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Review article

Advantages and disadvantages of composition and properties of biomass in comparison with coal: An overview

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HIGHLIGHTS

- Composition and properties of biomass were summarised.
- Comparative characterization between biomass and coal was given.
- Advantages of biomass composition and properties were described.
- Disadvantages of biomass composition and properties were discussed.

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ABSTRACT

An extended overview of the advantages and disadvantages of biomass composition and properties for biofuel application was conducted based on reference peer-reviewed data plus own investigations. Initially, some general considerations and comparisons about composition and properties of biomass and coal as the most popular solid fuel are addressed. Then, some of the major advantages related to the composition and properties of biomass and/or biomass ash (BA) are discussed. They include: (1) high values of volatile matter, H, structural organic components, extractives and reactivity of biomass, water-soluble nutrient elements and alkaline-earth elements in biomass and BA, and pH of BA; and (2) low values of C, fixed C, ash, N, S, Si and initial ignition and combustion temperatures of biomass, and low contents of many trace elements including hazardous ones in biomass and BA. Further, some of the major disadvantages connected with the composition and properties of biomass and/or BA are described. They comprise: (1) high values of moisture and O in biomass, water-soluble fraction, alkaline and halogen elements, and some hazardous trace elements in biomass and BA; (2) low values of energy density (bulk density and calorific value), pH and ash-fusion temperatures of biomass, and bulk density and size of BA; (3) highly variable composition and properties of biomass and BA; and (4) indefinite availability of sustainable biomass resources for production of biofuels. Finally, a discussion about the availability of sustainable biomass resources for production of biofuels and biochemicals is given. It was found that the disadvantages of biomass for biofuel and biochemical applications prevail over the advantages; however, the major environmental, economic and social benefits appear to compensate the technological and other barriers caused by the unfavourable composition and properties of biomass.

Contents

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Nomenclature

A	ash yield
AFT	ash-fusion temperature
BA	biomass ash
daf	dry, ash-free basis
db	dry basis
DTA	differential-thermal analysis
DWR	dry water-soluble residue
EDX	energy dispersive X-ray analyser
FC	fixed carbon
HHV	higher heating value
IAM	inorganic amorphous matter
ICP	inductively coupled plasma
IM	inorganic matter
LA	laser ablation
M	moisture
MS	mass spectrometry
OM	organic matter
SEM	scanning electron microscopy
TE	trace element
TGA	thermo-gravimetric analysis
VM	volatile matter
XRD	X-ray powder diffraction
%	weight%

1. Introduction

Biomass can be converted into solid, liquid and gaseous biofuels for generating bioenergy, as well as into some chemicals. It is widely accepted that biofuels combustion does not contribute to the greenhouse effect due to the CO_2 neutral conversion thanks to the renewability of biomass. The focus on bioenergy as an alternative to fossil energy has increased tremendously in recent times because of global warming problems originating mostly from fossil fuels combustion. Therefore, extensive investigations have been carried out worldwide recently to enhance biomass use instead of fossil fuels for energy production ([1–7] and references therein). Numerous biomass varieties among biomass groups, namely wood and woody biomass, herbaceous and agricultural biomass, aquatic biomass, animal and human biomass wastes, 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 their biomass mixtures can be used for biofuels and biochemicals [1,2]. In total about 95–97% of the world's bioenergy is currently produced by direct combustion of biomass and the perspective of increasing large-scale combustion of natural biomass and its co-combustion with semi-biomass 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]).

Two fundamental aspects related to biomass use as fuel are: (1) to extend and improve the basic knowledge on composition and properties; and (2) to apply this knowledge for the most advanced and sustainable utilisation of biomass. The fuel composition is a fundamental code that depends on various factors and definite properties, quality and application perspectives, as well as different technological and environmental problems related to any fuel [1]. Therefore, extensive reference peer-reviewed data plus own investigations for both biomass and biomass ash systems were used recently to perform several extended and consecutive overviews related to: (1) chemical composition of biomass [1]; (2) organic and inorganic phase composition of biomass [2]; (3) phase-mineral and chemical composition of biomass ash (BA) [3]; (4) potential utilisation, technological and ecological advantages and challenges of BA [4]; and (5) behaviour of biomass during combustion, namely phase-mineral transformations of organic and inorganic matter [5] and ash-fusion and ash-formation mechanisms of biomass types [6]. New classifications based on data from proximate, ultimate, ash, structural and mineralogical analyses, and ash-fusion tests of biomass or BA have been introduced therein [1–6]. Additional investigations on trace element concentrations and associations in biomass and BA have also been conducted

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