Development of a sustainable fermentation platform

Stud M.Sc.Eng. Martin Malthe Borch
DTU Systems Biology, Technical University of Denmark
MMBorch@gmail.com - +4561713656
Abstract for "Grøn dyst" DTU 25th of june 2010

Abstract

A sustainable fermentation platform is presented that recycles nutrients from the agriculture. A case evaluation has been done by phototrophic growth of the fresh water micro algae C*hlorella saccharophila* on wet oxidized (WO) anaerobic digested manure. Further the effects of the WO treatment on the manure composition have been investigated. These results together with earlier bioethanol fermentations of WO straw, where manure is used as process water and nitrogen source[1], shows that nutrients in industrial fermentations can be replaced by agricultural residues, with better or equivalent results. This demonstrates a large unexploded potential in nutrient recycling and lowering of the cost of both phototrophic and heterotrophic industrial fermentations.

BACKGROUND

Scientist in general agrees that we currently are registering a global warming, and that we will reach peak oil production within the next years, if not already reached. If the current living standards should be hold, new sustainable technologies need to be developed. A change from petrochemical production methods to biobased production, is seen as a mean to decrease the environmental pressure. To achieve this, sustainable biorefinery concepts and industrial fermentations needs to be developed.

The Danish agriculture currently consumes energy in form of diesel and electricity. Further 42 % of the protein rich fodder used in 2008 was imported, in total 3,89 million fodder units. Also, the Danish agriculture imports fertilizers both nitrogen, phosphor and potassium fertilizers 189, 13 and 56 KTons respectively. Resources are needed in form of energy, protein fodder and nutrients, at the same time as there is a large production of waste from livestock production[2]. Thus there is room in the Danish agriculture for improved self-sufficiency regarding many potential biomass derived products.

Anaerobic digestion is a well studied technology currently applied by the Danish agriculture to produce biogas, but there is currently only a production of 4PJ of an estimated biogas potential in Denmark of 40PJ. Due to this, the Danish government in the energy agreement from February 2008, raised the subsidy for biogas production. It is expected that many new biogas plants will be constructed the next years. Besides the nutrients from the manure the biogas plants will produce an excess of heat and CO_2.

Today many commercial fermentation processes is supplemented with complex medium components as yeast extract, tryptone mixtures or vitamins. By proper treatment of agricultural residues these nutrients could be easily available, thus, there are currently many prerequisites present for investigating biorefinery concepts designed for the Danish agriculture and industrial production.

---

[1] "Fermentation media comprising wastewater and use hereof" Patent, Anne Belinda Thomsen, senior scientist ph.d

[2] "Dansk landbrug I tal 2008" at www.LF.dk.

RESULTS

In the present study the growth characteristics of the micro algae C*hlorella saccharophila* was investigated when cultivated with different concentrations of WO anaerobic digested manure, treated at different temperatures. This was done to investigate the above described potentials and demonstrate proof of concept. It was found that:

- The WO treatment successfully removed the malodor from the manure.
- The WO treatment could degrade phenols completely from the medium, resulting in a clear medium suitable for phototrophic growth.
- The WO manure could completely replace defined growth medium, and equivalent growth or better was seen with WO manure concentrations from 0,5 to 7%.
- At concentrations of 15% equivalent or better growth rates was seen heterotrophic, but phototrophic growth was inhibited.
- At a concentration of 25% WO manure, inhibition of heterotrophic growth was seen and completely inhibition under phototrophic growth.

Opportunities and Perspectives

Different biorefinery concepts for production of biofuel, chemical building blocks or value added products have been suggested as sustainable replacement for fossil fuel derived compounds. Regardless whether the biorefinery process is 1st 2nd or 3rd generation the process should be designed with the local need for products and available resources in mind. Both the environment and the economy of industrial fermentation would benefit from an increased understanding of sustainable medium preparation by using different pretreatment methods and their ability to maintain and recycle nutrients from residues. Especially phosphorous have been pointed out as a resource that will be limited in the future. Here one process has been shown as a viable production of a sustainable phototrophic medium. The idea demonstrated here could further be transferred to the following processes:

- Macroalgae growth in connection with livestock production for feed, increased biogas production or as soil conditioner.
- 2nd generation bioethanol fermentations could be made more price competitive, if growth could be increased and no addition of nutrients would be needed.
- When engineering *E. coli* to grow on glycerol the addition of tryptone or yeast extract is needed to sustain growth, if not grown under microaerobic conditions.[3]

The project was defined by the student and a “part time” 5 point special course. The WO pretreatment and analysis have been conducted during fall 2009 at RISØ-Bio with Senior Researcher Anne Belinda Thomsen (abbj@risoe.dtu.dk) as supervisor. The algae growth experiments have been conducted at Aalborg University (AAU) Department of Biotechnology, Chemistry and Environmental Engineering, mainly during January 2010 with Associate Professor Niels T. Eriksen as supervisor (nte@bio.aau.dk). I express my gratitude to my supervisors, fellow students and all the technicians that have helped me in the laboratory and used time discussing the project.

[3] Durnin, Guyton et. Al. ”Understanding and Harnessing the Microaerobic Metabolism of Glycerol in Escerichia coli” 2008.