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Influence of lipid extraction methods as pre-treatment of microalgal biomass for biogas production

Viviane T. de C. Neves [a,*], Emerson Andrade Sales [b], Louisa W. Perelo [a]

[a] Polytechnic School, Federal University of Bahia, Brazil
[b] Chemistry Institute, Federal University of Bahia, Brazil

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ABSTRACT

One of the important issues concerning anaerobic digestion of microalgal biomass is the influence of the pretreatment on methane production. Various techniques can be used to extract lipids from microalgae, including thermal, chemical or physical processes. The process of lipid extraction can be considered as a pretreatment. Given the economic and ecologic importance of the integration of anaerobic digestion in the microalgae biodiesel production process, this article aims to review the literature about this subject, and relates the influence of various forms of lipids extraction on the methane generation by anaerobic digestion of residual microalgae biomass. The oil extraction using chloroform as a solvent should not be performed if the residue is to be exploited for anaerobic digestion, due to the inhibiting character of this solvent on methanogenic activity. The lipid extracted microalgal biomass presents higher methane yield compared to the raw microalgal biomass with few exceptions. The thermochemical method is the most commonly used pretreatment for lipid extraction of microalgal biomass. Nevertheless, research using pretreatment methods that require less energy such as mechanical and biological should be stimulated. Thus, the energy balance may become more favorable with the use of residual microalgae biomass as an energy source.

Contents

1. Introduction

The anaerobic digestion of residues after lipid extraction from microalgae is highlighted as a key step for the economic and energetic balance in several technoeconomic studies performed on the microalgae biodiesel process [1–4]. One of the important issues concerning anaerobic digestion of microalgal biomass is the influence of the pretreatment on the methane production. The importance of the pretreatment lies in the fact that the resistance of cell walls to rupture can be a major problem in the anaerobic digestion process resulting in low methane yields. Therefore, several researches have focused on the influence of pretreatment of the microalgal biomass on anaerobic biodegradability.

Thus a variety of methods aiming at the disruption of the cell walls of whole microalgae have been investigated, including

* Correspondence to: Laboratory of Bioenergy and Catalysis (LABEC),Environmental Engineering Department, Polytechnic School, Federal University of Bahia, Rua Aristides Novis, 02, 2nd floor, Federação, Salvador, Bahia 40210-630, Brazil.
E-mail address: vivianetcn@gmail.com (V.T.d.C. Neves).

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thermal, ultrasonic, microwave, chemical, mechanical, and other pretreatment [5–11].

The pretreatments described in the literature can be compared with the processes of *in-situ* extraction and transesterification of lipids for biodiesel. Both procedures include thermal, chemical or physical processes. Thus, the process of lipid extraction can be considered as a pretreatment [12]. The methane yield obtained in studies using full biomass after pretreatment can be related to those using residue of the biodiesel production process. However, in these letter process, the potential yield of methane is lower due to the lower energy content after the removal of oils. In the case of residual biomass after extraction processes, it should be considered that the efficiency of lipid extraction depends on the species and the method used [13,14,8].

Another point to be highlighted in the microalgae anaerobic digestion is the diversity of studied species. Several studies on methane production from microalgae of various species have been conducted. However, there is difficulty in comparing results for different pretreatment, co-digestion or extraction of lipids from microalgae [15]. In addition, pretreatments must be designed according to the species to be used [9].

Generally, the theoretical methane potential calculated is much higher than that shown by the experimental data, since they do not consider the various factors that can impair degradability, as the effects of sodium, in marine species, and ammonia released during fermentation, and the recalcitrance of cell walls [2, 16]. Despite the difference between theoretical and experimental data regarding the yield of CH_4 per gram of volatile solids ($mLCH_4\ g\ VS^{-1}$), the values found for the microalgae are comparable with other types of substrate as starch and lignocellulosic crops (Table 1) [17,18].

Given the economic and ecologic importance of the integration of anaerobic digestionin the microalgae biodiesel production

Table 1
Production of methane from various microalgae species under different pretreatment methods.

Feedstock	Pretreatmentmethod	Duration of experiment (days)	Temperature (°C)	CH_4 production	Reference
Chlorella spp.	Lipid extraction with 1-butanol	35	37	268 mL g^{-1} TDS	[16]
Chlorella spp.	Acid catalysed *in situ* transesterification process	22	37	230 mL g^{-1}TDS	[16]
Chlorella spp.	Without lipid extraction	37	37	425 mL $g-^{1}$ TDS	[16]
Chorella sp.	Acid catalysed *in situ* transesterification process	15	35	245 mL g^{-1} VS	[25]
Chlorella vulgaris	Lipid extraction (hexane/isopropanol 70 °C and 1500 psi)	25	35	314 ± 18 mL g^{-1} VS	[20]
Chlorella vulgaris	Without lipid extraction	25	35	337	[20]
Chlorella vulgaris	Ultrasonicated-frequency of 20 kHz and a power of 150 W	45	35	125.2 ± 6 mL CH4 g^{-1} COD added	[30]
Ettlia sp.	Without lipid extraction	117	35	125 g^{-1} VS	[22]
Ettlia sp.	Autoclavedresidue	117	35	176 mL g^{-1} VS	[22]
Ettlia sp.	Residue (250 W microwave)	117	35	162 mL g^{-1} VS	[22]
Ettlia sp.	Sonicated residue	117	35	92 mL g^{-1} VS	[22]
Nannochloropsis gaditana	Lipid extraction with ethanol	53	35	327 ± 2 mL g^{-1} VS	[12]
Nannochloropsis gaditana	Without lipid extraction	53	35	303 ± 5 mL g^{-1} VS	[12]
Nannochloropsis salina with grease waste	Lipid extraction *via* acid hydrolysis and hexane		37	540 mL g^{-1} VS	[14]
Nannochloropsis salina	Lipid extraction (hexane/isopropanol 70 °C and 1500 psi)	25	35	383 ± 13 mL g^{-1} VS	[20]
Nannochloropsis salina	Without lipid extraction	25	35	557 ± 5 mL g^{-1} VS	[20]
Nannochloropsis sp.	Lipid extraction (hexane/isopropanol 70 °C and 1500 psi)	25	35	399 ± 13 mL g^{-1} VS	[20]
Nannochloropsis sp.	Without lipid extraction	25	35	357 ± 5 mL g^{-1}	[20]
Nannochloropsis sp.(batch)	Wet extraction of lipids	77	35	482 mL g VS^{-1}	[23]
Nannochloropsis sp. (semi-continum, 4 L)	Lipid extraction, dry, presence of 2.9 g Na+L^{-1}	36	35	156 mL g VS^{-1}	[23]
Nannochloropsis sp. (semi-continum, 4 L)	Washed to remove salts, dried, lipid extraction	30	35	128 mL g VS^{-1}	[23]
Nannochloropsis sp. (semi-continum, 4 L)	Washed to remove salts, dried, lipid extraction	61	55	220 mL g VS^{-1}	[23]
Nanofrustulum sp.	Lipids extraction (methyl pentane as solvent)	25	35	304 ± 5 mL g^{-1} VS	[20]
Nanofrustulum sp.	Without lipid extraction	25	35	507 ± 5 mL g^{-1}	[20]
Phaeodactylum tricornutum	Lipid extraction (hexane/isopropanol 70 °C and 1500 psi)	25	35	339 ± 13 mL g^{-1} VS	[20]
Phaeodactylum tricornutum	Without lipid extraction	25	35	337 ± 15 mL g^{-1} VS	[20]
Scenedesmus sp.	Lipid extraction using hexane	32–40		212,3 ± 5.6 mL g VS^{-1}	[26]
Scenedesmus sp	Without oil extraction	32–40		140.3 ± 29.4 mL g VS^{-1}	[31]
Scenedesmus spp.	Lipid extraction and alkaline heat treatment (100 °C 8 h)		37	323 mL g^{-1} VS	[31]
Mixed culture enriched with *Scenedesmus* sp.	Lipid extraction with ethanol	35	38	240 mL g^{-1} VS	[21]
Mixed culture enriched with *Scenedesmus* sp.	Extraction of lipids followed by heating to 160 °C at 6 bar pressure followed by pressure decrease	35	38	380 mL g^{-1} VS	[21]
Mixed culture enriched with *Scenedesmus* sp.	Without lipid extraction	35	38	180 mL g^{-1} VS	[21]
Tetraselmis sp.	Supercritical CO_2 extraction	65	38	236 mL g^{-1} VS	[24]
Tetraselmis sp.	Without lipid extraction	65	38	160 mL g^{-1} VS	[24]