# Preparation of activated and N-doped carbons derived from pinecones

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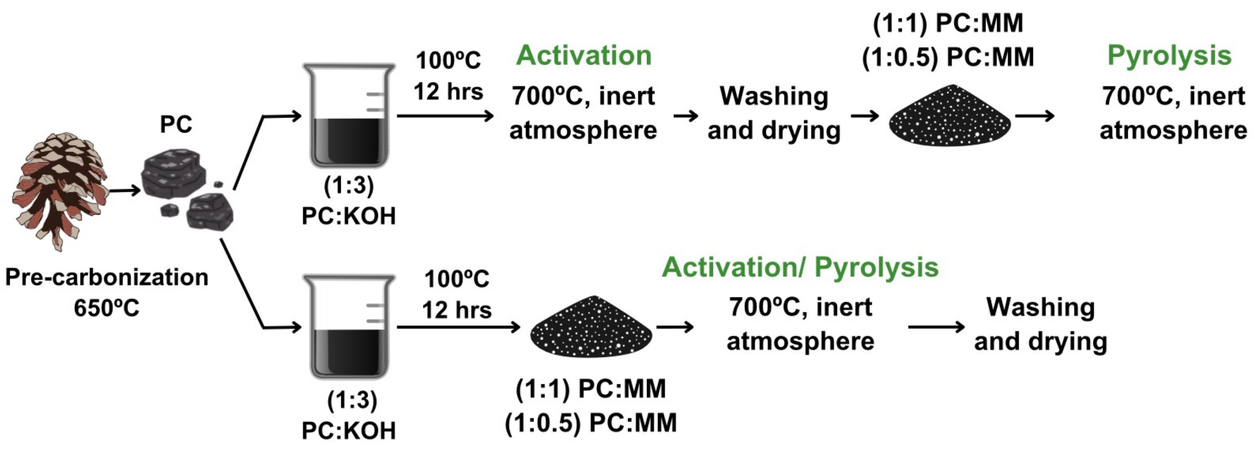
## Introduction

The increasing impact of environmental issues has driven the development of increasingly cleaner and renewable processes and products. Biomass-derived carbons have gained significant attention due to their high specific surface areas, hierarchical porous structures, cost-effectiveness and widespread availability [1]. Given the growing interest in these materials, the substitution of carbon atoms with heteroatoms (N, B, P and S) within the carbonaceous structure emerges as a mechanism to enhance the material's acid-base character. It can also alter the electronic structure of carbon, potentially increasing its electrical conductivity, chemical stability, and electron-donation properties [2]. This study aims to develop carbon materials from pinecones with high surface area, doped with nitrogen.

## Methodology

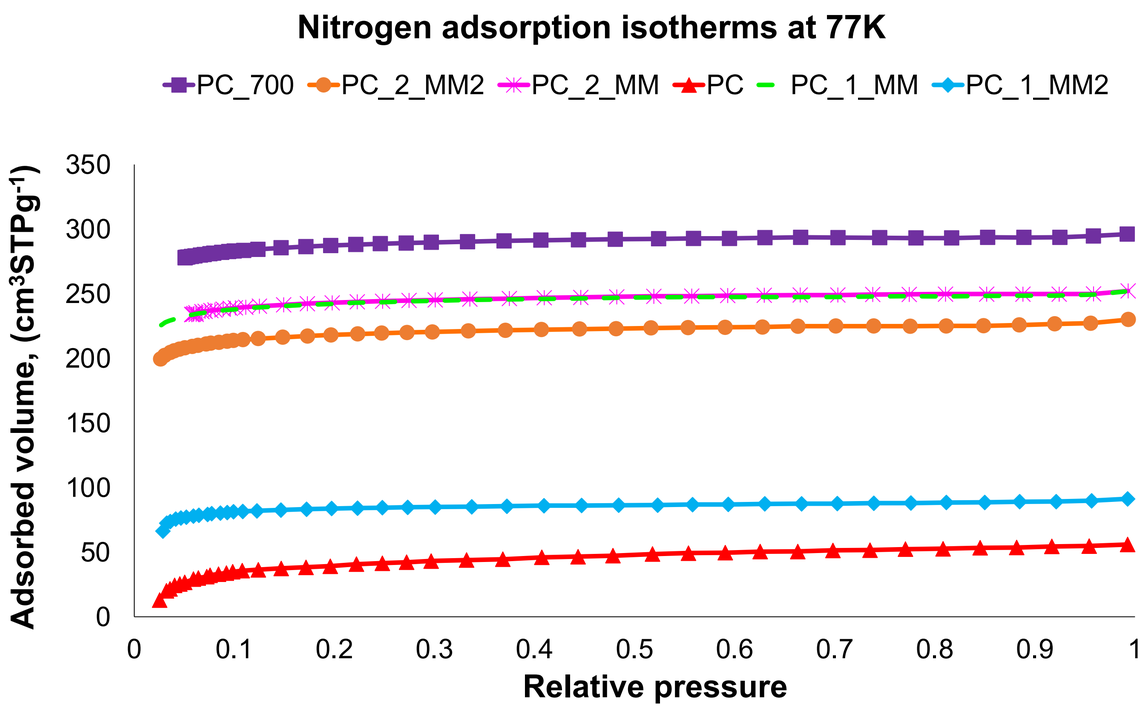
The carbonized material (PC) was activated with potassium hydroxide with a weight ratio PC:KOH of 1:3 and doped with melamine (MM) at different ratios PC:MM in an inert atmosphere.

Carbon materials were prepared using two different processes. In the single-step method, activation and doping were performed simultaneously. In the two-step method, activation was followed by doping.




## Results and discussion

As it can be seen, nitrogen adsorption isotherms are Type I, characteristic of microporous materials.




The results presented in the table show that the introduction of nitrogen leads to a decrease in the specific surface area ($S_{BET}$). Increasing melamine ratio leads to the production of more carbon residues, potentially causing pore blockage and an $S_{BET}$ decrease [3]. Doping with melamine proved to be effective in increasing the nitrogen content. Comparing the preparation methods, it can be observed that the two-step methodology results in higher nitrogen mass percentages. This procedure also allows the use of different temperatures in activation and doping steps. Other studies show that higher activation temperatures and lower doping temperatures lead to materials with increased $S_{BET}$ and nitrogen content [4].

**Textural characterization and nitrogen content**

| Sample | PC:MM | Steps | $S_{BET}$ [$m^2g^{-1}$] | $S_{external}$ [$m^2g^{-1}$] | $V_{micro}$ [$cm^3g^{-1}$] | N [%] |
|---|---|---|---|---|---|---|
| PC | - | 1 | 147 | 18 | 0.06 | 0.50 |
| PC_700 | - | 1 | 1070 | 2.0 | 0.45 | 0.00 |
| PC_2_MM | (1:0.5) | 2 | 904 | 6.9 | 0.38 | 5.30 |
| PC_2_MM2 | (1:1) | 2 | 857 | 6.6 | 0.34 | 4.10 |
| PC_1_MM | (1:0.5) | 1 | 920 | 4.0 | 0.38 | 0.60 |
| PC_1_MM2 | (1:1) | 1 | 322 | 7.2 | 0.13 | 2.32 |

## Conclusions

The biomass-derived carbons prepared have high specific surface areas and nitrogen contents. The two-step procedure leads to better results and seems to be a promising method to prepare these materials.

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