RESIDUAL BIOMASS CHARACTERIZATION AND EVALUATION OF ITS INFLUENCE ON PYROLYSIS PROCESSES

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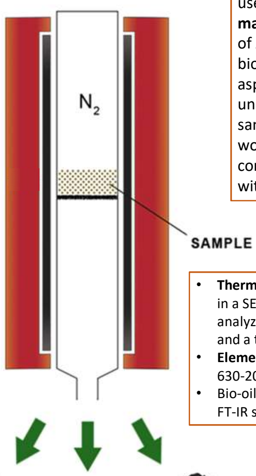
INTRODUCTION

Biomass is extensively accepted as one of the main potential sources for sustainable and renewable generation of fuels, chemicals and other carbon-based materials. Many advantages are reported using biomass as an energy source, such as being a non-polluting alternative and its carbon neutrality. Numerous processes can be used to convert biomass, and namely the pyrolysis process is a renewable, economical, and efficient way to produce chemicals and/or energy. Therefore, pyrolysis is an available technology for biomass conversion into energy. It consists of a thermal decomposition process with the absence of oxygen, converting biomass into 3 fractions: biochar (solid fraction), bio-oil (liquid fraction) and gases. Hence, pyrolysis is a recognized industrial process for biomass energy and chemical conversion. The bio-oil and biochar can be used as a fuel and as fertilizer respectively, and the gases can be recycled back into the process. Biomass samples were characterized by proximate analysis, determining fixed carbon, moisture, volatiles and ashes composition, and by ultimate analyses, determining the content of C, H, N, S and O. The content of hemicellulose, lignin and cellulose was also determined. The methodologies are described elsewhere [1-3] and all characterizations were performed on a dry basis. Pyrolysis tests were performed in a fixed-bed vertical pyrolysis oven, with a maximum temperature of 500 to 700°C, variable heating rate up to 50°C/min, retention time of 0.5 h, and N_2 flow of 20 mL/min. The bio-oil and biochar were qualitatively characterized using FTIR and the products distribution was analyzed in relation to the biomass samples previous characterization.

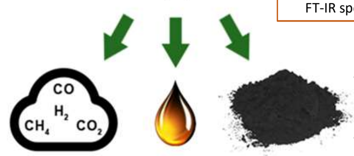
1. EXPERIMENTAL

Five samples of residual biomass were used in this work: **sugarcane pomace, malte pomace; pellets; Wood 1**, a sample of Aveiro`s region local residual wood biomass, homogeneous with straw aspect, thin and dried with particles sizes under 3 mm, and **Wood 2**, another sample of Aveiro`s region local residual wood biomass, heterogeneous, composed of leaves, branches, and roots, with thick particles.

- 5 g of biomass introduced in the cell into the fixed-bed vertical pyrolysis oven under nitrogen atmosphere for 2h.
- Furnace: T_{max} = 500 to 700°C; residence time = 30 min; heating rate = 10 to 50°C h^{-1}; N_2 flow = 20 mL min^{-1}.



- **Thermogravimetric analysis** (TGA) was performed in a SETSYS Evolution 1750 thermogravimetric analyzer (Setaram), using a nitrogen atmosphere, and a temperature range between 20°C and 800°C.
- **Elemental analysis** was performed using a Truspec 630-200-200 Elemental Analyzer.
- Bio-oil was analyzed by **FTIR** using a Perkin Elmer FT-IR spectrophotometer UATR Two infrared.



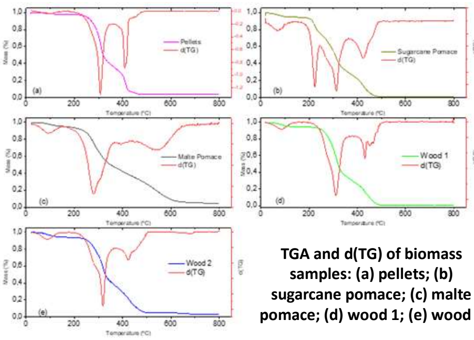
- **After the pyrolysis cell cooling, bio-oil which adhered to the cell removed using acetone.**
- **Bio-oil dried in an oven for 48 h at 80±5°C and weighed.**

2. RESULTS

	Pellets	Sugarcane Pomace	Malte Pomace	Wood 1	Wood 2
Moisture (wt %)	7.13	5.28	6.52	10.60	6.87
Volatile (wt %)	73.65	75.69	70.74	71.58	70.26
Ashes (wt %)	0.35	2.08	2.76	0.54	2.59
Fixed Carbon (wt %)	18.87	16.95	19.98	17.26	20.29
Hemicellulose (wt %)	55.56	60.54	-	30.27	29.61
Lignin (wt %)	41.17	24.16	-	54.23	66.18
Cellulose (wt %)	0.66	12.21	-	13.31	0.19
C (wt %)	47.80	41.42	47.16	47.83	47.18
H (wt %)	5.86	5.41	2.84	6.02	5.84
N (wt %)	0.16	0.37	6.95	1.30	0.55
S (wt %)	0.00	0.00	0.00	0.00	0.00
O (wt %)	46.18	52.80	43.05	44.85	46.43
[CHO index]	-0.007	0.361	0.654	-0.089	0.005

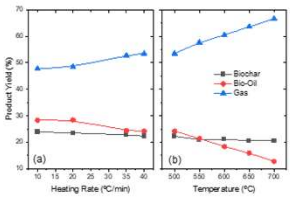
$$CHO_{index} = \frac{(2[O] - [H])}{[C]}$$

Proximate analysis, composition analysis and chemical composition of several residual biomass samples



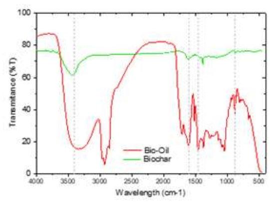
TGA and d(TG) of biomass samples: (a) pellets; (b) sugarcane pomace; (c) malte pomace; (d) wood 1; (e) wood 2

- For all samples, excluding the sugarcane pomace, the first main thermal event occurs at a temperature near 300°C.
- Every sample has its own characteristic TG and d(TG) curves, as some samples present two main thermal events, and other samples present three events.
- The proximity between the TG results and the proximate analysis highlights the trustability of the methodology used.



Effect of (a) heating rate and (b) maximum temperature on the yield of biomass pyrolysis products

- Increment of the heating rate induced a difference in the products yields. For the solid and liquid fractions, the increment of the heating rate diminished the yield of those products, whereas raised the yield of the gas fraction.
- This could be caused by the cracking of biomass components (endothermic reaction), thus, the increase in heating rate could facilitate the cracking of heavy molecules to produce smaller ones, generating more gaseous particles at cost of solid and liquid yield.



FTIR analysis of Biochar and Bio-oil sample produced during a pyrolysis run

- Main peaks observed are OH vibrations, in the region of 3100 to 3500 cm^{-1}, peaks between 1650 and 1720 cm^{-1} relative to the C=O stretching vibrations, peaks of 1600 and 1450 cm^{-1} related to aromatic rings, and peak in the range of 900 to 700 cm^{-1} concerning to substituents of an aromatic ring.
- Those peaks prove that bio-oil was formed, possessing carbonaceous aromatic structures that can be used to generate energy.

3. CONCLUSIONS

- ✓ Residual biomass samples were successfully characterized by several techniques and showed different characteristics.
- ✓ Pellets were the selected biomass for the pyrolysis test, due to their properties, low humidity and ash content, and homogeneous characteristics.
- ✓ Pyrolysis of residual biomass proved to be a viable technology for the valorization of a worldwide produced waste, obtaining Biochar, with yields around 20 to 23%.
- ✓ Bio-oil was successfully obtained by biomass pyrolysis, with yields in the range of 13 to 28%.
- ✓ Heating rate and maximum pyrolysis temperature proved to be critical parameters for this technology, with a major influence on the yields of the products.
- ✓ Increment of the heating rate caused a reduction of the biochar and bio-oil fraction yields, at the same time rising the yield of the gas fraction. The same phenomena were also observed for the maximum pyrolysis temperature.

References

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