BILINGUAL PUBLISHING CO.
Pioneer of Global Academics Since 1984

Non–Metallic Material Science
https://ojs.bilpublishing.com/index.php/nmms

ARTICLE

Bio-fuel Production From Carbondioxide Gas Using *S. elongatus* PCC 7942 from Cyanobacteria

Delia Teresa Sponza[1*] Cansu Doğanx[2]

1. Environmental Engineering Department, Engineering Faculty, Dokuz Eylül University, Buca-İzmir, Turkey
2. Sciences Institute, Deparment of Biology, Science Faculty, xAgean University, Turkey

ARTICLE INFO

Article history
Received: 17 April 2020
Accepted: 26 April 2020
Published Online: 30 April 2020

Keywords:
Bio-Fuel
Carbondioxide GAS *S. elongatus*
Cyanobacteria
1-butanol

ABSTRACT

The aim of this study, is 1-butanol production using CO_2 with *S. elongatus* PCC 7942 culture. The yields of 1-butanol$_{produced}$/$CO_{2utilized}$ have been calculated. The maximum concentration of produced 1- butanol is 35.37 mg/L and 1-butanol$_{produced}$/$CO_{2utilized}$ efficiency is 92.4. The optimum operational conditions were 30°C temperature, 60 W intensity of light, pH= 7.1, 120 mV redox potential, 0.083 m3/sn flow rate with CO_2 and 0.5 mg/l dissolved O_2 concentration. Among the enzymes on the metabolic trail of the production of 1-butanol via using *S. elongatus* PCC 7942 cyanobacteria. At maximum yield; the measured concentrations are 0.016 µg/ml for hbd; 0.0022 µg/ml for Ter and 0.0048 µg/ml for AdhE2. The cost analyses necessary for 1-butanol production has been done and the cost of 1 liter 1-butanol has been determined as 1.31 TL/L.

1. Introduction

The carbon dioxide levels in the atmosphere elevated 2,2 – 3,2 ppm every year, since the fossils was combusted. Although carbon dioxide in air was in minor level (between 0,01–0.036 %) it's concentration elavated significantly in municipal metropoullitan areas and industrial regions. The carbon dioxide level in the air increase 2,2 – 3,2 ppm in every year due to utilisation of fosil fuels as heating. The carbon dioxide concentrations in the organized fabriks was measured as high as 600-700 ppm [1]. 86 % of carbon dioxide in the air generated from the utilization of fuels (petrolium, coal and methane gas). 19 % of the carbon dioxide present in air coming from the humans, from the air pollutants and from the microorganisms by cleaving the complex organics. The contamination increase since petrolium, coal and methane gas were continously utilized. The experimental studies aim to decrease the carbon dioxide concentrations to the lower level (400 ppm) by decreasing the CO_2 emissions 60-85 % in year 2055. The green energy source 1-butanol is an candidate in the utilisation as fuel in the comparison to gasoline and methane. It can be produced by the wastes, it can be used as a source for heat, as car and motor fuel. By attaining the gasoline's place, 1-butanol is considered as an alternative to the potential fuel. The energy density of 1-butanol is 27 MJ/L. When compared, it has an energy density which is close to gasoline (32 MJ/L) and higher than ethanol (21 MJ/L) [2]. Besides, the CO_2 emission from the gasoline used for vehicles and derivatives exhausts and this constitutes a great threat for global warming. As the carbon in 1-butanol is obtained from *S. elongatus* PCC 7942's segmenting the carbon dioxide in

**Corresponding Author:*
Delia Teresa Sponza,
Environmental Engineering Department, Engineering Faculty, Dokuz Eylül University, Buca-İzmir, Turkey;
Email: delya.sponza@deu.edu.tr

 DOI: https://doi.org/10.30564/omms.v2i1.1809

the weather, burning 1-butanol does not cause a significant increase in carbon dioxide in the Earth's atmosphere. In the comparison of the costs of gasoline, the cost of 1-butanol is 3,8 times cheaper. Nowadays, the cost of 1 liter of gasoline is 4, 98 TL/L. The maximum cost of 1 liter of 1-butanol was found to be 1, 31 TL/L in this study. Therefore, 1-butanol, as an alternative source to to gasoline will both reduce the cost and be used sustainably and widely as a renewable energy source.

Nitrogen, phosphorus and inorganic carbon it is important growth parameters for generation of S. elongates. İnorganic carbon source CO2 in the polluted industrial regions at high levels stimulates the growth of S. elongates [8,9]. *Atsumi et al.,* found that S. elongates grow at very high rate in regions containing high CO2 levels compared to clean district areas [3]. It was determined that elevated CO2 levels improve the photoshynthesis in these bacteria. As aforementioned *S. elongatus* PCC 7942 Cyanobacteria types decrease the carbon dioxide percentages in the polluted air and can be fixing easily from the oceans, lakes and rivers. 1-butanol is a primary alcohol with a four carbon structure and its e chemical formula is C_4H_9OH. Its molecular weight 74.1216 g/mol, is colorless and have the same density as water. 1-Butanol can be accepted as a candidate energy source and can be used as energy instead of gasoline. The energy efficiency of 1-butanol (27 MJ/L) is higher than that of ethanol (21 MJ/L) and equivalent to that of gasoline (32 MJ/L) In addition, its hygroscopicity and compatibility also provide its excellent utilisation as energy source [2]. 1-butanol can be synthesized by butyryl-CoA from acetyl-CoA in Calvin cycle. 1-butanol production occurs by the existance of five enzymes: acebe cotyl-CoA acetyltransferase (AtoB), 3-hydroxybutyryl-CoA dehydrogenase (Hbd), crotonase (Crt), trans-2-enoyl-CoA reductase (Ter) and aldehyde alcohol dehydrogenase (AdhE2) [3]. Recent studies showed that Cyanobacteria produce isobutyraldehyde, isobutanol [3], ethanol [4,5], ethylene [6], isoprene [7], sugars [8], and lactic acid [9]. The extensive synthesis of isobutanol and isobutyraldehyde from CO_2 indicates the feasibility of 1-butanol. Furthermore, CO_2 emissions which were the main pollutant source in the industralized districs and in the villages can be converted to a helpfull tool [1,2,3].

1-butanol which is used as biofuel will be the alternative to the gasoline in next days in the world. Compared to gasoline, 1-butanol is more economical and eco-friendly [10,11,12]. S.elongatus PCC 7942 is obtained by splitting the CO_2 in the air so the carbon burned in 1-butanol doesn't cause an increase in earth's atmosphere [10,11]. With this reason, in order to prevent the increase of CO_2 in the atmosphere, the utilization of 1-butanol will be a strong alternative for energy source in the future [10,12]. The cyanobacteria genus were extensively used in biofuel and energy productions due to its non-expensive cost, and the easily fixing reasons from the oceans, lakes, sediments, river and sea-sides [12,13].They convert the CO_2 to 1-butanol using their photosynthetic properties.

1-butanol production from CO_2 with *S. elongatus* PCC 7942 culture was performed, in this study. The yields of $1\text{-butanol}_{produced}/CO_{2utilized}$ and the 1-butanol concentrations have been calculated.

2. Materials and Methods

The studies were carried with the optimum parameters which are 30°C temperature, 60W light intensity, pH = 7.1, 120 mV redox potential, 0,083 m^3/sec debit together with 0,5 mg/l CO_2 and dissolved O_2 concentration. The *S. elongatus* PCC 7942 cultures used in the test were pure (ATCC 33912) and were isolated from the coasts of Foça Sea, a district of Izmir, a spring in the estate of Foça Balaban Mountain, estate of Reis Dere in Tahtalı Baraj Lake (reservoir), in Izmir-Turkey. The *S. elongatus* PCC 7942 was grown in BB-11 broth at 37°C which has an OD_{730} level of 3.9–4.2 at 610 nm wave lentgh in an Spectrophotometer [2,3]. In each study, the concentrations of 3-hydroxybutyryl-CoA dehydrogenase (hbd), trans-2-enoyl-CoA reductase (Ter) and bifunctional aldehyde alcohol dehydrogenase (AdhE2) enzymes were measured in an Agilent HPLC with an C-18 column. 1-Butanol and CO2 emissions in the samples was measured in an Agilent GC-MS 7890-A system with flame ionization detector and DB-FFAP capillary column. The column flow was 3 ml/min and the retention time of 1-butanol was 2.485 min.

3. Results

The studies were carried with the parameters which are 30°C temperature, 60W light intensity, pH = 7.1, 120 mV redox potential, 0,083 m^3/sec debit together with 0,5 mg/l CO_2 and dissolved O_2 concentration. The *S. elongatus* PCC 7942 cultures used in the test were pure (ATCC 33912) and were isolated from the coasts of Foça Sea, a district of Izmir, a spring in the estate of Foça Balaban Mountain, estate of Reis Dere in Tahtalı Baraj Lake (reservoir), in Izmir. In each study, the concentrations of 3-hydroxybutyryl-CoA dehydrogenase (hbd), trans-2-enoyl-CoA reductase (Ter) and bifunctional aldehyde alcohol dehydrogenase (AdhE2) enzymes which are among the ones exist on the metabolic pathway, were measured in spectrophotometer.

The maximum concentration of produced 1- butanol

DOI: https://doi.org/10.30564/omms.v2i1.1809

is 35.37 mg/L and 1-butanol$_{produced}$/$CO_{2utilized}$ efficiency is 92.4%. The maximum yields have been achieved under the optimum operation parameters which are 30°C temperature, 60 W intensity of light, pH= 7.1, 120 mV redox potential, 0.083 m^3/sn flow rate with CO_2 and 0.5 mg/l dissolved O_2 concentration. Among the enzymes on the metabolic trail of the production of 1-butanol via using *S. elongatus* PCC 7942 cyanobacteria. At maximum yield; the measured enzyme concentrations were 0.016 µg/ml for hbd; 0.0022 µg/ml for Ter and 0.0048 µg/ml for AdhE2, respectively. The cost analyses necessary for 1-butanol production has been done and the cost of 1 liter 1-butanol has been determined as 1.31 TL/L.

In Calvin Chain 3-phosphoglyserate production provided by the rubisco enzym which i precursor in the binding of CO2 to ribuloz-1,5 biphosphate. Ribuloz-1,5 biphosphate reduce the acetil-CoA'to CoA'yaand as result 1-butanol was produced(Lan and Liao, 2012). In our study it was found that 1- butanol is produced via hbd enzym. This enzym oconvert the acetoacetil-CoA to-hidroksibutiril-CoA resulting in 1- butanol production as the final product [10,11].

4. Conclusions

Due to limited energy sources in Turkey the lowering of conventional energy souces like coal, fuel, and termic and some problems in the recovery of the energy sources necessitates the extensive utilization of the wind and sun energyes as clean-green technologies. THerefore in this study we suggest the utilization of 1- butanol in the cars as alternative to gasoline. This will decrease the cost and it will be used as an new recyclable energy source.

Acknowledgement

This study was prepared in the scope of Master of Sciences in Biotechnology, and at the same time it was supported by the Department of Scientific Resource Project (2014.KB.FEN.035), in Dokuz Eylül University Graduate School of Natural and Applied Sciences. Also, the author acknowledged The Scientific and Technological Research council of Turkey (TÜBİTAK) for financial support (1002 - Quick Support Program).

References

[1] Denhez, F.. Global Worming Chapter. İstanbul; Turkey NTV publication in Turkish, 2007.
[2] Lan, E.I., Liao, J.C.. Metabolic engineering of cyanobacteria for 1-butanol production from carbon dioxide. Metabolic Engineering, 2011, 13: 353-363.
[3] Atsumi, S. Hanai, T., Liao, J.C.. Non-fermentative pathways for synthesis of branched-chain higher alcohols as biofuels. Nature, 2008, 451: 86–89.
[4] Deng, M.D., Coleman, J.R.. Ethanol synthesis by genetic engineering in cyanobacteria'. Applied and Environmental Microbiology, 1999, 65: 523–528.
[5] Dexter, J., Fu, P.C.. Metabolic engineering of cyanobacteria for ethanol production', Energy & Environmental Science, 2009, 2: 857–864.
[6] Takahama, K. Matsuoka, M. Nagahama, K., Ogawa, T.. Construction and analysis of a recombinant cyanobacterium expressing a chromosomally inserted gene for an ethylene-forming enzyme at the psbAI locus. Journal of Bioscience and Bioengineering, 2003, 95: 302–305.
[7] Lindberg, P. Park, S., Melis, A. Engineering a platform for photosynthetic isoprene production in cyanobacteria, using Synechocystisas the model organism. Metabolic Engineering, 2010, 12: 70–79.
[8] Niederholtmeyer, H. Wolfstadter, B.T. Savage, D.F. Silver, P.A., Way, J.C.. Engineering cyanobacteria to synthesize and export hydrophilic products. Applied and Environmental Microbiology, 2010, 76: 3462–3466.
[9] Shen, C.R. Lan, E.I. Dekishima, Y. Baez, A. Cho, K.M., Liao, J.C.. Driving forces enable high-titer anaerobic 1-butanol synthesis in Escherichia coli', Applied Environmental Microbiolgy, 2011, 77: 2905–2915.
[10] Boynton, Z.L. Bennet, G.N., Rudolph, F.B.. Cloning, sequencing, and expression of clustered genes encoding beta-hydroxybutyryl-coenzyme A (CoA) dehydrogenase, crotonase, and butyryl-CoA dehydrogenase from Clostridium acetobutylicum ATCC 824. Journal of Bacteriolgy, 1996, 178(11): 3015-3024.
[11] Allakhverdiev, S.I. Nishiyama, Y., Suzuki, I., Tasaka, Y. Ana e Murata, N.. Genetic engineering of the unsaturation of fatty acids in membrane lipids alters the tolerance of Synechocystis to salt stress. Proceedings of the National Academy of Sciences, Paris, France.
[12] Allakhverdiev, S.I. Sakamoto, A. Nishiyama, Y., Murata, N.. Inactivation of photosystems I and II in response to osmotic stress in Synechococcus: contribution of water channels', Plant Physiolgy, 2000, 122: 1201–1208.
[13] Kuan, D. Duff, S. Posarac, D., Bi, X. Growth optimization of Synechococcus elongatus PCC 7942 in lab flasks and 2-D photobioreactor. The Canadian Journal of Chemical Engineering, 2015, 93: 640-647.
[14] Murray, R., Badger, ve T. ve Andrews, J.. Photosynthesis and inorganic carbon usage by the marine cyanobacterium. Synechococcus sp. Plant Physiology, 1982, 70(2): 517-523.

 DOI: https://doi.org/10.30564/omms.v2i1.1809