Fuel 181 (2016) 1–33

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Review article

Composition, properties and challenges of algae biomass for biofuel application: An overview

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HIGHLIGHTS

- Composition and properties of algae and algae ash were summarized.
- Comparative characterization between algae and other solid fuels was given.
- Advantages of algae composition and properties were described.
- Disadvantages and challenges of algae composition and properties were discussed.

ARTICLE INFO

Article history:
Received 22 March 2016
Received in revised form 21 April 2016
Accepted 21 April 2016
Available online 28 April 2016

Keywords:
Algae
Algae ash
Composition and properties
Advantages
Disadvantages

ABSTRACT

Algae-based fuels are considered to be the most sustainable, renewable, effective and environment friendly response to climate change and food–feed security, as well as the only renewable energy resource that has the capacity to meet the global demand for fuels in the long-term. Therefore, an extended overview of the composition, properties and challenges of algae biomass for biofuel application was conducted based on reference peer-reviewed data plus own investigations. Initially, some general considerations such as current bioenergy situation and significance of biofuel generations, as well as different aspects related to biomass use as biofuels are discussed. Then, common issues concerning taxonomical classification, habitat environment, carbon reserve capacity, production, use, and main advantages and disadvantages of algae or algae biofuel are addressed. Further, more than 135 characteristics related to the chemical, phase and mineral composition and properties of algae and algae ash are evaluated and compared to those of terrestrial biomass, coal and their ashes. As a result specific benefits and obstacles connected with the composition and properties of algae and algae ash are discussed. The behaviour of organic and inorganic matter during algae combustion is also described. Finally, the major technological and environmental challenges related to algae-based fuels are emphasized. The present data demonstrate that the high contents of inorganic matter with unfavourable modes of element occurrences (chlorides, sulphates, carbonates, oxalates, nitrates and some oxyhydroxides, phosphates and amorphous material) in algae and algae ash provoke the most critical technological and environmental challenges during algae processing for biofuel application and especially during algae thermochemical conversion. Another very important challenge addressed is the indefinite availability of sustainable algae resources for production of biofuels and biochemicals and certain recommendations are given. It was found that the disadvantages of algae biofuel application prevail significantly over the advantages; however, the major economic, environmental and social benefits appear to compensate the technological and other barriers caused by the unfavourable composition and properties of algae.

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http://dx.doi.org/10.1016/j.fuel.2016.04.106
0016-2361/

Nomenclature

AA	algae ash
AFT	ash-fusion temperature
BA	biomass ash
daf	dry, ash-free basis
db	dry basis
DTA	differential-thermal analysis
DWR	dry water-soluble residue
FC	fixed carbon
GHG	green house gasses
HHV	higher heating value
HTA	high-temperature ash (>500 °C)
MM	marine macroalgae (sea lettuce)
ppm	part per million
SEM	scanning electron microscopy
TE	trace element
TGA	thermo-gravimetric analysis
VM	volatile matter
XRD	X-ray powder diffraction
%	weight %

1. Introduction

1.1. General considerations about biomass and biofuel

Biomass as a renewable source can be converted into solid, liquid and gaseous biofuels for generating bioenergy, as well as into some chemicals. Bioenergy has been recognised as an important component in many future's energy scenarios and could contribute significantly to economic, social and environmental goals [1,2]. For example, biomass currently contributes about 8–15% of the world energy supplies as heat, electricity and fuels for transportation and up to 33–50% of the world's current primary energy consumption could be met by biomass by 2050 ([3] and references therein). Additionally, the substitution of fossil fuels by biofuels appears to be an effective strategy to meet not only the future world energy demands but also the requirement for reducing greenhouse gasses (GHG) and particularly carbon emissions originating mostly from fossil fuels combustion [2]. Therefore, the focus on bioenergy as an alternative to fossil energy has increased tremendously in recent times because of global warming problems.

In total about 95–97% of the world's bioenergy is currently produced by direct combustion of biomass. The perspective of increasing large-scale combustion of natural biomass and its co-combustion with semi-biomass (contaminated biomass and industrial biomass wastes such as municipal solid waste, refuse-derived fuel, sewage sludge, demolition wood and other industrial organic wastes) and solid fossil fuels (coal, peat, petroleum coke) seems to be one of the main drivers for biofuel promotion in many countries worldwide in the near future ([3] and references therein). Biofuels are more environment friendly than fossil fuels [4,5]; however, important potential constraint for global biofuel expansion is the ongoing debate on criteria for sustainable production, energy balances and GHG savings of biofuels [2]. For instance, terrestrial bioenergy production systems are now facing issues related to food