RECENT ADVANCES IN THE APPLICATION OF RED SEAWEEDS FOR THE SYNTHESIS OF BIOFUELS

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ABSTRACT

The growing global population has significantly increased energy demand, heavily reliant on fossil fuels. To reduce dependence on these fuels and mitigate greenhouse gas emissions, there is a rising demand for clean energy and renewable materials. Biorefinery offers a promising alternative, enabling the conversion of waste into high-value biomass. Various industrial wastes have been utilized to generate biofuels due to their high energy potential and potential as carbon source. Among these, seaweeds, with over 20,000 species globally, have gained attention for industrial applications. Seaweeds can be used in food production, cosmetics, fertilizers, and hydrocolloids like agar. However, the seaweed industry generates significant solid waste, specifically red algae biomass (RSB), which is rich in carbohydrates, proteins, and other compounds. This study aims to summarize and discuss the potential of RSB for biofuel production, highlighting its biochemical composition and potential as a renewable carbon source. Utilizing RSB for bioenergy production addresses waste disposal issues, promoting the generation of clean, renewable energy. This research underscores the environmental benefits and industrial potential of RSB in synthesizing biofuels and high-value products, contributing to the advancement of green energy industries.

Keywords: Bioethanol, Biogas, Bioefuel, Red seaweed biomass, Waste management.

1 INTRODUCTION

As the world's population grows, energy demand also increases, putting pressure on the system, which is largely based on fossil fuels. In an attempt to reduce this dependence and greenhouse gas emissions, there has been a significant increase in demand for different sources of clean energy and renewable materials in recent years. Therefore, biorefinery presents itself as a promising alternative for the industry, enabling the conversion of waste into high-value biomass. Various residues have been used to generate biofuels such as lignocellulosic residues from eggplant peel[1], date palm[2] and sugar cane[3], due to their high energy potential.

Seaweeds have emerged as a promising resource for industrial applications, with more than 20,000 species distributed along the entire global marine coast, they are classified according to their pigmentation and may be used to produce food products, ingredients in cosmetics and fertilizers, and in production of hydrocolloids such as agar. However, this industry generates considerable amounts of solid waste, composed of red algae biomass (RSB), which is a promising raw material for bioenergy production due to its rich content in carbohydrates, proteins, and other compounds[4]. In this context, algal biomass emerges as a renewable source of organic carbon, gaining prominence in the conversion into value-added chemical products and biofuels. These components have the potential to be converted into a range of pharmacological and cosmetic products, and their residues are converted into renewable fuels, such as biogas, bioethanol, biodiesel, biohydrogen, and biobutanol[5] as shown in Figure 1.

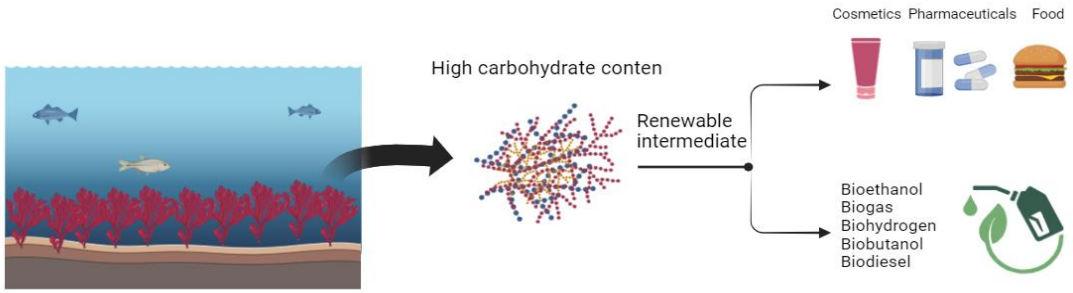

Figure 1 Production of red algae bioproducts

Thus, this work aims to summarize and discuss literature data on the biochemical composition of red seaweeds and their potential for biofuel production, presenting the RSB potential for energy production. Thus, improving the overall knowledge of the usage of wastes for the synthesis of high-value products, in environmentally friendly applications, enhancing the green industry of fuels production.

2 MATERIAL & METHODS

This research was conducted systematically to evaluate the potential of red marine macroalgae biomass as a feedstock in biorefineries aiming to produce biofuels from RSB. The search for works in the literature was carried out using the Scopus database, a multidisciplinary bibliographic platform provided by Elsevier. The database search strategy was designed to identify relevant scientific productions, recently published (2014-2024). Resulting in 89 articles to search for the chosen keywords ("red", "seaweed", and "biofuel"), in the "Article title, Abstract and Keywords" category.

3 RESULTS & DISCUSSION

RSB is mainly composed of proteins with a low lipid content (0.4 - 2.4%) and a large amount of carbohydrates (30 - 60%) of the dry mass [2], mainly in the form of polysaccharides, which can be converted into sugars for the production of bioproducts through the anaerobic digestion process. Table 1 presents the final yield of several biofuels produced from the biomass of different algae, highlighting bioethanol, biogas and biohydrogen obtained from red algae. There is a greater production of these energy sources, especially bioethanol, reaching 0.48 g/L h^{-1} of bioethanol produced in continuous production. Biogas production was also carried out, both for the production of CH_4 and H_2, resulting in the consumption of carbohydrates present in RSB, yielding 132 mL/g and 179 mL/g, respectively, which is representative of the high potential of RSB.

Table 1 Biofuel production and conversion yields macroalgae.

Bioproduct	Red algae species	Performance	References
Bioethanol	*Gracilaria verrucosa*	0.48 g/L h	[6]
Biogas	*Gracillaria vermiculophylla*	132 (mL CH4/g VS)	[7]
Biohydrogen	*Pachymeniopsis elliptica*	179 mL/g VS	[8]
Biobutanol	*Laminariajaponica*	15.8mL/g	[9]
Biodiesel	*Rhizoclonium sp*	46,3% g/g	[10]

*VS- Volatile solids

The utilization of RSB in biofuel production is a strategy to mitigate possible environmental problems related to the RSB incorrect disposal, also enhancing the production of more clean and renewable energy. Thus, Figure 2 present the main subjects related to the published papers. It is observed that "Environmental Science" is the main area of the published papers, due to its Ambiental appeal. Also, "Chemical Engineering" is related to the optimization of the industrial processes related to biofuel production, especially in a high scale, and "Energy" is related to the main goal of scientific production, as a means of renewable energy generation. Thus, these three topics represent 49.5% of the total paper production, being representative of the main goal of the RSB utilization.

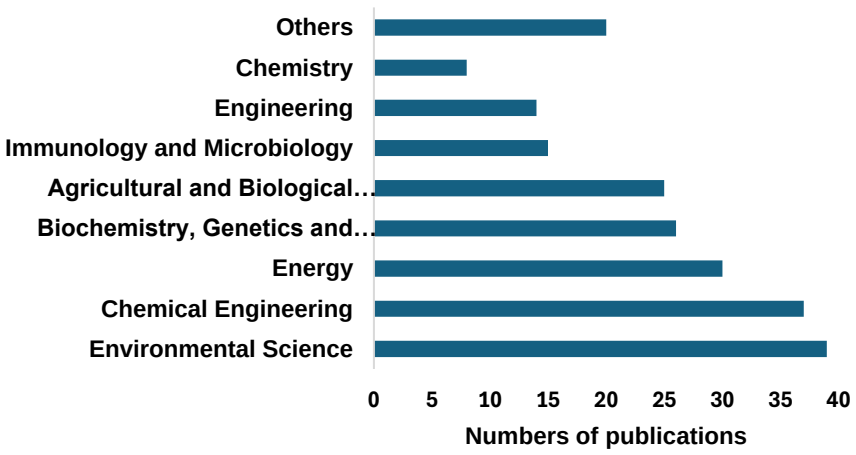

Figure 2 Main subject area of recently published papers (2014-2024) about the application of RSB in the production of biofuels

Figure 3 presents the countries with high production of scientific papers about the RSB usage in biofuels synthesis in recent years. It is observed that countries such as India, South Korea, Malaysia, China and United States have been leading the scientific founding in the field. This is probably due to the geographical position of these countries, which are near tropical waters, where most of the red seaweeds are cultivated. It is important to mention that although Brazil does not present a high number of publications in this field, the country has a high potential for biofuel production using RSB, as it has a high production of seaweeds, especially for agar production.

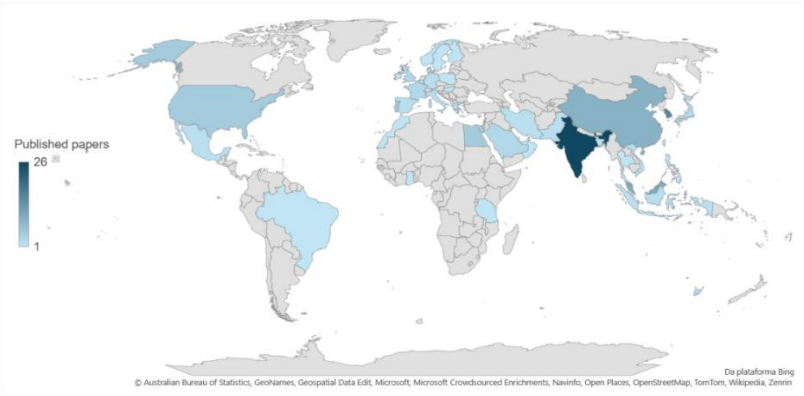

Figure 3 Recent published papers (2014-2024) related to the production of biofuels using res seaweed biomass.

Figure 4 presents the main topics of the previously mentioned research. The production of biofuels using RSB may occur by microbial catalyst, thus it is observed the presence of keywords such as “fermentation” in the cluster map (Figure 4A), as it usually results from the consumption of sugars such as glucose and galactose, which may be released from hydrolysis or pyrolysis processes, and fatty acids may be used in the production of biodiesel, also presents in the map. Figure 4B presents the main biofuels produced in recent papers. Bioethanol and biogas are the main produced biofuels, probably due to the low-cost production of both bio microbial catalyst using the sugars containing in the RSB, as it is also present in the cluster map.

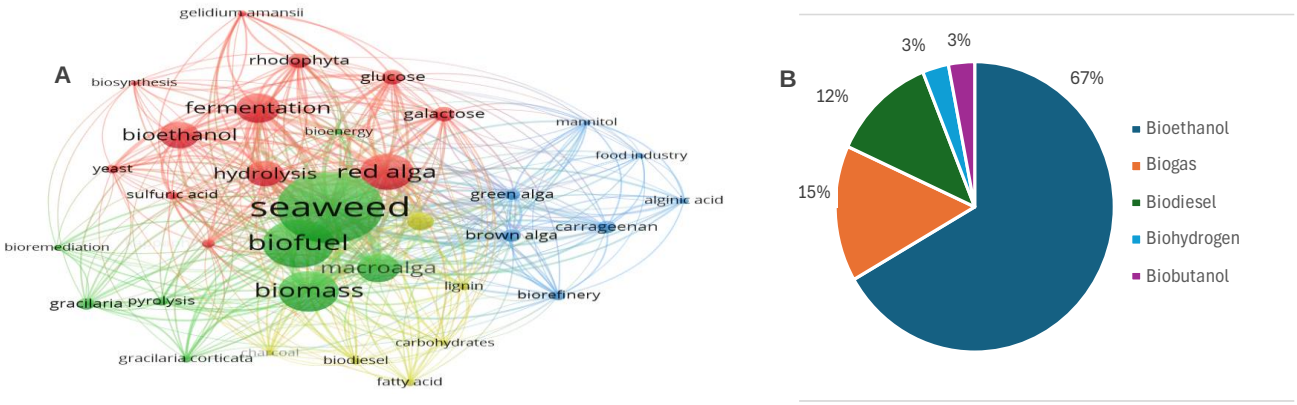

Figure 4 Biliometric analysis of the biofuel production using red seaweed biomass: (A) keyword co-occurrence cluster map from 2014-2024 and (B) mainly produced biofuels using RSB.

4 CONCLUSION

This study highlights the substantial potential of red seaweed biomass (RSB) as a valuable resource for biofuel production, due to its rich biochemical composition. Despite Brazil's relatively low publication output, its high seaweed production capacity promotes its high potential for RSB usage in energy production. This research underscores the importance of continuing to explore and optimize the use of RSB in biorefineries, advancing the green industry and contributing to a more sustainable future. By enhancing the knowledge and application of RSB, we can improve waste utilization, reduce dependence on fossil fuels, and support the development of high-value products in an environmentally friendly manner.

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