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Evaluation of composition and biogas production potential from seagrass (*Halodule uninervis*) native to Abu Dhabi.

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Abstract

Seagrass (*Halodule uninervis*) native to Abu Dhabi was sampled in various locations thorough February to June 2013. Chemical composition was analyzed, which included ash, extractives, structural carbohydrates, acid insoluble residue and CHNSO content. The theoretical methane yield was calculated based on the CHN content using Buswell's formula. Anaerobic digestion was performed with the use of sewage sludge. Three concentrations of seagrass biomass were tested (1%, 3%, 5% of VS) to evaluate the practical methane yield. The highest specific methane yield was obtained for 1% loading rate and resulted in 122 ml/gVS, which corresponds to 30% of theoretical methane yield.

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Keywords: Seagrass, biomass, anaerobic digestion, biogass

1. Introduction

Biofuels from aquatic biomass can be a promising source of sustainable energy. Algae and seagrasses are considered to be some of the most rapid growing sources of biomass. Their growth rate is estimated to be 10 times higher when compared to the terrestrial plants. Their natural habitat makes them ideal biomass for biofuel production as they do not compete with land-based crops in terms of land use and food production [1]. Abu Dhabi coast area is a habitat for 121 species of seaweed and 3 species of seagrass *Halodule uninervis, Halophila ovalis and Halophila stipulacea* [2]. It is estimated that the mean seagrass biomass yield along the western Arabian Gulf coast ranges from 53 to 235 g /m^2, out of which 75% is *Halodule uninervis* [3].

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2. Objective

The main objective of this study was to perform the chemical characterization of seagrass (*Halodule uninervis*) in order to evaluate theoretical biogas potentials. In addition batch experiments were performed to estimate the practical biogas potential.

3. Materials and methods

The samples of *Halodule uninervis* were collected in between February and June 2013 in different locations around Abu Dhabi (Figure 1).

Figure 1 Sampling locations of *Halodule uninervis* collected between February and June 2014

The samples were washed with fresh water and dried for further processing. Compositional analysis was performed according to NREL protocols. Dry matter content and ash were determined by drying at 105^{o}C and ashing at 575^{o}C, respectively using standard methods [4, 5]. Water and ethanol extraction was done using Soxhlet apparatus [6] while sugar content and acid insoluble residue were measured by two step acid hydrolysis [7].

Inoculum for the biogas batch test was obtained from a biogas plant treating sewage sludge (both primary and secondary) at a local waste water treatment company (Al Wathba Water treatment Plant 2). The total solids (TS), volatile solids (VS) and ash content were measured to be 4.25% +/- 0.19%, 2.73% +/- 0.14%

and 1.52% +/- 0.06%, respectively (all presented per wet matter basis, as received). The pH of the sludge was 7.56 +/- 0.09.

As most of the seagrass was collected on 19 March 2013, this batch of biomass was used for biogas experiment trials. The elemental analysis including carbon, hydrogen, nitrogen, oxygen and sulphur were carried out using elemental analyzer (Thermo Scientific, Flash 2000). These numbers were used for the calculation of theoretical methane potential (TMP) following Buswell's formula (where n, a, b stands for the number of atoms of the elements of the organic source material:

$$TMP = \frac{\left(\frac{n}{2}+\frac{a}{8}-\frac{b}{4}\right)22.4}{12n+a+16b}, \quad \left[\frac{L\ CH4}{g\ VS}\right] \quad C_nH_aO_b + \left(n-\frac{a}{4}-\frac{4}{2}\right)H_2O \rightarrow \left(\frac{n}{2}+\frac{a}{8}-\frac{b}{4}\right)CH_4 + \left(\frac{n}{2}+\frac{a}{8}+\frac{b}{4}\right)CO_2$$

Three different loading concentrations of seagrass 1%, 3%, and 5% of volatile solids (VS) were tested to evaluate the methane yield of the seagrass during anaerobic digestion with sewage sludge (1% VS corresponds to 1.52% DM). The experiments were performed in serum vials with a thick rubber septum at 37^{o}C in shaking bed incubator at 120 RPM under anaerobic conditions. Seagrass biomass was mixed with 50 g wet weight of inoculum and filled with nutrient medium [8] to reach 100 g in total. The headspace was flushed with nitrogen to achieve anaerobic conditions. The pH of the mixtures was measured to be between 7.0 – 7.1 for all experiments. The experiment was run for 50 days. Gas samples from the head space were collected using a pressure lock syringe every second day for the first two weeks and then once a week. The gas samples were analysed on gas chromatography unit (SRI Instruments, SRI 8610C) using silica gel column and equipped with flame ionization detector and thermal conductivity detector. Blank samples containing only sludge and nutrient medium were run in parallel to determine the biogas production from the inoculum only. All the experiments were performed in triplicates.

4. Results

The results of compositional analysis of *Halodule uninervis* are presented in Table 1 and Figure 2.

Table 1 The chemical composition of *Halodule uninervis* collected between February and June 2014, AVG = average, STDEV = standard deviation

Date	5-Feb-13		5-Mar-13		19-Mar-13		17-Apr-13		23-Jun-13 A		23-Jun-13 B	
Location	A		B		C		D		C		C	
GPS coordinates	24°35'8.70"N, 54°35'23.70"E;		24°31'3.90"N, 54°32'45.90"E		24°27'36.70"N, 54°32'13.23"E		24°23'49.48"N, 54°18'3.11"E		24°27'36.70"N, 54°32'13.23"E		24°27'36.70"N, 54°32'13.23"E	
Components [% DM]	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
Ash	31.14	1.53	28.84	3.13	34.18	2.76	37.03	1.45	24.24	0.10	26.65	0.57
Water extractives	7.05	0.14	35.35	1.43	18.69	1.01	23.07	3.02	24.65	1.90	31.09	1.39
Ethanol extractives	1.13	1.22	3.88	2.28	0.89	0.09	0.25	0.03	1.86	0.81	1.29	0.17
Glucan	16.63	0.24	24.93	0.60	16.89	0.22	17.24	1.56	23.16	0.00	25.59	0.25
Xylan	5.08	0.05	4.50	0.06	5.71	0.00	5.85	0.10	5.72	0.04	4.56	0.08
Arabinan	4.15	0.01	2.48	0.10	3.69	0.00	2.96	0.01	3.83	0.08	2.70	0.02
Acid insoluble residue	17.15	0.58	10.56	0.94	14.90	3.46	15.75	2.07	18.96	1.16	17.72	3.88

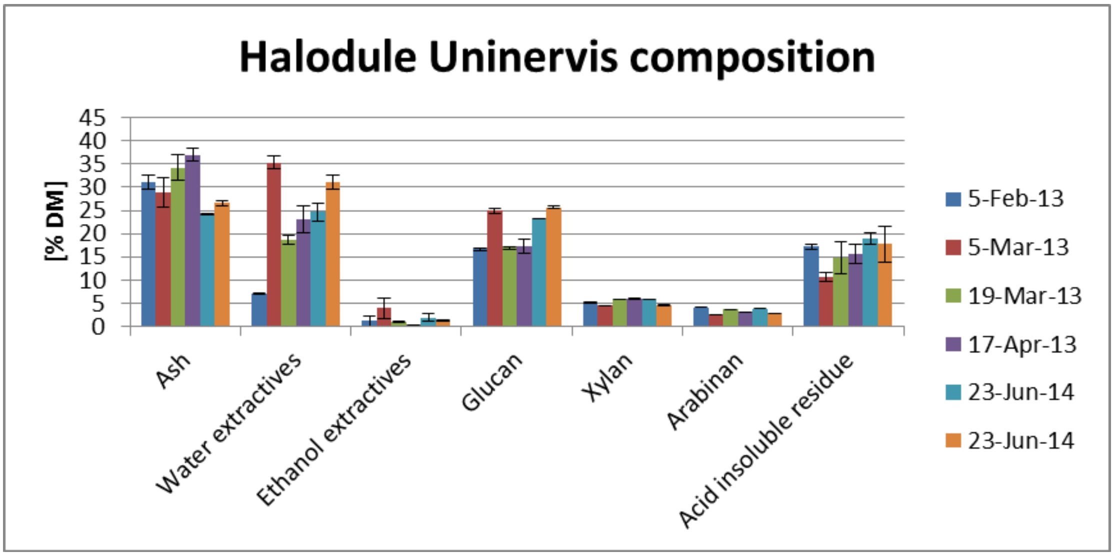

Figure 2 The chemical composition of *Halodule uninervis* collected between February and June 2014

The results showed that chemical composition of *Halodule uninervis* varies in time of harvest. The high ash content (between 25 and 35%) reduces the biofuels production potential as only organic matter can be converted to biofuels. The glucan content was measured between 15 and 25%, xylan and arabinan content showed small variation with average around 5% for xylan and 3% for xylan.

Elemental analysis results are presented in Table 2. The nitrogen content was measured with Khjeldahl method as well and showed similar results as from EA. Theoretical methane potential, calculated according to Buswell's formula, resulted in 405 mL CH4/gVS.

Table 2 The CHSNO content in Halodule Uninervis, AVG = average, STDEV = standard deviation

Nitrogen [%]		Kjeldahl Nitrogen [%]		Carbon [%]		Hydrogen [%]		Sulphur [%]		Oxygen [%]	
AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
1.88	0.03	1.77	0.07	29.19	0.84	3.74	0.17	0.77	0.08	32.25	0.35

The results showed that cumulative methane production was higher with higher loading rates of seagrass (Figure 3). The highest accumulative methane production was observed for samples with 5% VS resulting in 523 ml. Methane volume in sample with 3% VS reached 430 ml and in sample with 1% VS reached 238 ml methane after 50 days of experiment. The blank sample produced 115 ml of methane after 50 days. For all treatments the maximum methane production was achieved after 2-3 weeks.

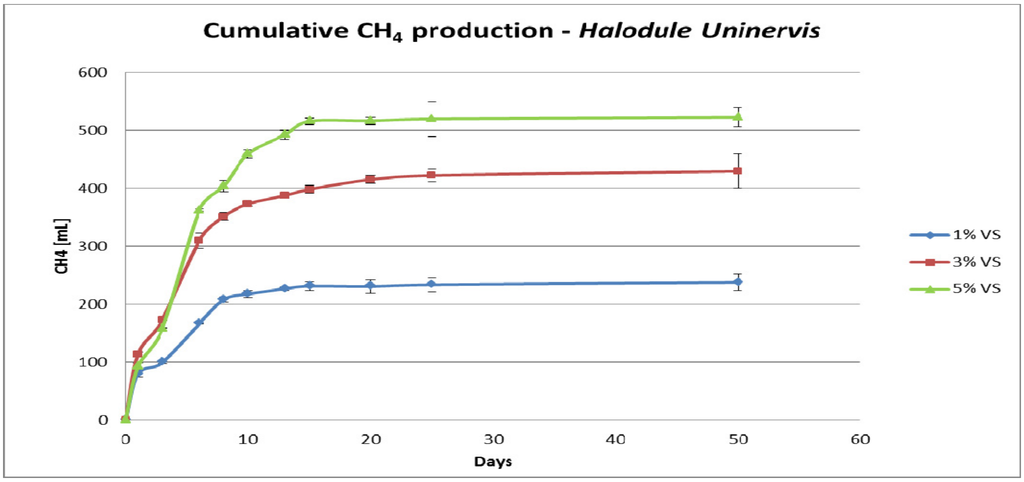

Figure 3 The effect of different loading rates of *Halodule uninervis* on cumulative methane production.

Specific methane production was calculated as volume of CH4 per gram of VS of seagrass samples added. The highest specific methane production was observed for sample with 1% VS reaching 122 ml/g VS. The samples with 3% VS reached 105 ml/gVS, while sample with 5% VS produced 84 ml/gVS after 50 days.

The production of carbon dioxide measured in the head space was observed mostly within first week and then only slight changes were observed. Cumulative carbon dioxide production in the headspace after 50 days reached 133ml, 477ml, and 605 ml for samples with 1%, 3% and 5% VS respectively. The pH measured with the pH indicator paper was relatively stable around 7 for all the samples throughout the whole experiment.

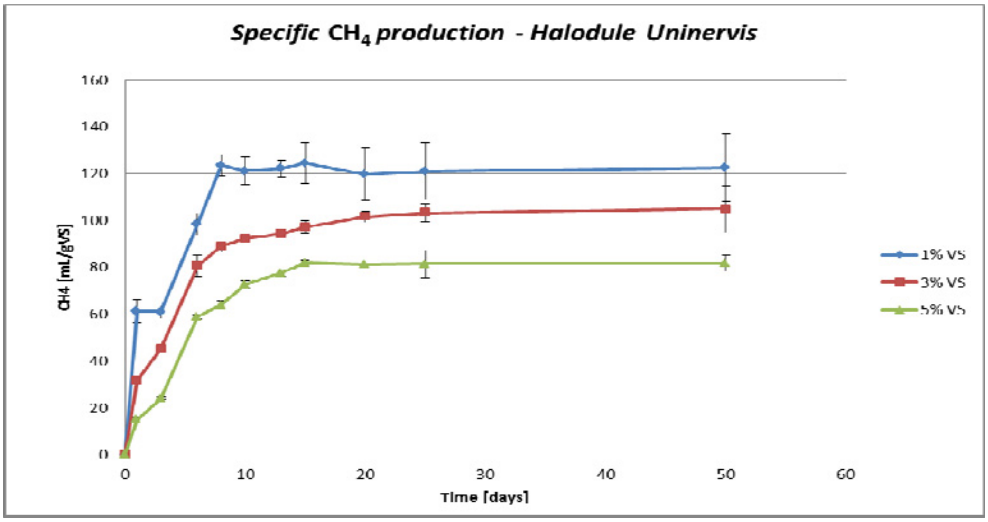

Figure 4 The effect of different loading rates of *Halodule Uninervis* on specific methane production.

After 50 days, the trial of re-addition of seagrass to the serum bottles was performed in order to see if the microorganisms adapted better for the digestion of seagrass biomass, but the same or slightly lower specific methane yields were obtained after running the experiments for 50 more days.

5. Conclusions

The results showed that cumulative methane production increased with higher VS loading, a 80% and 120% increase was observed when VS loading was raised from 1% to 3% and 5% respectively. Specific methane production decreased with higher VS loading resulting in 14% and 31% decline when VS loading was increased from 1% to 3% and 5% respectively, indicating an inhibition of the anaerobic process with increasing concentration of seagrass. The highest specific methane yield observed in this study was relatively low when compared with industrial biogas processes. When comparing practical methane production (122 ml/g VS for 1% VS loading rate) with theoretical methane production (405 ml/g VS) only 30% of conversion of organic matter to methane was observed for *Halodule uninervis*. Co-digestion with other wastes could be a way of solving the inhibition problems using seagrass as substrate for biogas production but it requires further investigation.

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References

[1] Borines MG, de Leon RL, McHenry MP. Bioethanol production from farming non-food macroalgae in Pacific island nationjjs: Chemical constituents, bioethanol yields, and prospective species in the Philippines. Renewable and Sustainable Energy Reviews 2011;15:4432.
[2] EAD. Marine and costal environment of Abu Dhabi Emirate. Environmental Agency of Abu Dhabi; 2007.
[3] Abdessalaam TZA. Marine Environment and Resources of Abu Dhabi: Environment Agency - Abu Dhabi; 2007.

[4] Sluiter A, Hames B, Hyman D, Payne C, Ruiz R, Scarlata C, et al. Determination of total solids in biomass and total dissolved solids in liquid process samples. Laboratory Analytical Procedure, NREL/TP-510-42621. Golden, CO: National Renewable Energy Laboratory, Golden, CO.; 2008, p. 1.
[5] Sluiter A, Hames B, Ruiz R, Scarlata C, Sluiter J, Templeton D. Determination of ash in biomass. Golden, Co: National Renewable Energy Laboratory; 2008, p. 1.
[6] Sluiter A, Ruiz R, Scarlata C, Sluiter J, Templeton D. Determination of extractives in biomass. Golden, CO: National Renewable Energy Laboratory; 2008, p. 1.
[7] Sluiter A, Hames B, Ruiz R, Scarlata C, Sluiter J, Templeton D, et al. Determination of structural carbohydrates and lignin in biomass. Laboratory Analytical Procedure, NREL/TP-510-42618. Golden, CO: National Renewable Laboratory, Golden, CO.; 2008, p. 1.
[8] Angelidaki I, Alves M, Bolzonella D, Borzacconi L, Campos JL, Guwy AJ, et al. Defining the biomethane potential (BMP) of solid organic wastes and energy crops a proposed protocol for batch assays. Water Science & Technology—WST 2009;59:927.

Biography

Dr. Grzegorz Brudecki is a Post Doctoral Researcher at Masdar Institute of Science and Technology in Abu Dhabi. His research focuses on the characterization and conversion of aquatic biomass (algae, seagrass) and terrestrial halophytic plants for biofules and bioproducts. He is an author and co-author of several peer-reviewed publications, book chapters and conference contributions on the biofuels production.