Pyrolytic temperature evaluation of macauba biochar for uranium adsorption from aqueous solutions

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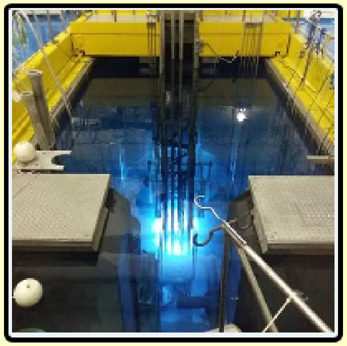
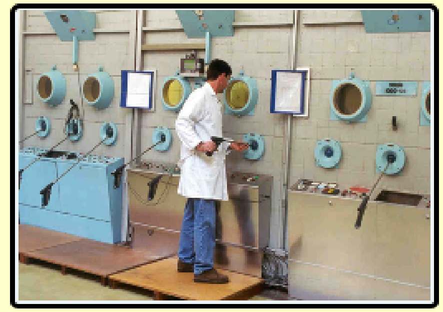
Radioactive Waste Management

IEA-R1 Research Reactor



Radioisotopes Production



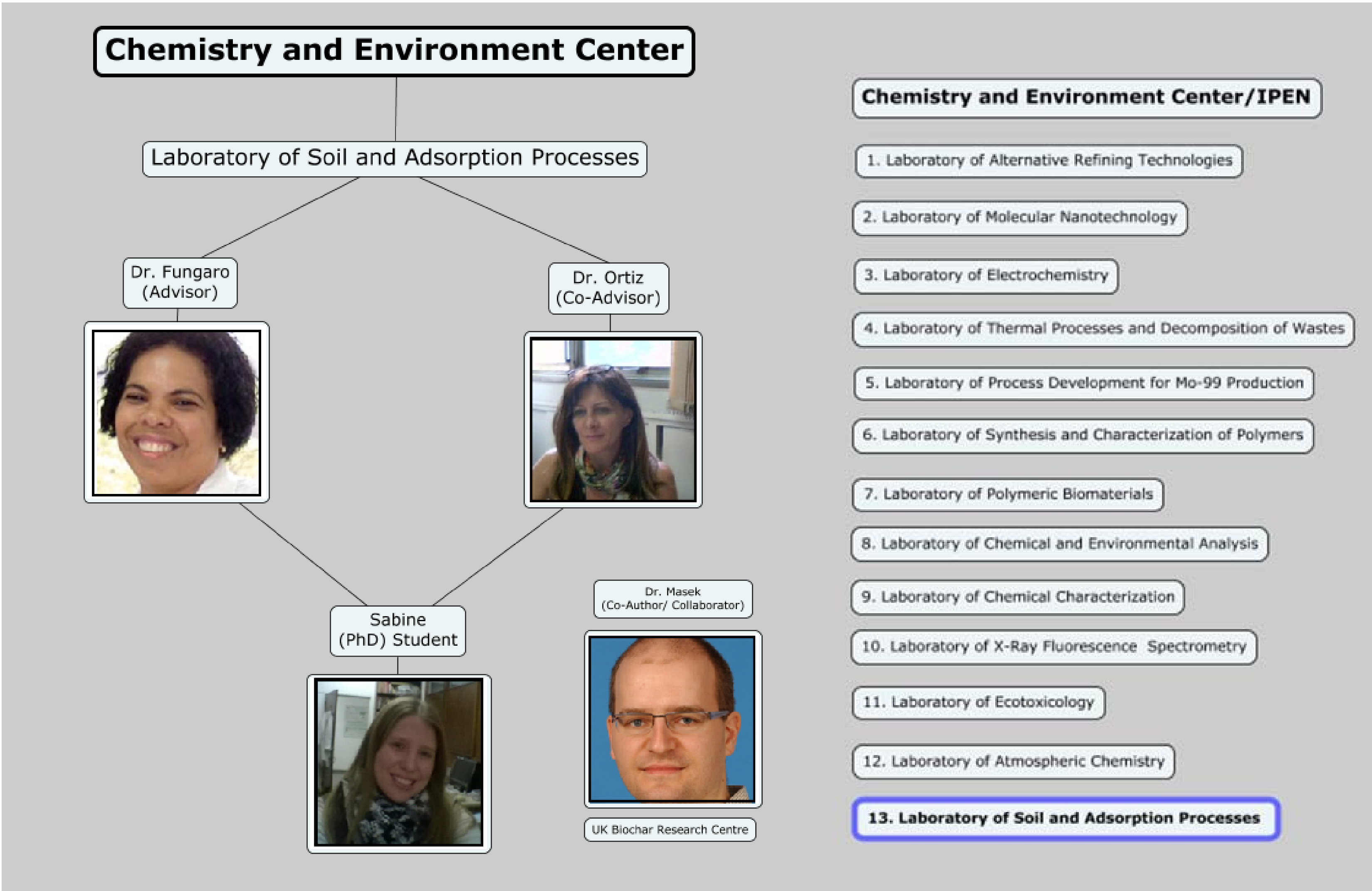
Instituto de Pesquisas Energéticas e Nucleares

Nuclear and Energy Research Institute

Co-60 Irradiator

Cyclotron C18

Tc-99m Generator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Laboratory of Soil and Adsorption Processes
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Dr. Ortiz (Co-Advisor)
Sabine (PhD) Student
Dr. Masek (Co-Author/ Collaborator)
UK Biochar Research Centre
Chemistry and Environment Center/IPEN
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2. Laboratory of Molecular Nanotechnology
3. Laboratory of Electrochemistry
4. Laboratory of Thermal Processes and Decomposition of Wastes
5. Laboratory of Process Development for Mo-99 Production
6. Laboratory of Synthesis and Characterization of Polymers
7. Laboratory of Polymeric Biomaterials
8. Laboratory of Chemical and Environmental Analysis
9. Laboratory of Chemical Characterization
10. Laboratory of X-Ray Fluorescence Spectrometry
11. Laboratory of Ecotoxicology
12. Laboratory of Atmospheric Chemistry
13. Laboratory of Soil and Adsorption Processes

Problem: Radioactive wastes

- Various activities in the nuclear industry (mining, research, fuel cycle, nuclear medicine) generate **aqueous wastes containing radionuclides**;
- Reduce the release of radioactive and toxic substances in the environment requires constant improvement of processes and technologies for treatment and conditioning of these wastes;
- Treatment of liquid radioactive wastes involves the application of several steps, such as filtration, precipitation, sorption, ion exchange, evaporation and/or membrane separation;
- It must meet the requirements for both – the release of decontaminated effluents into the environment and the conditioning of waste concentrates for disposal;

Problem: Radioactive wastes

- Uranium is a radioactive heavy metal occuring naturally in almost all rocks and soils;
- Natural uranium is a **mixture of 3 isotopes ^{234}U (0,005%), ^{235}U (0,711%) e ^{238}U (99,284%),** among which the most abundant is the U-238, with a half-life of 4.5 billion years;
- Chemically, they behave the same way;
- However, the U isotopes **decay through alfa-particle emission** in order to reach stability;
- **Alfa particles are highly ionizing** (cause damage to living tissues), although little penetrating;
- When ingested or inhaled, uranium particles can irradiate a person from the inside;
- EPA establishes a maximum of 0.03 mg of U/L (30 ppb) in potable water / Brazil admits only 0.02 mg/L.

Problem: Radioactive wastes

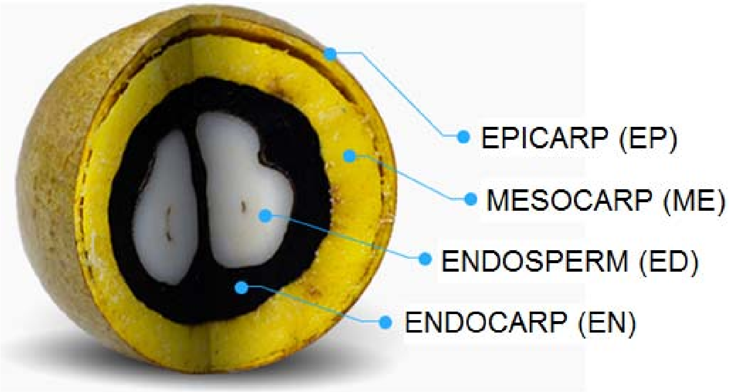
- The **nuclear fuel cycle involve a series of steps in which several uranium compounds are generated**;
- IPEN's research reactor uses a 19.75% enriched uranium fuel of uranium silicide U_2Si_3 (nuclear power plants require na average of 4% enriched fuel);
- IPEN's Chemistry and Environment Center performs a series of analysis along the production chain in order to qualify the fuel;
- One consequence of these analysis is the **generation of aqueous wastes containing uranium in low concentrations (about 250 x higher than the maximum allowed limit);**
- High concentrations of U in solution can be treated by precipitation, followed by filtration;
- Most of the times, this process is not 100% effective and reminiscent ions remain in the solution – usually at concentrations above the maximum established limits;
- Treatment of low concentrated solutions require a more refined technique – Adsorption is a simple and cost-effective technique, with the ability to specifically remove undesired substances from solutions;
- Several adsorbent materials are available and can be tested and improved – **Biochar can be a good adsorbents for heavy metals because of their porous structure, charged surface, and surface functional groups. Moreover, they can be produced from natural renewable feedstocks.**

Feedstock selection

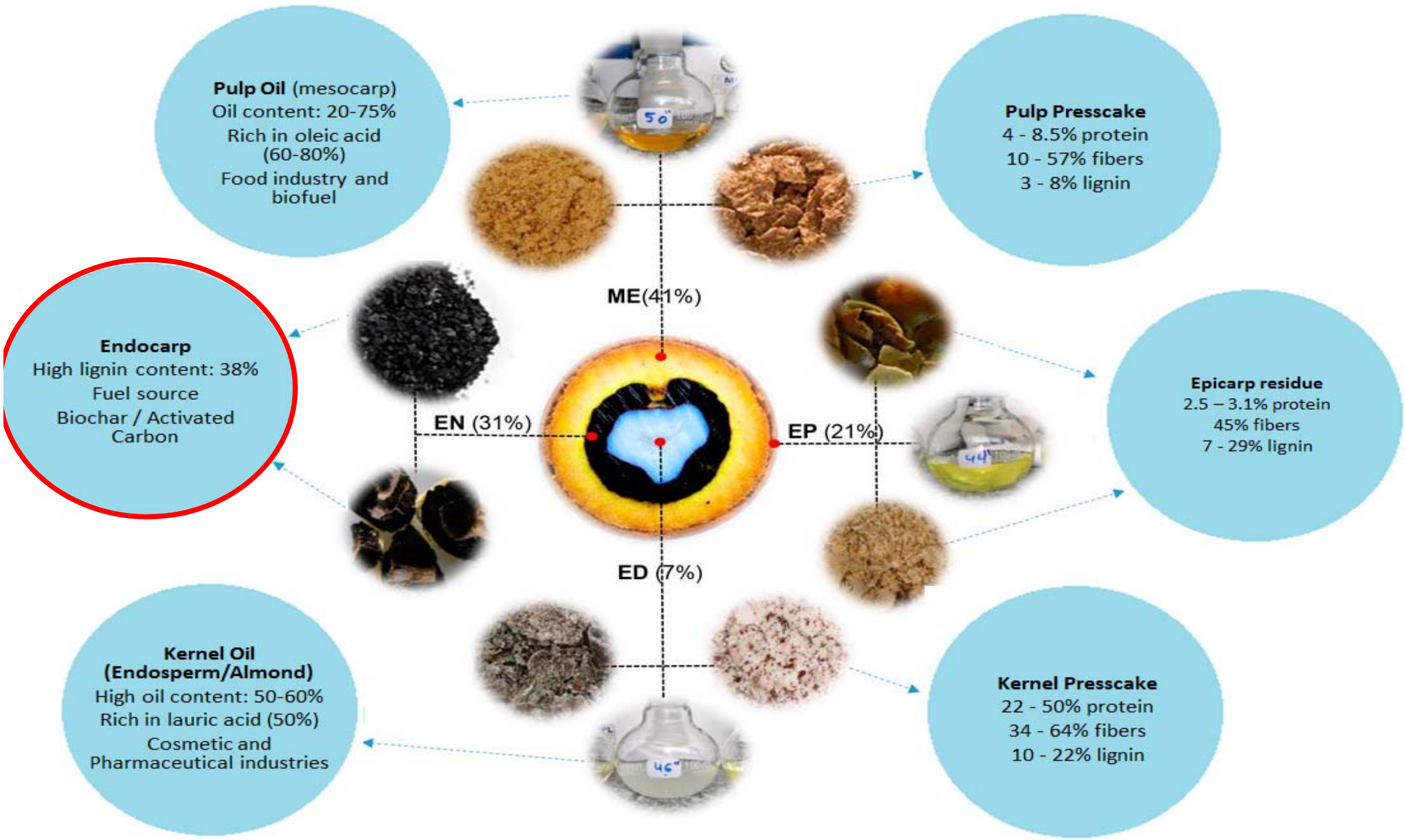
Macauba Palm Tree
(*Acrocomia aculeta*)

Palm tree native to Brazil, with potential to be produced in so-called silvopastoral systems without land use change and in na ecomically and socially sustainable way.

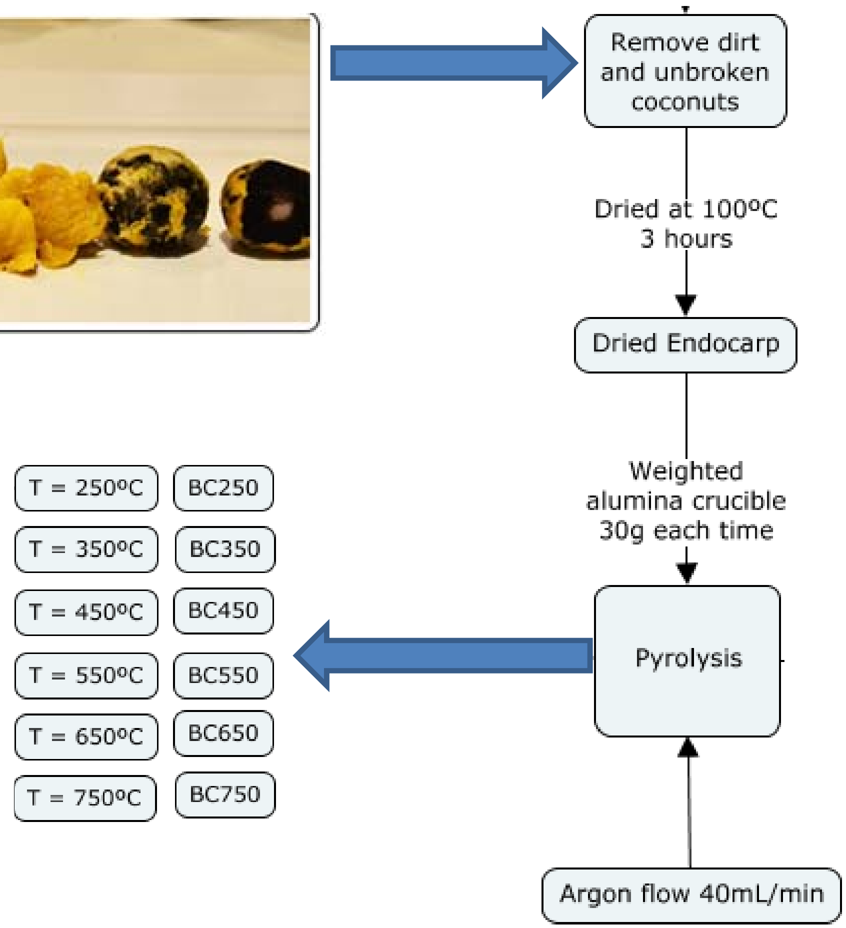
It has great economic potential. Its fruits/coconuts can be processed into plant oil destined for food and cosmetic industries as well as for the production of biodielsel and biokerosene; and animal fodder (press cake).



Endocarp = approx. 33% of the whole fruit


Pulp Oil (mesocarp)
Oil content: 20-75%
Rich in oleic acid (60-80%)
Food industry and biofuel
Pulp Presscake
4 - 8.5% protein
10 - 57% fibers
3 - 8% lignin
ME(41%)
Endocarp
High lignin content: 38%
Fuel source
Biochar / Activated Carbon
EN (31%)
EP (21%)
Epicarp residue
2.5 – 3.1% protein
45% fibers
7 - 29% lignin
ED (7%)
Kernel Oil (Endosperm/Almond)
High oil content: 50-60%
Rich in lauric acid (50%)
Cosmetic and Pharmaceutical industries
Kernel Presscake
22 - 50% protein
34 - 64% fibers
10 - 22% lignin

Biochar production

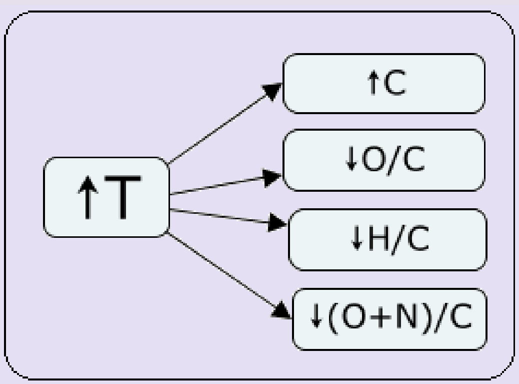


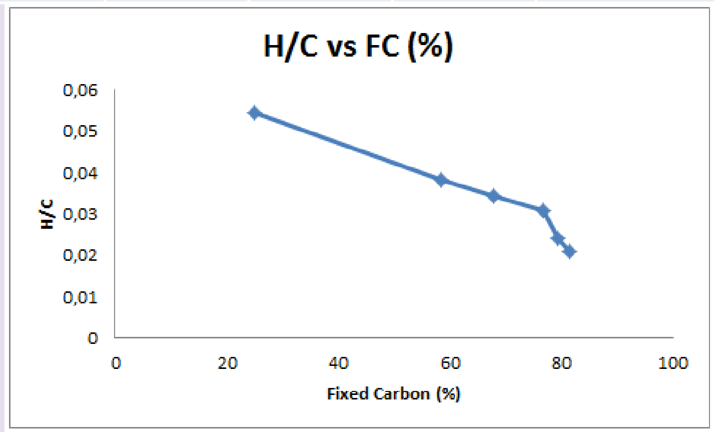
Biochar tield and proximate analysis

Parameter	Yield(%)	VM(%)	FC(%)
BC250	75.21	65.64	24.97
BC350	46.09	35.13	58.44
BC450	38.88	27.35	67.81
BC550	35.57	18.92	76.74
BC650	34.10	15.56	79.36
BC750	33.44	13.00	81.50

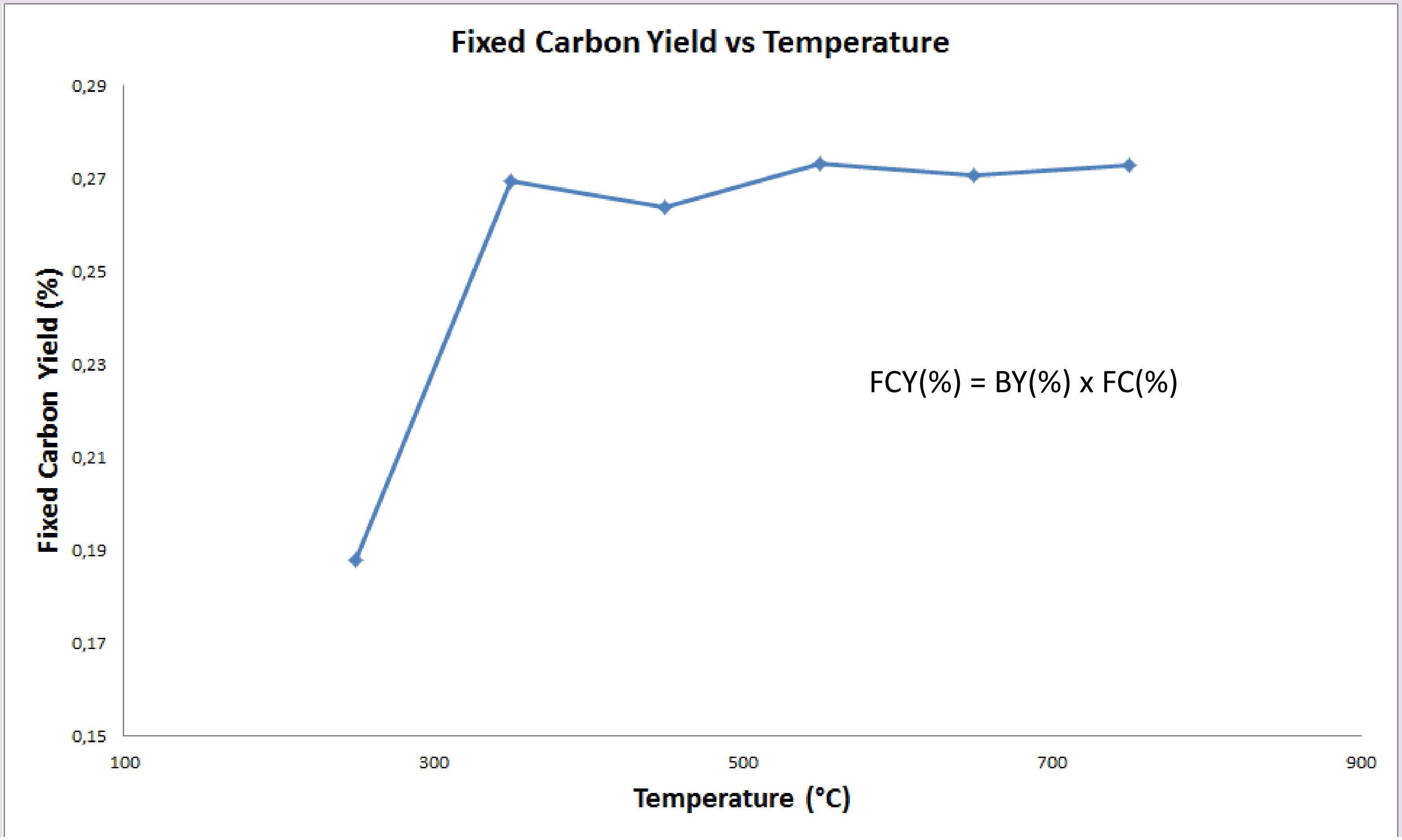
Elemental analysis

BC	C (%)	H (%)	O (%)	N (%)	S (%)	H/C	O/C	(O+N)/C
BC250	52.4	2.85	44.6	0.75	0.26	0.054	0.851	0.865
BC350	57.5	2.18	28.1	0.59	0.25	0.038	0.489	0.499
BC450	62.4	2.14	23.2	0.57	0.24	0.034	0.372	0.381
BC550	69.5	2.13	22.4	0.53	0.24	0.031	0.322	0.330
BC650	70.8	1.69	17.8	0.51	0.23	0.024	0.251	0.259
BC750	75.1	1.56	16.5	0.41	0.23	0.021	0.220	0.225

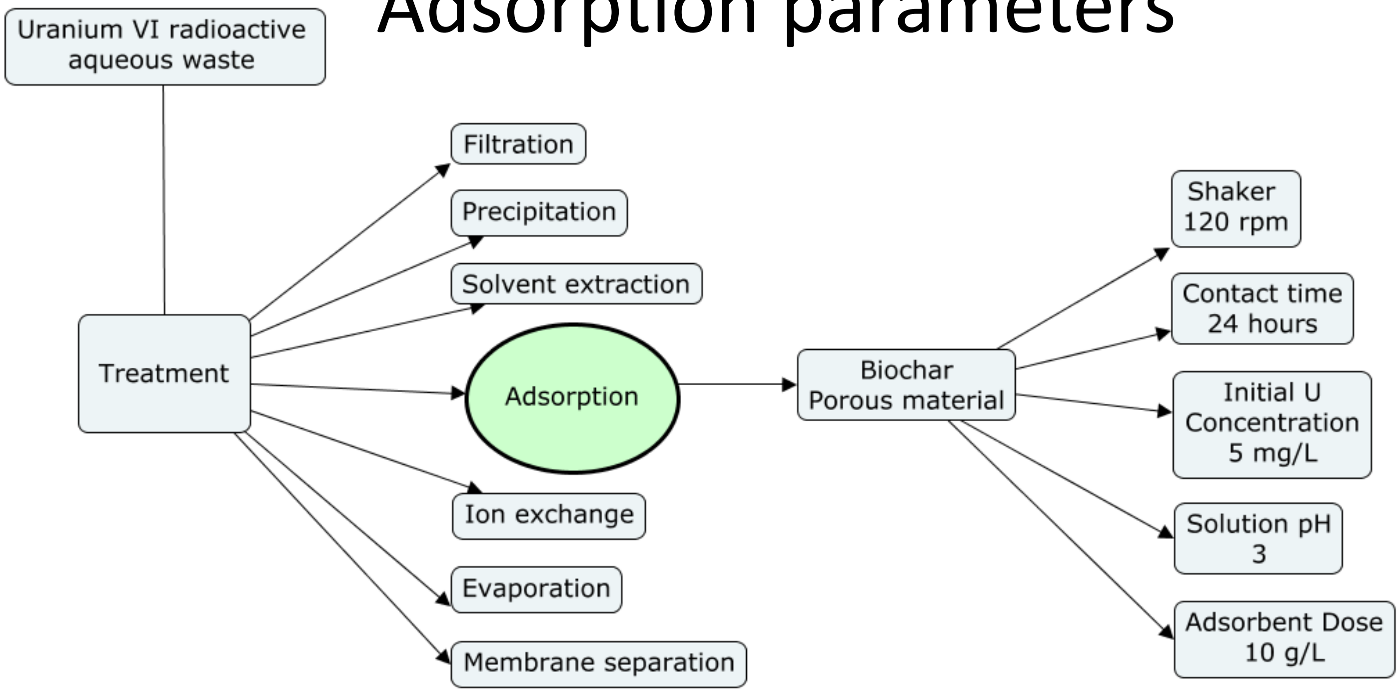




Fixed carbon yield



Adsorption parameters

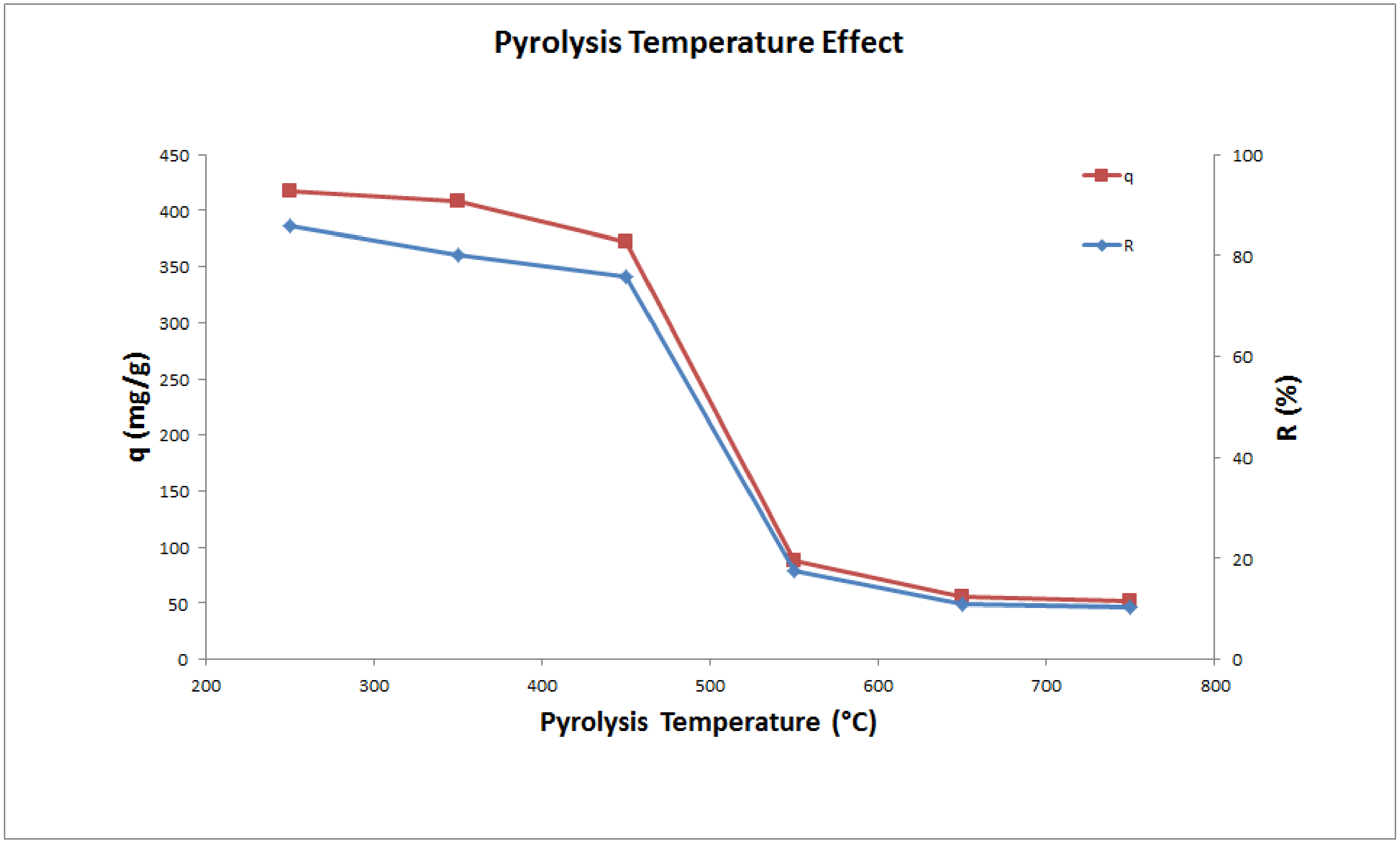


The adsorption capacity (q, mg/g) and the extraction efficiency (R, %) are calculated

$$q_t = \frac{(C_0 - C_t)\ x\ V}{M}$$

$$R\ (\%) = \left(\frac{C_o - C_t}{C_o}\right) x\ 100$$

Adsorption experiments



Conclusions

- Based on proximate analysis, BC350 was selected as the working biochar (BC) for adsorption studies aiming at the removal of uranium U(VI) from aqueous solutions;
    - Submitting the endocarp to temperatures higher than 350°C is unnecessary: this is important for saving time and reducing operational costs;
- Macauba biochar proved to be a suitable adsorbent for the removal of uranium: an 80.1% removal was achieved when BC350 was used (Note: for the NON-ACTIVATED biochar);
- O/C and H/C are relevant parameters when adsorption capacity of the material is being evaluated, indicating that oxigenated and hidroxilated functional groups are probably responsible for the adsorption of uranium onto the biochar's surface.

Next Steps

- Perform adsorption studies to determine the influence of parameters such as pH, adsorbent dose and initial concentration on the adsorption of U(VI)
- Evaluation of the adsorption process through isotherms mathematical models – should provide some light about the model that best describes the adsorption;
- Characterization of the biochar employing **X-ray diffraction**, **X-ray fluorescence**, **scanning electron microscopy**, **infrared spectroscopy** and other techniques – should provide enough information about the biochar's surface chemistry and properties, allowing a better understanding of the mechanisms that might be involved in the adsorption process;
- Perform the activation of the biochar to evaluate the possibility of improvement in the uranium removal;

Special thanks to:

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