SINGLE CELL PROTEIN FROM LANDFILL GAS

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1. Introduction

- It is estimated that between 1980 and 2000 the annual demand for protein as food for animals will increase from 44 million tons to 108 million tons. Biotechnology is being applied to the rapid improvement of conventional food sources, both plant and animal, in an effort to meet the increased demand for food.

- BioPotin has already demonstrated a 10,000 MTY SCP plant.

- The raw materials must be sustainable because the use of biomass which would have otherwise been flared in the creation of single cell protein (SCP) could then be used for animal feed. A case study on the Point Loma wastewater Treatment Plant (PLWTP) in USA was investigated to see the viability of producing SCP from the waste CH.[3]. PLWTP was chosen due to a availability of information on amount of methane produced as well as other relevant information such as the amount of wastewater treated.

- CH is the second most important greenhouse gas after CO2.

- Current Research; NASA Goddard Institute for Space Studies; Global Warming Potential (GWP) of CH3 is 33 times that of CO2, over 100 years[11].

2. Case Study

- PLWTP burns off every day 1.1 million cubic feet (31,149 m3) of CH. Instead of selling or burning the CH, to generate electricity the CH can be converted into SCP which is a much more valuable product.

- Bio Protein A/15 states that it utilizes 2m of CH/kg SCP.

- The proposed SCP plant at PLWTP is expected to produce 5686 TPC.

- Mainly due to the high protein content and the relatively fast growth rate, Methyllococcus capsulatus is the bacteria chosen for the process[6]. The optimal growth temperature for Methyllococcus capsulatus is approximately 45°C which practically excludes infection of the culture by normal scavengers.

- Total number of industrial pigs that can be fed on 5686 TPC = 19000 pigs/year

- Total Land Usage: 1.4 km2 of which 80% Waste Water Facility (WWF), 12% Bio-gas Facility (BGF) and 8% Rearing of Pigs.

3. Assumptions

- Methane is obtained from the treatment of solid waste materials (landfills), waste from waste water treatment plants (WWTP) and slaughter houses.

- The methane produced is then sent to a purification facility where corrosive gases such as H2S and inert gases such as CO2 are removed (H2S are harmful to organisms).

- The methane is then used as the primary feed for protein manufacturing in the UniBio process.

- 2.5 kg/3 days of SCP is used in the feed mixture for pigs[11].

- A pig can eat approximately 2 kg/day of feed[11].

- To meet the demand of the pig market a pig is slaughtered every 6 months.

- A typical WWTP facility processes 1 million gallons per day (MGD) of wastewater for every 10,000 in population served[11].

- Project viability is more probable for facilities that are within 15 miles of a waste water treatment plant[11].

4. Theory SCP Process Requirements

- The overall stoichiometry for the reaction

\[ CH_4 + 1.45 \times 0.04 NO = \text{SCP} + 0.52 \text{CH}_4 \text{H}_2 \text{O} + 0.45 \text{CO}_2 + 1.69 \text{H}_2 \text{O} \]

- For an aerobic process the energy to be removed Q to keep the reaction at its optimal temperature 45°C is approx.

\[ Q = 4600 \text{GJ/t methane} \]

- Rate at which O2 is transferred from the gas to the liquid phase

\[ \text{O2} = \text{O2} \text{transfer} = \text{liquid} \]

5. Single Cell Protein Cycle

- Methane from Landfill

- Biogas from Landfill

- Wastewater treatment to energy

- Energy and Economics

- From calculation 52.1 MJ/kg biomass/oil heat needs to be removed which can be achieved by external heat exchangers and nearly pure oxygen needs to be used for proper oxygen transfer.

- The initial reasoning by companies such as BP and ICI to enter SCP production was to produce, at a lower cost, high value SCP from petroleum, for addition to animal feed. The intention was to replace imported protein additives such as soybean meal. Factors which contributed to the failure of hydrocarbon SCP to make a major commercial impact included the 1973 dramatic oil price increases, which raised feedstock and energy costs and the lower price increases achieved by agricultural products such as soybean.

- According to Lewis et al. due to future technological advancements the possible future Gross Energy Requirement (GER) of SCP can decrease from 130 to 125 MJ/kg SCP[11]. For this current case study an estimate of 28 Gbton SCP is calculated which is comparable to the ammonia process which currently uses 28 Gbton NH3.

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7. Future Work

- Methane, removed in the scrubbing of the biogas can be used in a myriad of applications such as[31]:

- The CO2 produced should be harnessed, for example in enhanced oil recovery or if near to an industrial complex for the production of methanol.(SCP can also be produced from methanol)

- A catalytic process to convert CO2 to formic acid

- New types of biodegradable aliphatic polycarbonates can also be made from CO2. The polymers, contain 30-50% CO2 by weight and have gas-barrier and degradation properties that make them attractive for food packaging, automotive parts, and electronics processing applications.

- CO2 reduction in electrochemical cells. The idea is to develop a catalyst capable of reducing CO2 to useful fuels.

- The methane fuel cell uses methanol and produces CO2 and water. If the process could be reversed CO2, water and electric power (spare electricity from a wind farm or any other renewable energy source), can chemically reduce the carbon dioxide and water into methanol. Methanol is also an attractive energy carrier compared to hydrogen and eliminates storage issues associated with hydrogen.

- Other issues to consider:

- H2S content in the biogas: H2S can be converted to sulfur for production H2SO4, a valuable chemical

- Disadvantages of using methane as compared to methanol as a substrate is the greater oxygen requirements necessary to fully oxidize methane and the low solubility of methane in water. It is envisaged however given the substrate is a byproduct and is assumed to be “free”, it may still be advantageous to use methanef(estimated 40 – 60% of the SCP cost is in the feed[31]). As an alternate substrate it has been estimated that the volume of cellulotic wastes is sufficient to supply all additional protein needs on a continuing basis for cellulose as a renewable resource[11]. The major obstacle however is the biodegradation of lignin and lignin-cellulose complexes so that microorganisms that can then utilize lignocellulose for single cell protein production.

8. Conclusion

- This project merges two concepts which are currently isolated and operating independent of each other. The LPG produced is the second most important greenhouse gas and thus should be utilized in the best way possible instead of being released into the atmosphere.

- The increase production of SCP has major future benefits such as a Fish-meal replacement whose price has gone from approximately 500 to 2000 USD/Ton from 2005-2009[31].

- The SCP project is most viable if the WWF, BGF and SCP plant are in close proximity.

- Governments/Municipalities should look at existing info-structure in future planning.

- Waste treatment must be efficient and effective in order to safely handle everyday waste obtained from both industrial and domestic processes.

- A crude overall mass balance of the process was presented and it is estimated that the waste from animals fed with SCP as part of their diet (pigs) will return approximately 13.6% of CH4 to be re-used for SCP production in the overall cycle.

References:


