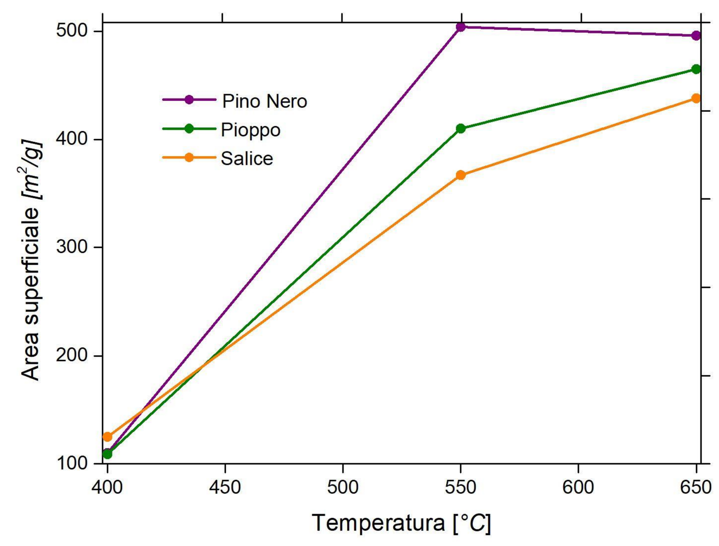


Figure 4: BET analysis showing total surface area obtained in biochar for production test at different process temperatures

MERCURY POROSIMETER

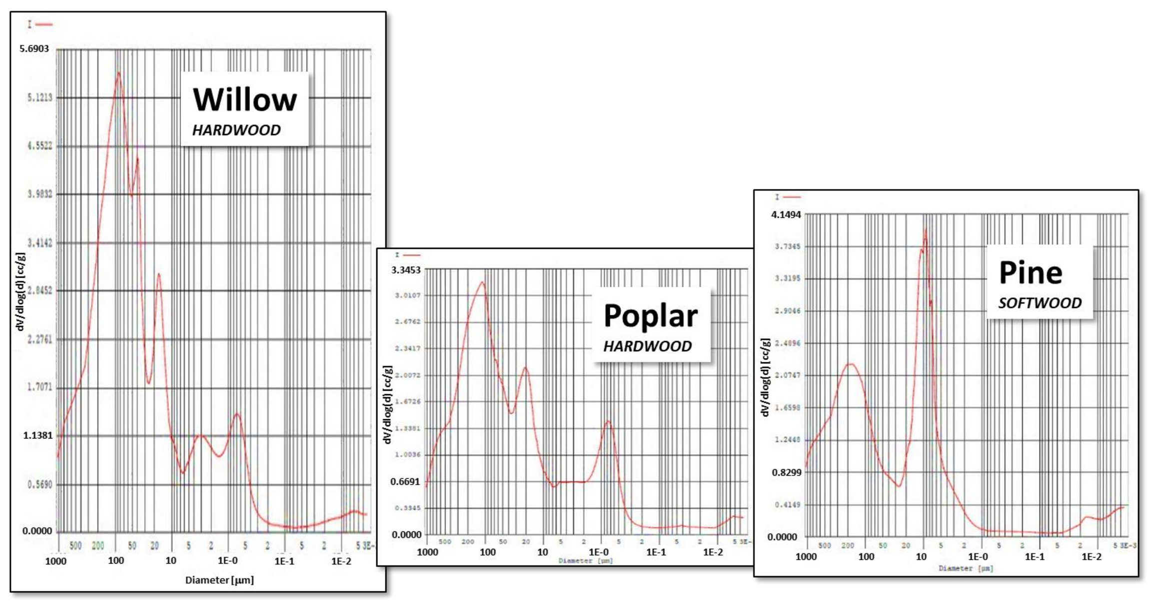
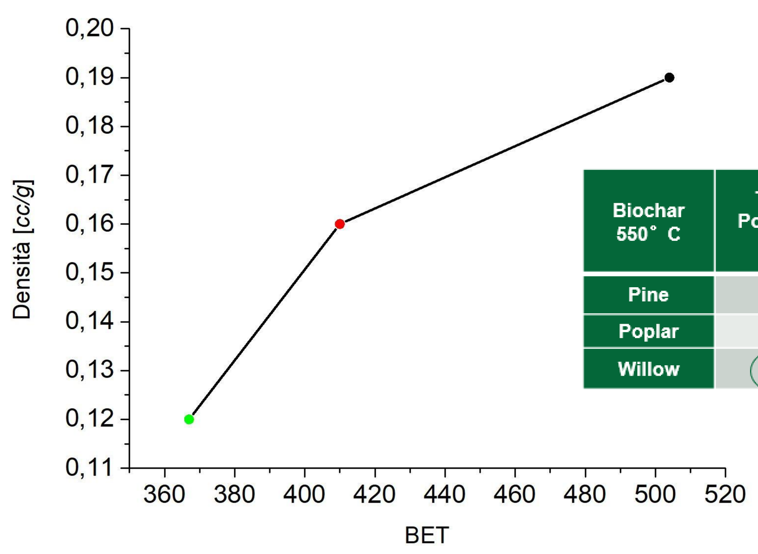


Figure 5: Mercury porosimeter analysis for different feedstock tested

Table 2: Results of different total surface analysis

Wood	BET - Specific Surface (m2/g)	Mercury Porosimeter - Surface Area (m2/g)	Mercury Porosimeter -Total Intruded Volume (cc/g)
Willow	367	97.16	7.69
Poplar	410	78.85	5.33
Pine	504	126.86	4.53



Biochar 550° C	Total Porosity [%]	Density [g/cc]	Total intruded volume Hg [cc/g]
Pine	86	0,19	4,5
Poplar	86	0,16	5,3
Willow	91	0,12	7,6

Figure 6: Biochar produced @ 500°C: Pino (●), Poplar (●), Willow (●).

From the comparison between surface area and density it has been verified that biochar derived from willow and poplar are characterized by a high macroporosity and lower density and surface area values than pine. Therefore hardwood, in particular willow, would be better to regulate the availability of water in the ground compared to softwood.

SEM ANALYSIS

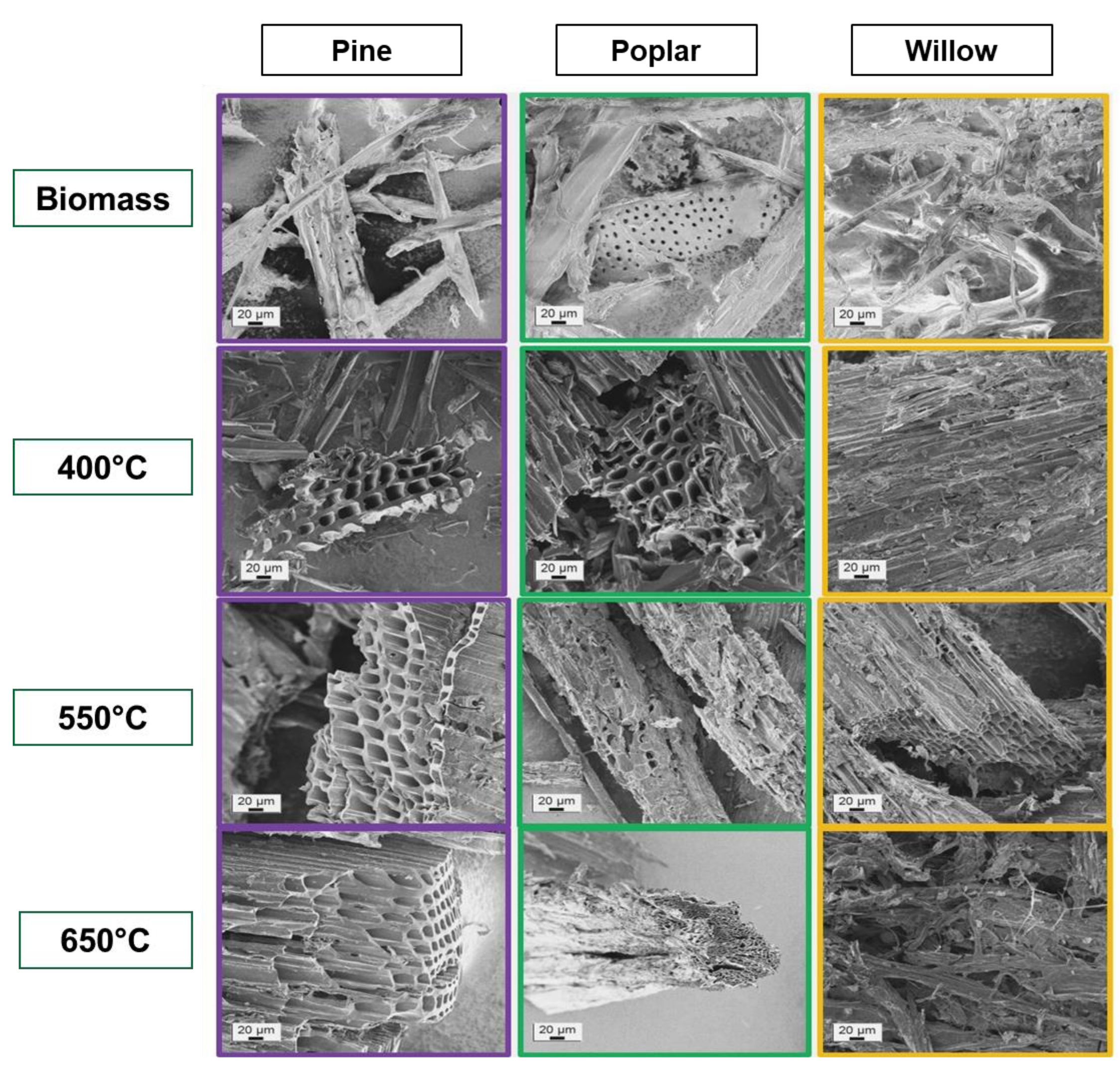


Figure 7: SEM analysis for different feedstock pyrolyzed at different temperature

CEC AND FUNCTIONAL GROUPS

CEC – NH_4^+

Willow, 400 °C: highest CEC-NH4+. Trend in agreement with the reduction of oxygenated functional groups with temperature

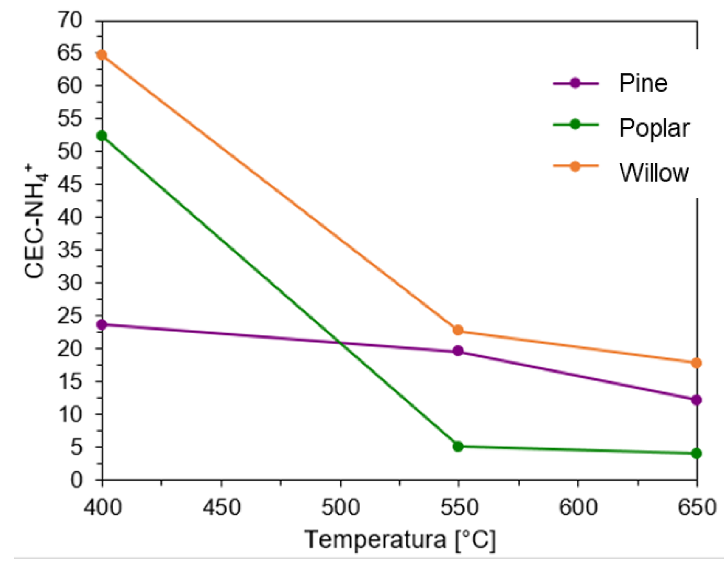


Figure 8: CEC-NH4+ analysis results

Table 3: CEC-NH4+ analysis of biochar obtained by production test at different process temperatures

Sample	CEC-NH_4^+
Pine 400°C	23,7
Pine 550°C	19,6
Pine 650°C	12,2
Poplar 400°C	52,3
Poplar 550°C	5,1
Poplar 650°C	4,1
Willow 400°C	64,7
Willow 550°C	22,7
Willow 650°C	17,8

Criteria for assessment	CEC cmol(+)/Kg
High	> 20
Average	10-20
Low	< 10

The cation exchange capacity is greater for poplar and willow biochar produced at 400 °C than for pine. This result shows a low correlation of CEC with the superficial area; the parameter seems related more on macroporosity than mesoporosity.

FT-IR

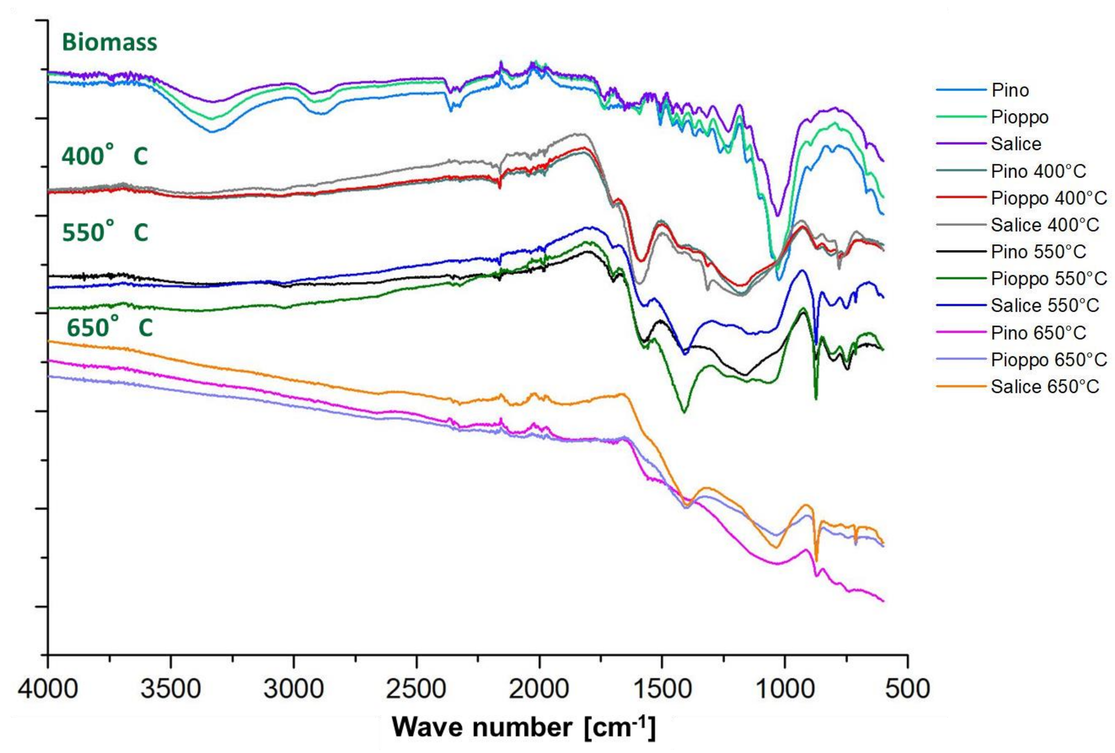


Figure 9: FT-IR analysis of biochar obtained by production test at different process temperatures

CONCLUSIONS AND FUTURE WORKS

RESULTS

Results are in good agreement with literature and expectations:

- Softwood: higher BET surface (550°C).
- Hardwood: more macropores (consistent with wood structure). Better feedstock for plant water available water.
- CEC max at 400°C, decreasing with T (less oxygenated functional groups)

ONGOING R&D WORK

- Investigation of fresh and aged or partially oxidized biochar, both at lab and pilot scale
- Assessment of biochar characteristics vs plant and soil
- Final goal: framing process conditions and feedstock selection in the industrial scale of biochar production

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