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Evaluation of physical and chemical characteristics of different biomass as a potential energy source

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Highlights:

- Properties of industrial sludge, microalgae biomass and eucalyptus chips and bark were compared.
- Use of microalgae biomass as energy source can minimizing environmental impacts.
- Microalgae biomass can be a renewable energy source in a circular economy approach.

Keywords: microalgae biomass; industrial sludge; renewable energy.

INTRODUCTION

The increase in population and the resulting generation of residues, combined with the ongoing threat of climate change and its effects on human health and well-being, have dramatically increased the need for considerable research into renewable energy sources (Farghali et al., 2023). Biomass is one of the most promising, widely publicized, and heavily subsidized renewable energy sources. This biomass includes any organic matter derived from biological organisms, whether animals or plants - such as wood and wood wastes, agricultural residues, food crops, aquatic plants and algae, industrial wastes, paper residues, food wastes, sewage and industrial sludge and municipal solid wastes. When the biomass is converted into electricity, heat, power, or transportation fuels, is referred to biomass energy, or bioenergy (Benti et al., 2021).

The most important properties of biomass for energy conversion processes include moisture content, density, proximate chemical analysis (volatile matter, fixed carbon and ash content), elementary chemical composition (carbon, hydrogen, nitrogen, sulfur and oxygen), and heating value. Therefore, before attempting to utilize biomass as bioenergy, it is essential to understand these properties.

In this context, within the scope of the circular economy, this study evaluates the physical and chemical characteristics of industrial sludge and microalgae biomass, which are residues of continuous production that become significant environmental problem when not disposed of correctly. Additionally, the study examines the characteristics of two types of wood wastes: eucalyptus chips and bark. By comparing these results, the study aims to determine which biomass – industrial sludge or microalgae – is the better option as an energy source.

METHODOLOGY

Industrial sludge was obtained from an activated sludge system in a paper mill effluent treatment plant located in Ponte Nova (Minas Gerais, Brazil), with the capacity to treat 720 $m^3.d^{-1}$ and generates 5 $t.d^{-1}$ of sludge with a solids content of 15% after dewatering in a centrifuge. The Eucalyptus (Eucalyptus

sp.) chips (2-3 cm length) and bark (0.5-1.5 cm length) were collected from a pulp and paper mill. The production of microalgae biomass was carried out at the Federal University of Viçosa (Minas Gerais, Brazil), using domestic wastewater previously treated in a septic tank as the cultivation media.

The characterization of the biomass was performed using the following analyses: elementary chemical composition, including carbon, hydrogen, nitrogen and sulfur using the Elemental Analyzer Perkin Elmer, PE-2400, series II, and oxygen, measured by the difference from the sum of C, H, N, S and ash from 100; proximate chemical analysis, specifically, moisture content, volatile matter, ash content and fixed carbon based on ASTM (2012); and higher heating value (HHV) of industrial sludge and eucalyptus chips and bark, according to ASTM (2019). The HHV of microalgae biomass was calculated using the Equation 1 (Magalhães et al., 2022).

$$HHV = 2.79 + 0.2989C + 0.401N \quad (1)$$

RESULTS AND CONCLUSIONS

The characteristics of the biomass, on a dry basis (d.b.), are presented in Table 1. Compared to other biomass types, the industrial sludge has high ash content and lower carbon and hydrogen contents, which results in a lower HHV. The nitrogen content in microalgae biomass is higher than in other biomass due to the presence of protein (Su et al., 2022), and the sulfur content is close to zero, similar to eucalyptus chips and bark.

Biomass		Industrial sludge	Microalgae biomass	Eucalyptus chips	Eucalyptus bark
Immediate analysis (%, d.b.)	Moisture content	10.4	2.77	14.5	12.3
	Volatile matter	65.1	83.6	87.3	81.2
	Fixed carbon	0.62	0.96	12.5	15.2
	Ash content	34.3	12.7	0.22	3.56
Elementary composition (%, d.b.)	C	22.8	42.5	49.5	46.3
	H	2.33	6.69	6.00	5.30
	O	37.1	30.4	43.0	43.7
	N	2.20	7.15	0.44	0.36
	S	1.21	0.65	0.76	0.77
HHV ($MJ.kg^{-1}$, d.b.)		10.3	18.3	19.4	18.5

Table 1. Immediate analysis, elementary composition and heating value of the biomass.

The volatile matter exceeds 80% for microalgae biomass and eucalyptus chips and bark, and above 60% for industrial sludge. This parameter is important for determining the subsequent processing of the biomass. In this regard, biomass with high volatile matter content is suitable for biofuel production via pyrolysis due to the high proportion of condensable products (López-González et al., 2015).

The oxygen content of eucalyptus chips and bark is higher than that of other biomass types. Along with their high carbon and hydrogen contents, volatile matter, and HHV, makes these materials excellent energy sources. Therefore, since microalgae biomass exhibits similar characteristics, it can be a more attractive option than industrial sludge as a renewable energy source.

The potential of using microalgae biomass in energy conversion processes is a promising field. However, further research is necessary to evaluate the appropriate treatment to utilize microalgae as an energy source, aiming at the circular economy.

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