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MICROALGAE HYDROTHERMAL LIQUEFACTION PROCESS OPTIMIZATION

AUTHORS
Lucie MATRICON / CEA, 17 AVENUE DES MARTYRS, GRENOBLE
Anne ROUBAUD / CEA, 17 AVENUE DES MARTYRS, GRENOBLE
Geert HAARLEMMER / CEA, 17 AVENUE DES MARTYRS, GRENOBLE
Christophe GEANTET / UNIV LYON, UCB LYON 1, CNRS, IRCELYON, UMR 5256, 2, AVENUE ALBERT EINSTEIN, VILLEURBANNE

PURPOSE OF THE ABSTRACT

The objective of this study is to produce biofuel from microalgae via hydrothermal liquefaction. Microalgae biofuels are still expensive and the conversion yield is a key parameter to reduce the final cost. Therefore, optimisation of the whole process route is needed from cultivation to upgrading and so the HTL conversion step. This study on HTL was done with Chlorella sorokiniana selected for its capacity of lipids accumulation reported in the literature. Algae batches coming from two different culture conditions (different nitrogen content in culture medium), resulting in different macromolecular compositions, were studied. The biomass composition is a key parameter regarding the process efficiency and the bio-oil composition. Hydrothermal liquefaction was performed at 270 and 350°C, approximately 100 bar, during 5 and 20 min and with 10 and 17% by weight organic matter concentration in water. After reaction, a gaseous phase (90% of CO2), an aqueous phase and a biocrude (mix of bio-oil and char) is produced. Finally, a separation step is necessary to obtain the bio-oil composed of 75% carbon, which will be the product of interest (Fig. 1). The main criteria to evaluate bio-oil quality is the nitrogen and oxygen content because they can damage catalysts, are hard to remove during bio-oil hydrotreatment upgrading and prevent the use of up-graded bio-oil as fuel due to toxic gas emission. A predictive approach based on sensitivity analysis and machine-learning modelling gives a global overview of the microalgae behaviour during HTL.

The parameter study gave some information on the bio-oil yield and quality in different HTL conditions and considering different biomass compositions. For instance, a bio-oil yield of 58% is reached at 350 °C, 5 min reaction time and 17% organic matter for the algae cultivated in normal culture conditions against 34% after 20 min reaction for the one cultivated in nitrogen-depleted medium. However, the latter contain less nitrogen (3.8% against 5.8%) and thus improve bio-oil quality. In fact, a higher protein content increases the bio-oil yield but decreases the quality. This sensitivity analysis gave an idea of the optimal HTL conditions for two different microalgae composition. However, machine-learning approach is interesting to extend the prediction range to other compositions or HTL parameters. It allowed to leverage all data gathered for now (with several resources and HTL conditions) and to reach a correlation coefficient of 0.97 using Gradient boosting for bio-oil yield prediction instead of 0.68 with a simple linear regression. Moreover, these batches gave an idea of the chemical behaviour during HTL of microalgae. For instance, a high temperature combined with long holding time results in decarboxylation and condensation reaction.

The reaction conditions and the biomass composition have a great impact on bio-oil yield and quality after HTL. Moreover, modelling approach using machine-learning tools like Random Forest or Gradient boosting is interesting to predict bio-oil yield. Next, a more precise and comprehensive model will be done to predict the bio-oil composition from HTL conversion of several microalgae species. Accurate analyses of bio-oil and aqueous phase along the time will be done in order to define a reaction network and to propose a kinetic model. This model will be useful to predict conversion of various microalgae species through HTL for biofuel production as well as helping in the design of a future industrial process at a larger scale.

FIGURES

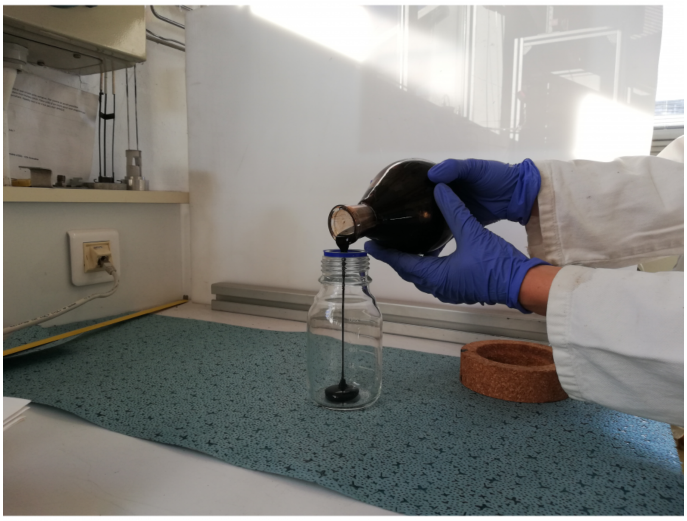

FIGURE 1

Fig. 1

Bio-oil from hydrothermal liquefaction of Chlorella sorokiniana

FIGURE 2

KEYWORDS

Biofuels | microalgae | hydrothermal liquefaction | modelling

BIBLIOGRAPHY