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AGRIMA

Greening Agriculture: Investigating Hidden Risks in Basil-Waste Biochar

Summer Camp | July 7 – 11, 2025 | Marseille, France

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Agri-food Waste Management for Sustainable bio-economy through Higher Education curricula and upskilling

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Goals

AGRIMA aims to foster universities' **capacity building** for the **green transition** through **innovative practices and higher education curricula updating in agri-food waste management** for the **circular bioeconomy**.

AGRIMA addresses:

1. **Advancing pedagogical methods** for industrial agri-food waste valorisation **based on business-academia synergies**.
2. **Integrating citizen science** in bio-economy-enhanced waste valorisation as a means of **civic engagement and environmental advocacy**.

Partners

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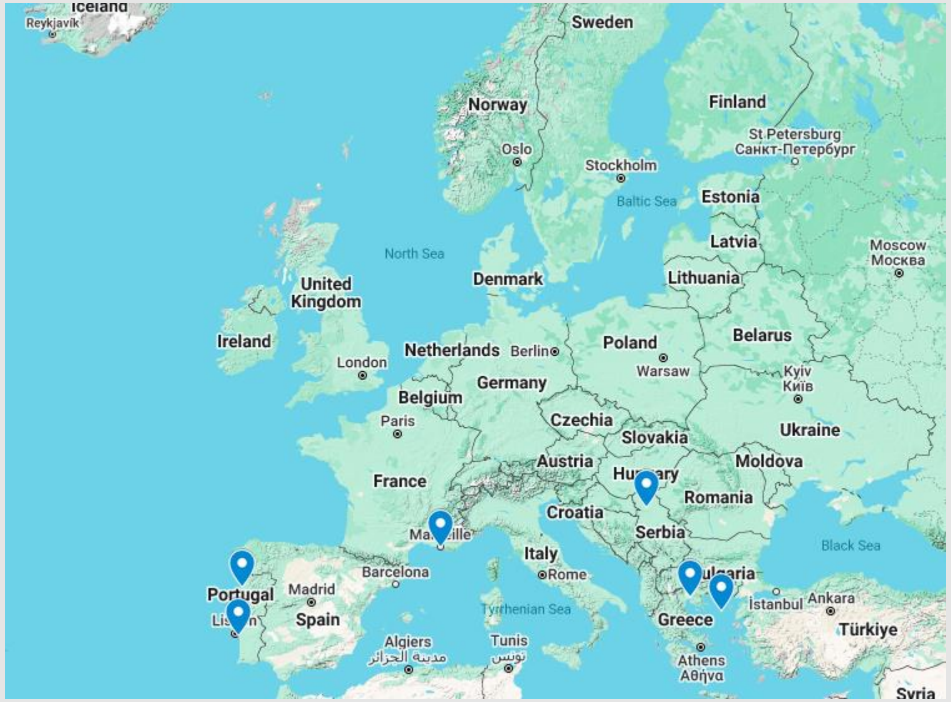

amU Aix Marseille Université

AVIPE Associação de Viticultores do Concelho de Palmela

P.PORTO

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Web2Learn Open, social learning

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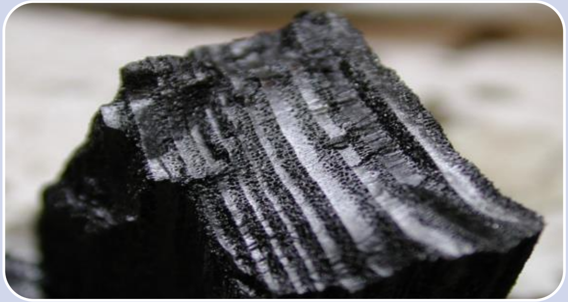
Introduction to Biochar



Definition of Biochar

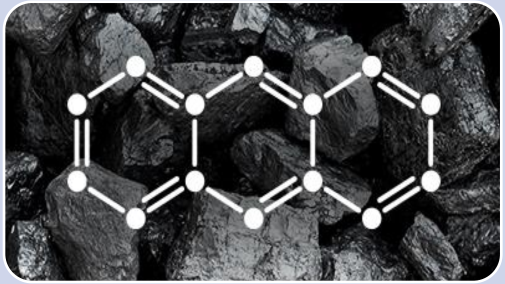
Biochar is a **stable, carbon-rich product** obtained through the pyrolysis of organic materials.

It is known for its **high carbon content, specific surface area, and substantial porosity**, making it a valuable tool for sustainable agriculture.

Production Via Pyrolysis of Agri-Food Waste

Biochar is produced by **pyrolyzing agri-food residues** at elevated temperatures under oxygen-limited conditions.

This process valorizes organic waste into a useful material, supports sustainable waste management, and reduces toxic emissions.



PAHs Formation

During biomass pyrolysis, **Polycyclic Aromatic Hydrocarbons (PAHs)** are commonly formed, mainly due to incomplete combustion of organic material or through transformation reactions. PAHs are toxic environmental pollutants with carcinogenic, teratogenic, and mutagenic properties.

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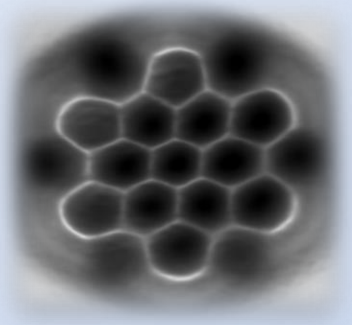
Quality, Safety and Certification



A significant increase in the agricultural use of biochar has been observed since 2015.

Feedstock Selection

Choosing the right **feedstock** can significantly impact biochar quality and safety.

Lignocellulosic-rich materials tend to produce heavier and more toxic PAHs.

Production Conditions

Controlling **pyrolysis parameters** and reactor type is crucial for minimizing toxic compounds.

Higher temperatures favor the formation of heavier and more toxic PAHs, while shorter residence times tend to reduce the total concentration formed.

Certification Compliance

Adhering to standards like **European Biochar Certificate** (EBC), ensures biochar meets quality and safety requirements.

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Problem statement

Is biochar safe for use as a soil conditioner?

1 **Waste Valorisation**

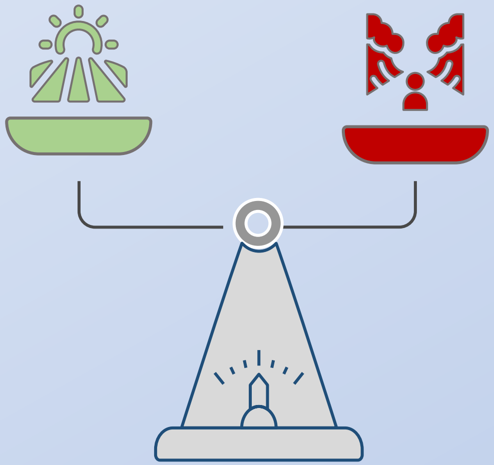
Converts agricultural waste into a valuable soil conditioner, reducing the need for virgin raw materials

2 **Soil Properties Improvement**

Promotes nutrient retention and structural stability; increases water-holding; reduces use of chemical fertilizers; moderates soil acidity.

3 **Circular Economy Promotion**

Supports sustainable resource management; reduces environmental impact (toxic emissions)



PAHs and Heavy Metal Contamination 1

During its production, these toxic and potentially carcinogenic contaminants are generated

Unclear Safety 2

It remains unclear whether the application of biochar as a soil conditioner is safe

Environmental and Health Risks 3

Raises questions about the safety of biochar application

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How to optimize a greener PAHs extraction from biochar?

Although new analytical methods for PAHs are being explored, few studies focus on their extraction from biochar.

Explore ***New Methods***

Focus on **developing innovative analytical techniques** for PAHs extraction

Optimize *Existing Methods*

Adopt **more eco-friendly approaches for PAH quantification** compared to conventional methods that rely on toluene and require extended extraction times

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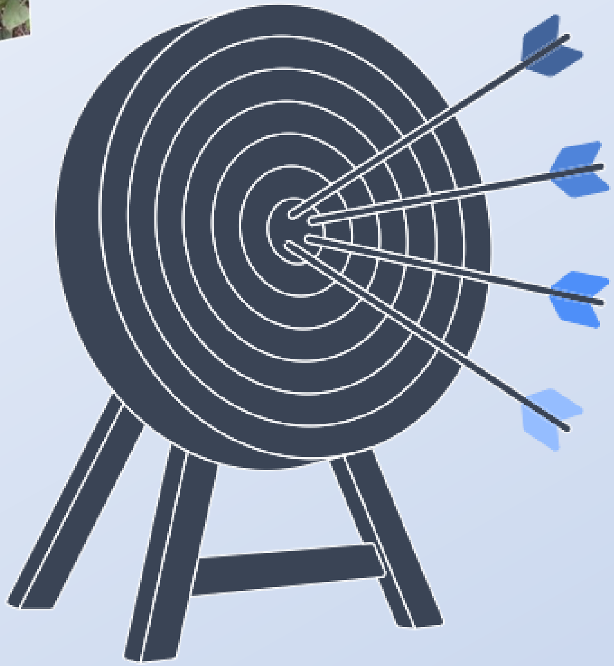
Research Objective

Assessing the Formation of PAHs in basil-derived biochar



Polycyclic Aromatic Hydrocarbons

Assess and quantify16 priority PAHs (US EPA)

Sustainable Extraction Method

Develop a more sustainable extraction method using green solvents

Food Safety and Environmental Health

Evaluate hidden risks associated with its use as a soil conditioner.

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16 Priority PHAs (US EPA)

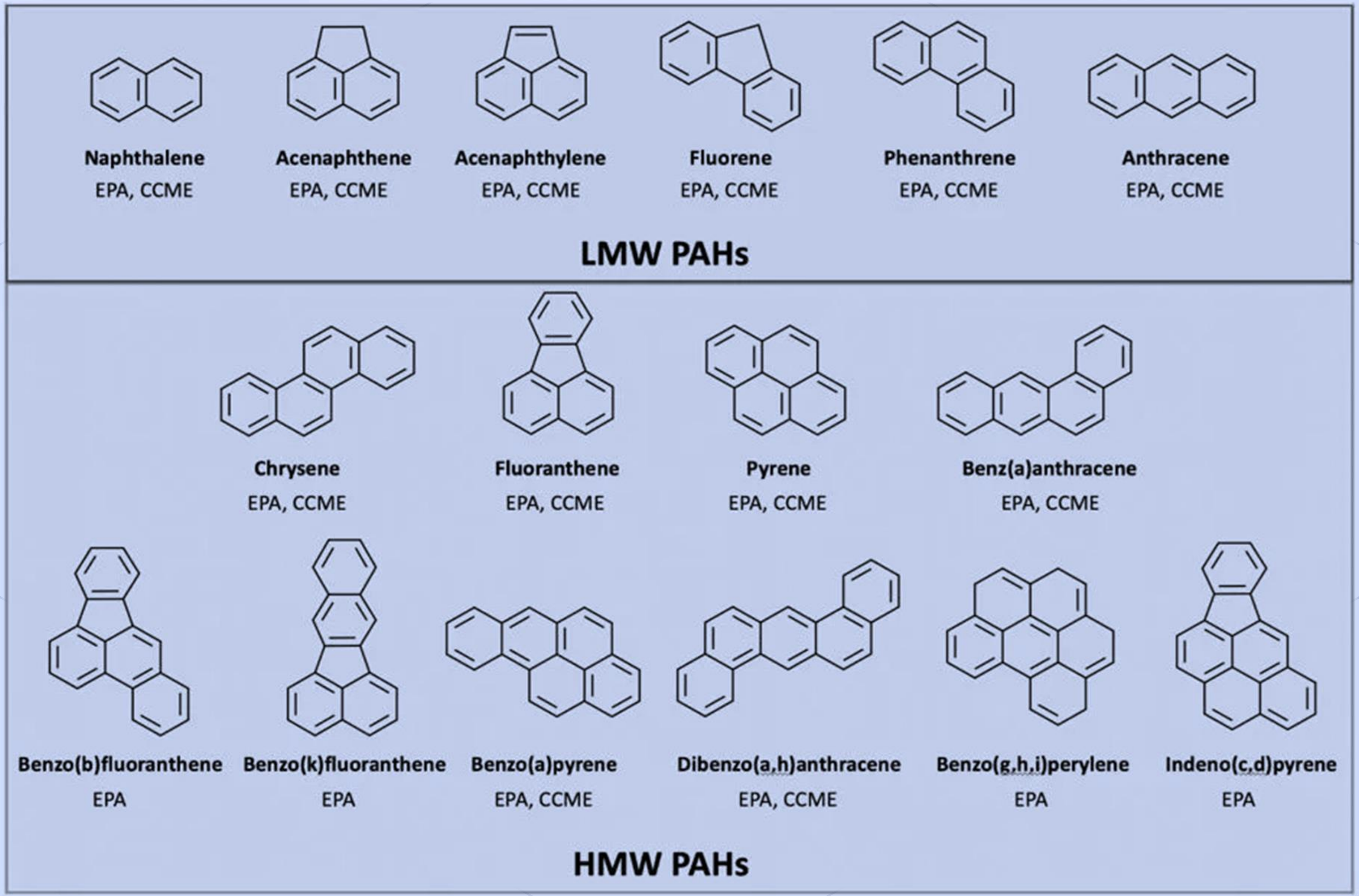

Image from Chemistry Matters

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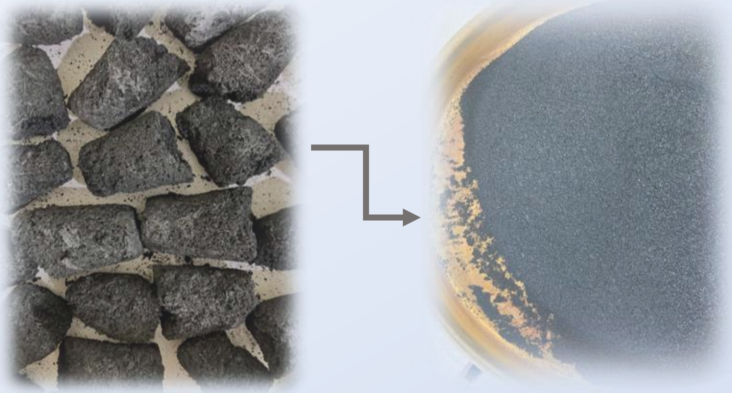
Basil-Biochar Source and Production



Feedstock

- Biochar produced from **basil plant residues** (*Ocimum basilicum L.*)
- Supplied by **REQUIMTE/LAQV**

Production Conditions

- Slow pyrolysis
- Temperature: **500 °C**
- Duration: **14 hours**

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PAHs Experimental Extraction Proceedure

01

Biochar Preparation

02

Ultrasound-Assisted Extraction (UAE)

03

Centrifugation Filtration

04

Concentration (N_2 stream)

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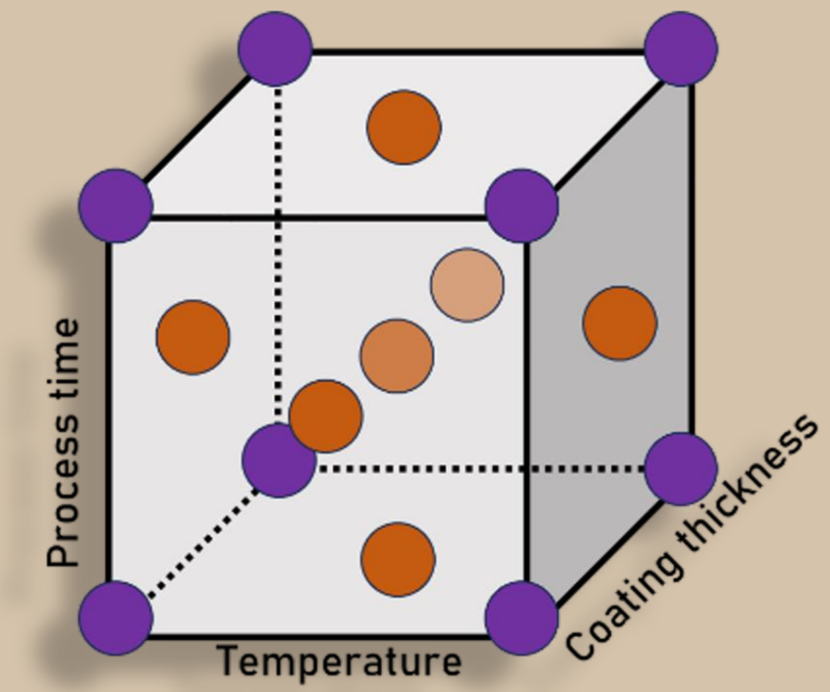
PAHs Extraction Analysis

Design of Experiments



CENTRAL COMPOSITE DESIGN (CCD) FOR OPTIMIZATION

Evaluate the interaction effects of four variables (**solvent type, solvent-to-biochar ratio, extraction time, and temperature**)

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PAHs Extraction Conditions

ULTRASSOUND-ASSISTED EXTRACTION

Solvents Acetonitrile (ACN), Acetone	ACN 20%, 50%, 80%
Ratio S:L [g:mL]	10; 30; 50
Temperature [ºC]	30; 45; 60
Time [min]	15; 37,5; 60

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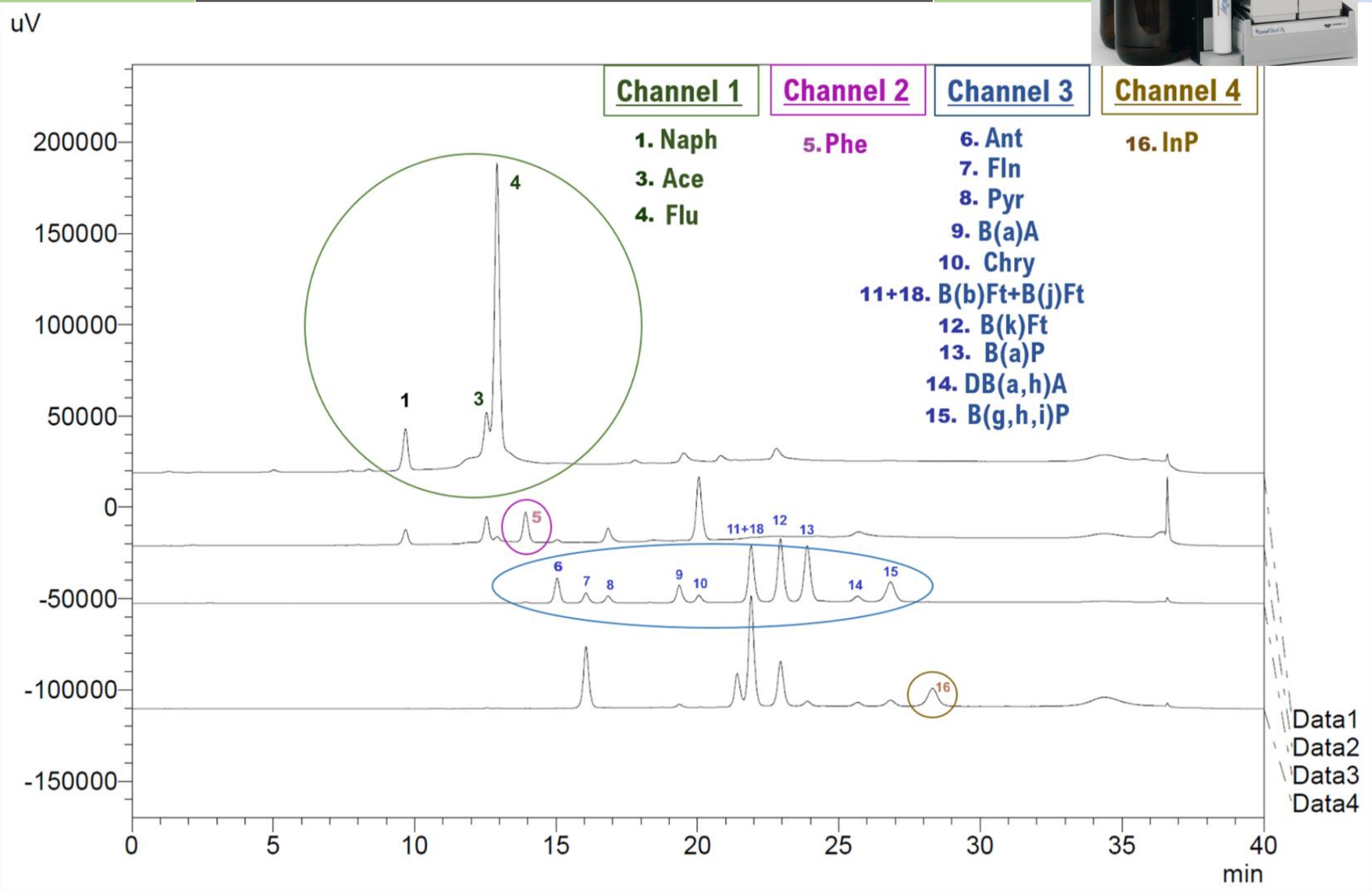
PAHs Data Analysis

- **HPLC-FLD** system analysis with fluorescence detectors.
- Compound separation on a **C18 column** at room temperature (25 ± 1 °C).
- **Mobile phase:**
  50% ACN
  50% Water

Chromatogram of a Basil-Biochar Sample



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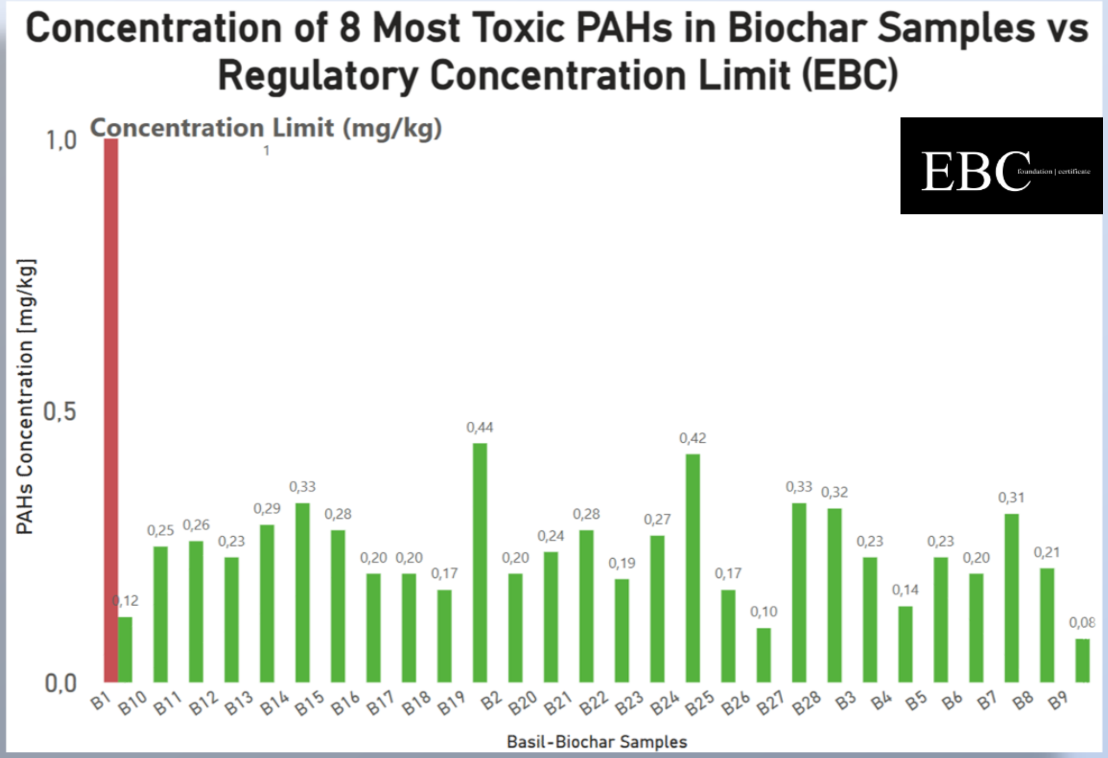
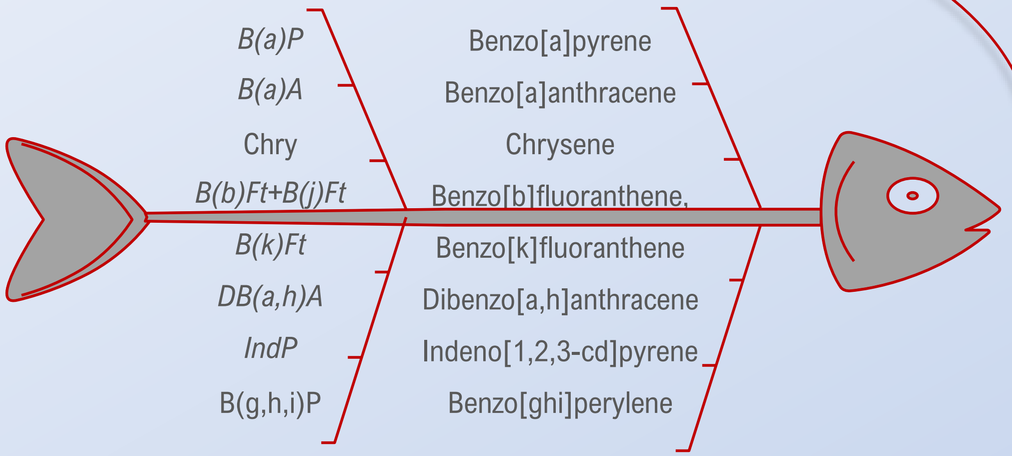
Results

PAH Concentrations vs. EBC Limits

Quantitative analysis of the biochar samples revealed that the sum of the concentrations of the 8 most toxic PAHs, as identified by the *European Food Safety Authority* (EFSA), was significantly below the established regulatory limits



8 Most Toxic PAHs by EFSA



PAHs Analysed	Individual PAHs Concentration [mg/kg]	∑ PHAs Concentration Limit [mg/kg]
∑ 8 (LMW)	MIN: 0,08 MAX: 0,44	1
∑ 16 (HMW)	MIN: 2,44 MAX: 6,66	~ (6 ± 2,4)

Concentration Limits from "European Biochar Certificate - EBC"

Moreover, the concentrations of the 8 PAHs analyzed—considered the most carcinogenic—were among the lowest detected.

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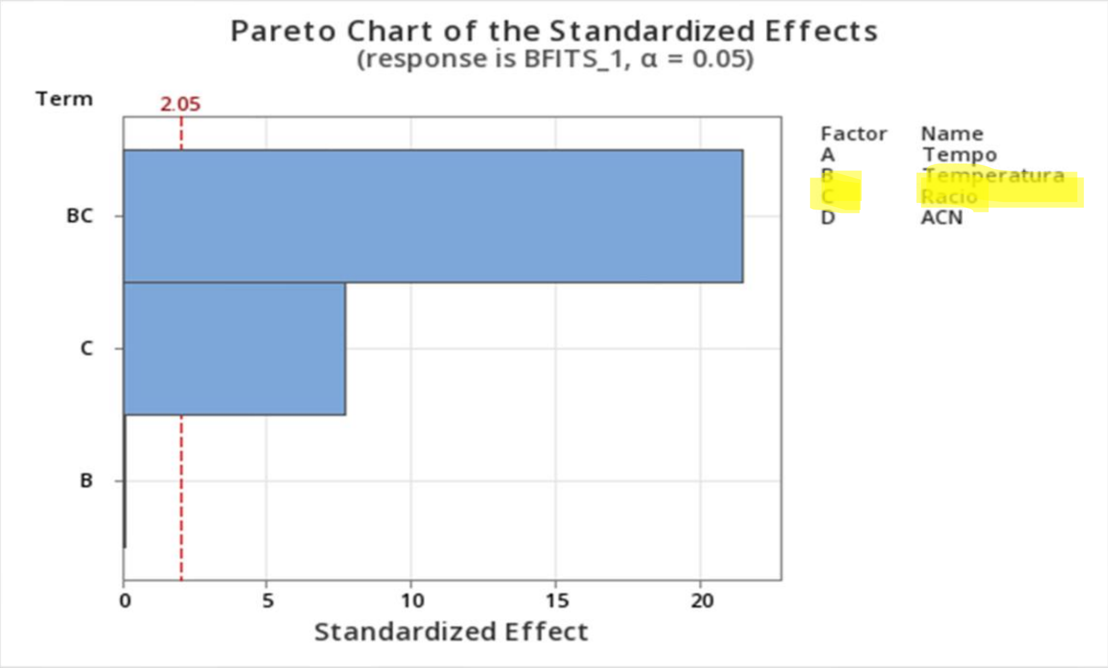
CCD Results – Model Validation

Model Summary			
S	R^2	R^2 (adj)	R^2 (pred)
0,29624	95,10%	94,56%	93,44%

Analysis of Variance					
Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	3	45,9992	15,3331	174,72	0,0000
Linear	2	5,2298	2,6149	29,8	0,0000
Temperature	1	0,0015	0,0015	0,02	0,8980
Racio	1	5,2283	5,2283	59,58	0,0000
2-Way Interaction	1	40,7694	40,7694	464,57	0,0000
Temperature*Ratio	1	40,7694	40,7694	464,57	0,0000
Error	27	2,3695	0,0878		
Lack-of-Fit	21	2,3695	0,1128	*	*
Pure Error	6	0	0		
Total	30	48,3686			



Model and factors are highly significant
P-Value values < 0.05 and F-value < 14
Only the interaction Temperature*Ratio is significant

- The model showed a **coefficient of determination (R^2) greater than 80%**, indicating a good fit between the predicted and experimental data
- The results obtained for the studied parameters were **consistent with model predictions**, confirming the **validity** of the statistical model

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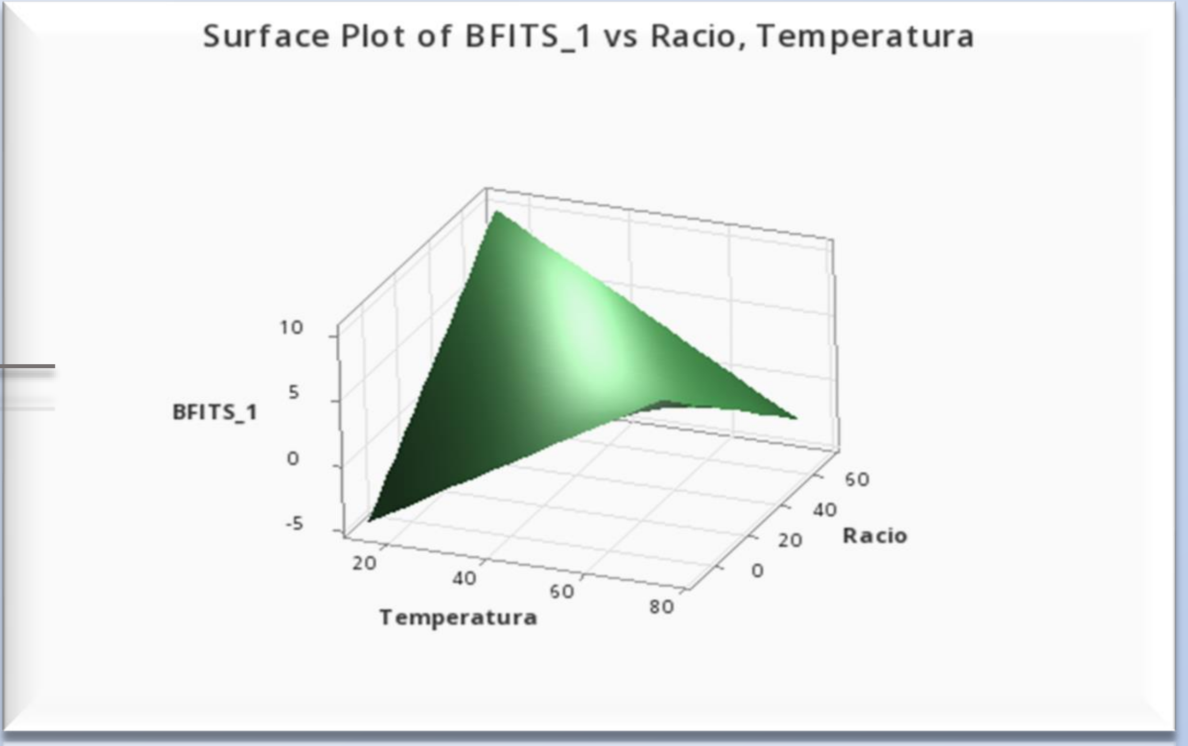
CCD Analysis Results

Future Work: PAHs Extraction Optimal Point

Solvents (Acetonitrile, Cetone)	**ACN 20%**
Racio S:L	**1g: 70 mL**
Temperature Extraction	**25 ºC**



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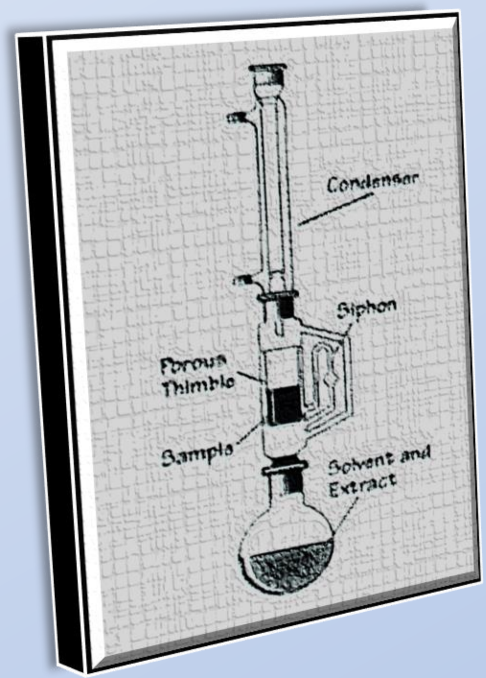
CCD Analysis Results

Future Work: Comparison of Results with *Soxhlet* Method

PAH Extraction according to DIN EN 17503

In this method must be used:

1. **2.5 g** sample of pre-dried and crushed biochar is extracted with at least **100 mL of toluene for 6 hours**
2. The solvent is evaporated in a rotavapour
3. The extract is then dissolved in **10 mL of n-hexane**



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Conclusions

The PAHs analyzed in the basil biochar are present at levels below the limits established by the *European Biochar Certificate*, ensuring its suitability for agricultural use and food safety.

Although PAH concentrations are below the established limits, it is crucial to implement strict quality control of biochar, as the presence of these contaminants may pose risks to human health and the environment. The limits set by the EBC are essential to ensure the safety of biochar used in agriculture.

Acknowledgments

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