USES OF A WATER-ALGAE-PHOTO-BIO-SCRUBBER FOR SYNGAS UPGRADING AND PURIFICATION

Giulio Allesina, Simone Pedrazzi, Laura Arru, Meltem Altunöz Hatipoğlu, Marco Puglia and Paolo Tartarini
BEELab (Bio Energy Efficiency Laboratory) - Department of Engineering "Enzo Ferrari"
Via Vivarelli, 10/1 – 41125 Modena, Italy.Phone: 00390592056229 Mail: giulio.allesina@unimore.it

ABSTRACT: Aim of this work is to try to put together the two worlds of syngas filtering and syngas upgrading troughthe use of a water-algae water photo-bio-scrubber. The system studied consists of a 10 kWel downdraft gasifier provided with a water scrubber where the syngas is bubbled in a solution of water, nutrients, algae and artificial light (. The heat provided by the syngas keeps the scrubber to the proper temperature where tars are condensed and algae can grow at proper rate. At the same time the CO_2 content in the gas can be, in part, converted into biomass by the algae. From the scrubber it is disposed a multi-phase liquid composed of water, biomass, tars and char. The first analysis carried out in this work consisted in a two phases process of the gas. First, in the gasification system, part of the gas was derived into a simple water scrubber where al the flows where measured and the temperature was kept constant at 30 °C. Then the water obtained in such a way was used as basis for algae grown in lab conditions. Results shown the capability of such a system to be used in existing gasification facilities.
Keywords: algae, gasification, syngas, tar

1 INTRODUCTION

The Achille's heel of a gasification systems is the filtering apparatus. In fact, while dry filtering processes result simple and reliable, the filtering material defines the maximum temperature that the filter can resist and, in some cases, if this temperature is not high enough, some tar condensation already occurred [1,2]. On the other hand, wet filters are very effective but they drop the gas temperature down where most of the tars and the steam content in the gas is condensed [1,2]. This can be a "plus" from the engine maintenance point of view, but then arrives the moment when the costs for all the condensate disposal need to be accounted, leaving a big minus on the gasifier balance sheet.

A complete different topic of research is represented by the syngas upgrading systems. These system are aimed at getting rid of the gases that do not produce any calorific contribution, thus increasing the heating value of the fuel and, sometimes, increasing the efficiency of the systems where the syngas is used, i.e system for bio-SNG production [3].

In addition, the presence of high shares of CO_2 and N_2
reduces the efficiency of methanol production from syngas in Fisher-Tropsh reactors [4].

The idea presented in this work is to analyze and discuss the effects of water-algae scrubbers in syngas power plants. The water acts as filtering and cooling medium and the algae reacts with the CO_2 content of the gas to produce O_2 and C that is used by the algae to grown.

The choice of the right micro-algae strain needs to be done in the intersection between the set of strains capable of efficient CO_2 sequestration (reported in Fig.1) and the set of strains with high ecological resilience to the hostile conditions generated by the syngas interaction with the water.

A summary of organisms capable of assimilating CO_2 is reported in Fig. 1 taken from [5]. The scope is further extended, with the advent of enabling technologies such as genetic engineering, metabolic engineering, system and synthetic biology, and protein engineering.

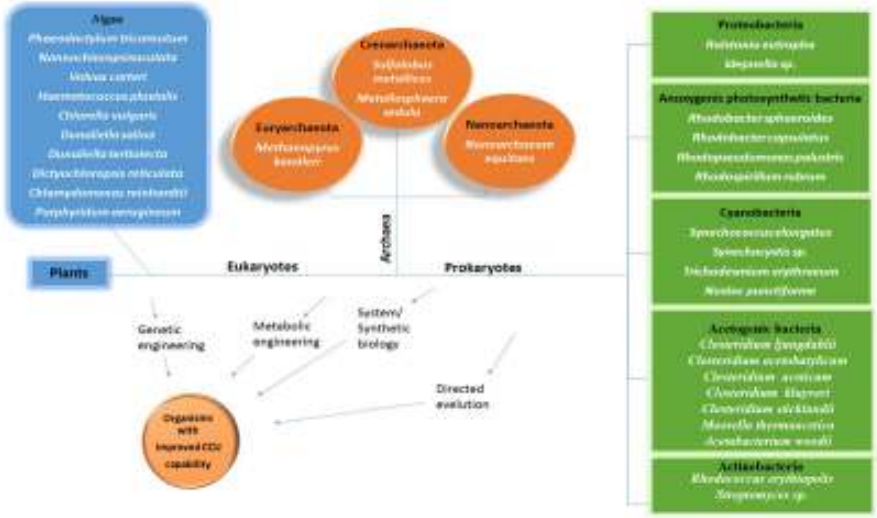

Figure 1: A summary of organisms capable of assimilating CO_2 (adapted from [5])

1.1 Gasifier facility

A 10 kW gasifier power plant was used in this work [6]. It is an imbert type downdraft gasifier fueled with wood chips. The syngas generated by the reactor is roughly filtered in a drum filter where wood chips are used by filter media. The values of tar, water and particulate in the filtered gas was measured in a previous work and are reported in Table I. As depicted in Figure 2, part of the wood-gas is derived after the biofilter and it is sent the Water Algae Photo Bio Scrubber system (WAPBS): a series of 4Drechsel bottles filled with about 0.4 l of syngas cleansing water (SCW). The syngas volume that pass through the bottles is measured by a gas meter.Into the bottles the syngas is cooled down from 50 °C to 30 °C, tar and particulate are trapped into the water while part of the CO_2 is available for the micro algae to be converted into biomass. The syngas flow through the bottles is very low (about 0,5 Nm^3/h), in such a way all the pollutants of the syngas are trapped into the bottles.

Three tests was done increasing the volume of the syngas filtered in the bottles. Table III resumes the results in terms of condensate water, particulate and tar in each sample of scrubbing water.

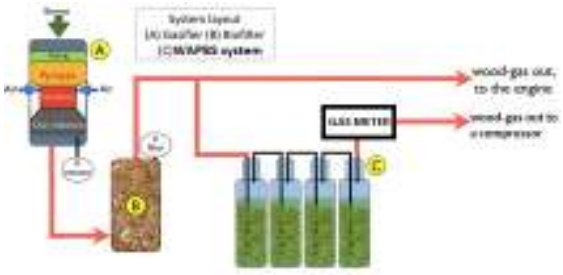

Figure 2: Gasifier facility

Table I: Syngas pollutant values after biofilter[7]

Syngas volumetric tar amount [mg/Nm^3]	349
Syngas volumetric particulate amount [mg/Nm^3]	140
Syngas volumetric water amount [g/Nm^3]	36,09

1.2 Algae growth

Fourteen days old *Neochlorisoleoabundans* microalgae were transferred into flasks containing syngas cleansing water (SCW). Three different SCW samples were diluted with BG11 microalgal growth medium [8] in 3 different ratios (9 samples plus control). Table II resumes SCW-BG11 proportion in each sample. Algal cell concentration, growth rate, optical density, pigment content and cell volume have been monitored along a period of 10 days. The flasks containing the microalgal cultures were placed inside an incubator (Isco SRL-FTD-250 Plus-Cooling Incubator, USA) exposed to a photon flux density of 150µmol m^2 s^{-1},under 8/16 h photoperiod at the temperature of 26 °C. The pH of each medium were adjusted to 7.4 ±1.

Table II: SCW dilution with BG11

	Sample name	Syngas Cleansing Water (SCW) (%)	BG11[8] (%)
A Bottle	A1	50	50
	A2	70	30
	A3	30	70
B Bottle	B1	50	50
	B2	70	30
	B3	30	70
C Bottle	C1	50	50
	C2	70	30
	C3	30	70
BG 11	Ctrl	100	

1.2.1 Cell Size, Concentration, Optical Density and Growth Rate

Concentration of microalgae cells was measured using Improved Neubauerhaemocytometer [9] under the light microscope; sizes and volumes of the microalgal cells were measured by the calibrated software of digital imaging microscope systems (Nikon Corporation Instruments Company, Advanced Research Microscope Eclipse 80i, Japan). The cell concentration (cells/ml) was calculated according to the formula of Guillard[10]. At the end of 10th day the optical density (OD) of *N. oleoabundans* extractwas measured at 665 nm, by using UV-Vis/NIR Spectrophotometer (The JASCO V-500/V-600 Series Instruments, Japan). The growth rates of the samples were derived on the basis of the concentration values of the microalgal cells [11]

1.2.2 Photosynthetic Pigments Content

Pigments were extracted by re-suspension of microalgae in 90% methanol, supernatant was taken for measuring the absorbance spectrum between 350 nm and 800 nm. The analytical determination of chlorophyll a, chlorophyll b and carotenoids (carotene and xanthophylls) was performed with UV-Vis/NIR Spectrophotometer at 470 nm, 652.4 nm and 665.2 nm by subtracting absorbance values at 750 nm (Ritchie 2006). The formula to calculate pigments content was used according to the solvent, which is methanol in this study (Lichtenthaler and Buschmann 2001).

2 RESULTS AND DISCUSSION

2.1 SCW results

Syngas cleaning water pollutants contents are reported in Table III. The syngas volume column reports the volumes of syngas purged into the bottle for every SCW sample. Water concentration column reports the syngas condensed water into the SGW sample.

Sample C is the worst in terms of pollutants concentration. Infact, it presents an high amount of tar concentration (661 mg/l) which could be toxic for the algae growth.

Table II: SCW pollutants concentrations

SCW sample	Syngas vol.[l]	Water vol.[l]	Tar conc. [mg/l]	Particulate conc. [mg/l]	Water conc. [g/l]
A	263	0.3	306	123	32
B	500	0.4	436	175	45
C	750	0.4	611	262	63

2.2 Algae growth in SCW

In this section, we evaluated the ability of microalgae to grow in contaminated syngas cleansing water. The effect of SCWs was evaluated. Three different SCW samples were diluted in 3 different concentrations (9 samples). One of the conditions (C2) was strongly toxic for microalgae growth and it was not considered in the analysis.

For the microalgae grown in each sample, the relation between O.D. and cell concentration was examined and the algae grown in B3 showed the highest values of OD and cell concentration, close followed by the ones grown in B1 (see Figure 3). According to the growth rate, microalgae grown in A1, B1, B3 samples returned the highest values as shown in Figure 4,5,6. Instead, the microalgae grown into the B3 and B1 SCWs have the highest amount of pigments content (see Figure 7).

According to the cell volume, after 10 days growth, microalgae in B3 sample have clearly the largest biovolume (see Figure 8).

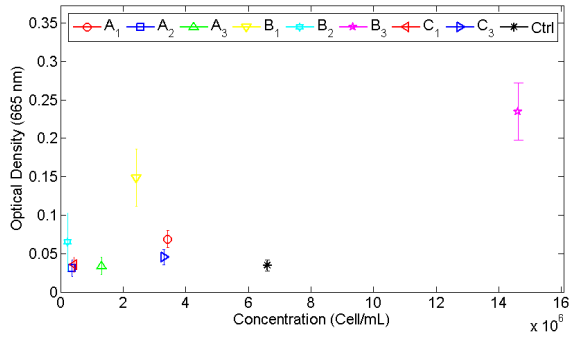

Figure 3: Optical Density at 665nm and cell Concentration of the microalgae strains

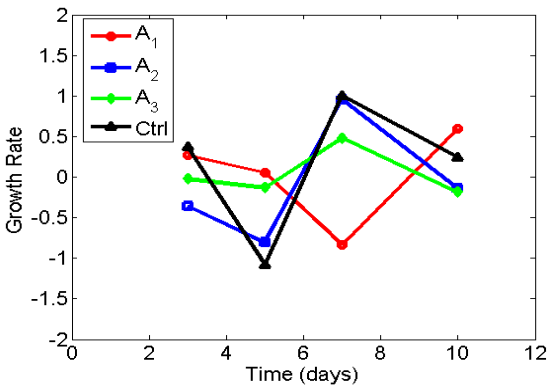

Figure 4: Growth Rate within 10 days experiment in A1 SCW sample

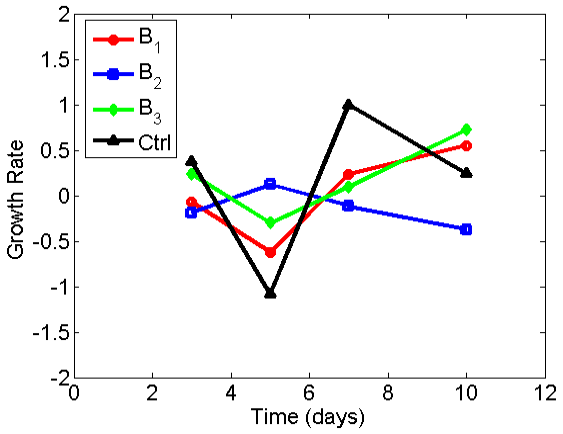

Figure 5: Growth Rate within 10 days experiment in B1 SCW sample

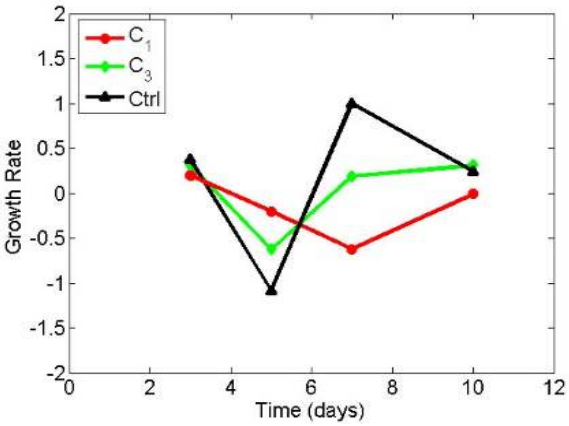

Figure 6: Growth Rate within 10 days experiment in B3 SCW sample

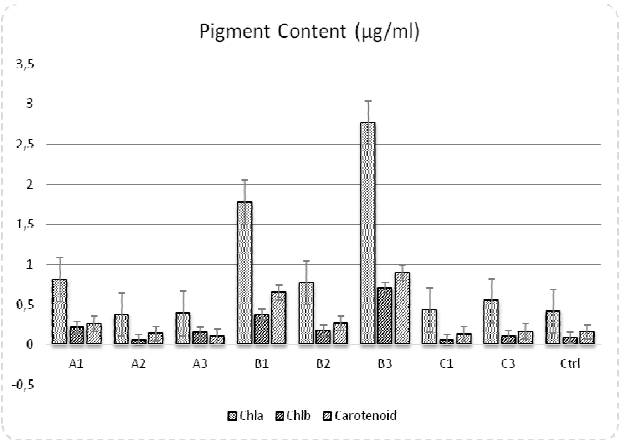

Figure 7: Photosynthetic pigment content within 10 days

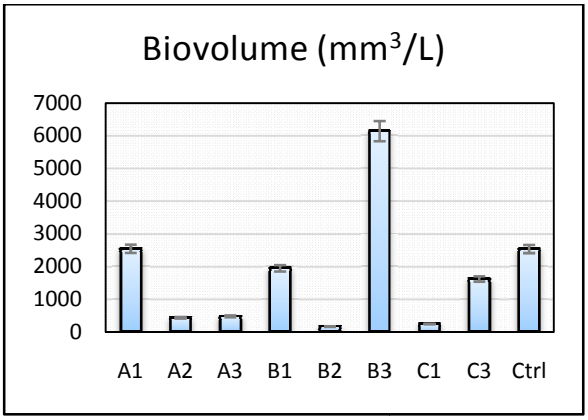

Figure 8: Algae biovolume after 10 days growth

3 CONCLUSIONS

Results confirm that syngas cleansing water samples are not toxic for the *Neochlorisoleoabundans* microalgae. The maximum values of OD and cell concentration within 10 days was reached using B3 mixture composed by 30% of sample B syngas cleasing water and 70% BG11 microalgal growth medium.

This mixture will be used in WAPBS system in order to cool, purify and upgrade the syngas produced by wood gasification. The design of an experimental prototype of this filter will be take into account the properties of the SCW-BG11 mixture here discussed.

Therefore, some secondary compounds derived from the gasification process, such as ammonia and light tars can compromise the efficiency of the conversion into biomass of the CO_2 of the gas. Future work will be aimed at the prototyping of a full scale facility in order to perform long runs of several hours.

4 REFERENCES

[1] NourredineAbdoulmoumine, Sushil Adhikari, Avanti Kulkarni, ShyamsundarChattanathan, A review on biomass gasification syngas cleanup, Applied Energy, Volume 155, 1 October 2015, Pages 294-307.

[2] Patrick J. Woolcock, Robert C. Brown, A review of cleaning technologies for biomass-derived syngas, Biomass and Bioenergy, Volume 52, May 2013, Pages 54-84.

[3] Pedro Haro, Filip Johnsson, Henrik Thunman, Improved syngas processing for enhanced Bio-SNG production: A techno-economic assessment, Energy, Volume 101, 15 April 2016, Pages 380-389.

[4] S.N. Naik, Vaibhav V. Goud, Prasant K. Rout, Ajay K. Dalai, Production of first and second generation biofuels: A comprehensive review, Renewable and Sustainable Energy Reviews, Volume 14, Issue 2, February 2010, Pages 578-597.

[5] Jajesniak P, Omar Ali HEM, Wong TS (2014) Carbon Dioxide Capture and Utilization using Biological Systems: Opportunities and Challenges. J Bioprocess Biotech 4:155.

[6] All Power Labs 10 kW Power Pallet V.4, available at www.allpowerlabs.com

[7] Puglia M., 2016, Sviluppo di metodi sperimentali ed analitici per il monitoraggio e la valutazione di impianti di gassificazione, M.Sc. Thesis, Department of Engineering "Enzo Ferrari", University of Modena and Reggio Emilia, Italy.

[8] Rippka R., 1988, Isolation and purification of cyanobacteria, Methods Enzymol, 167, pp. 3–27.

[9] McAteer JA, Davis J. Counting cells in suspension. In: Basic cell culture—aa practical approach. Oxford, England: IRL Press;1996. p 126

[10] Guillard,R.R.L. (1978) Counting slides. In Sournia,A. (ed.), Phytoplankton Manual-Monographs on Oceanographic Methodology. UNESCO, Paris, France.

[11] Guillard,R.R.L. (1973) Division rates. In Stein,J.R. (ed.), Handbook of Phycological Methods: Culture Methods and Growth Treatment. University Press, Cambridge, London, p. 289.