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Solar hydrothermal liquefaction of agricultural waste: From lab to pilot scale

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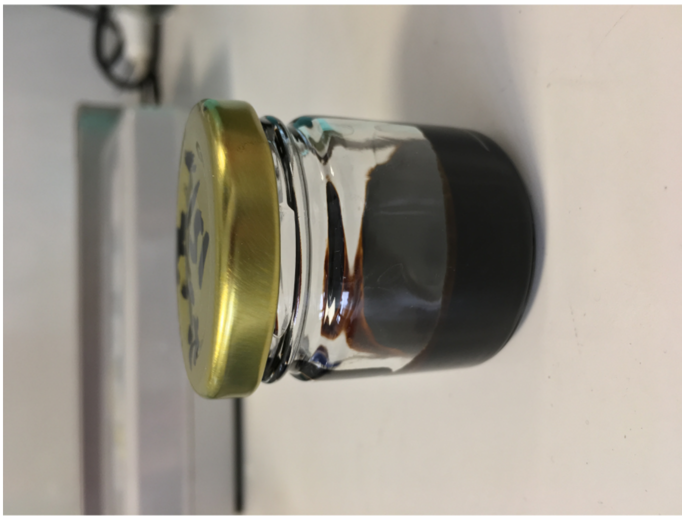
PURPOSE OF THE ABSTRACT

ABSTRACT. Hydrothermal liquefaction (HTL) is a thermochemical method for the conversion of residual biomass into biocrude by processing it at sub- or supercritical conditions (250-500oC and 5-35 MPa) with the addition of water which acts as both a reactant and solvent [1,2]. The biocrude occurring from HTL process can be further treated in order to be upgraded and attain properties similar to those of hydrocarbons [3]. Concentrated Solar Power (CSP) can be used as the heating means of the process instead of electrical power, leading to an efficient, environmentally friendly and low carbon footprint technology.
The purpose of the present study is the evaluation of products and biocrude yield (Figure 1) resulting from sustainable solar HTL of vegetable oil and cattle manure. Bio-oil yield was calculated with the following simplistic equation [4]:
Bio-oil yield(%)=w_biocrude/w_feedstock x 100
where wbiocrude and wfeedstock are the weight of the biocrude (g) and the dried feedstock (g) respectively. Feedstocks were tested under temperatures ranging from 300 to 375oC (25oC step), at two different initial pressures (1, 20 bar) and a retention time of 30 min, while water to feedstock ratio was kept constant at 90/10 wt%. Preliminary tests were held in an electrically heated ~2L autoclave reactor and the relative results were compared and verified using an in-house solar simulator (Figure 2) as the heating means [5]. The temperature and pressure rise rates accomplished this way were 6.2oC/min and 3.5 bar/min, significantly increased than the corresponding ones attained with the electric heater (3.2oC/min and 1.9 bar/min). Biocrude yield achieved by converting cattle manure reached ~40%, while in the case of vegetable oil, it exceeded 80%. Raw materials and products were characterized in terms of higher heating value (HHV) with a Parr Isoperibol 6200 calorimeter, while the composition of the produced gas phase was determined by a Shimadzu Nexis GC-2030 gas chromatographer (GC). Regarding cattle manure biocrude HHV, an increase from 17.6 to 36.8 MJ/kg was observed compared to the feedstock, while vegetable oil biocrude showed similar values to its feedstock which is probably attributed to the higher O/C ratio implying incorporation of oxygen atoms into the biocrude. According to GC results, gas composition consisted of C3H6, C3H8, C2H4, C2H6, CH4, CO2 and CO in concentrations that differ depending on the raw material and process conditions. Currently, a pilot-scale unit comprising of two ~6L tube reactors is being designed and constructed. Heating is planned to be provided by concentrated solar radiation using parabolic trough collectors, while the entire process is expected to be placed on a mobile platform.

FIGURES



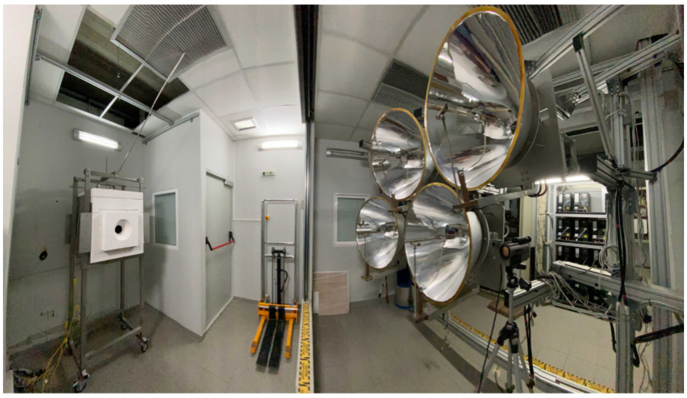


FIGURE 1
Figure 1

Biocrude produced by solar hydrothermal liquefaction of cattle manure

FIGURE 2
Figure 2

Lab-scale reactor arrangement placed in the in-house solar simulator lab

KEYWORDS
hydrothermal liquefaction | biocrude | agricultural waste | Concentrated Solar Power

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