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Biological Upgrading of Biogas and Production of Single Cell Proteins

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Abstract The Danish utility company BIOFOS is leading a large development project called VARGA introducing several technologies transforming WWTP Avedøre (350.000 PE) into a Water Resource Recovery Facility. A pilot plant has been running for one year and results from anaerobic digestion of biowaste shows methane yields of ~360 Nm^3 CH_4/ton VS at relatively stable operation. The produced biogas is being biologically upgraded using methanogenic microorganisms to natural gas quality. In a new spin-off project called FUBAF, led by the consultant company EnviDan, the upgraded biogas is converted to Single Cell Proteins. Production of nutrients using a novel Electrochemical System (ES) is a key element in the overall FUBAF concept, which is evaluated in terms of environmental sustainability.

Keywords: Upgrading of biogas, single cell proteins, nutrient recovery, food production, resource recovery, bioeconomy.

The largest wastewater utility in Denmark, BIOFOS, is leading a large development project in which a traditional Wastewater Treatment Plant (WWTP) is transferred into a Water Resource Recovery Facility (WRRF). The project, called VARGA, is taking place at Avedøre WWTP. VARGA is getting financial support from the Ecoinnovation fund through the Ministry of Environment and Food in Denmark.

One of the work packages in VARGA cover separate anaerobic digestion of source-separated organic waste from households in the Copenhagen area. The generated biogas is being biologically upgraded using methanogenic microorganisms to natural gas quality and bioaugmentation experiments are performed to be able to cope with possible ammonia inhibition. The high quality digestate produced will be applied in organic farming through field trials in Spring 2019 to test the fertilizer characteristics. Organic fertilizers are in high demand in the Eastern part of Denmark, so the digestate is expected to have a good market potential. All experiments have been performed in laboratory scale at the Technical University of Denmark, DTU (e.g. Khoshnevisan et al., 2018) before going to pilot scale.

A pilot plant has been in operation since January 2018 at Avedøre WWTP with very stable process conditions. The methane yield has been expectedly high at ~360 Nm^3 CH_4/ton VS and there have been no signs of ammonia inhibition (manuscript under preparation). Biological upgrading of the biogas has successfully been performed in the laboratory using ceramic membranes (manufactured by silicon carbide or aluminium oxide) with different pore sizes for hydrogen dispersion (see Figure 1.1, manuscript under preparation). All membranes are performing well (>90% CH_4) at gas retention times (GRT) of 10 hours with H_2 and CO_2 utilization efficiency more than 95%. The efficiency decreases at lower GRT as seen in Figure 1.1. The

experiments are still been performed in the laboratory with focus on process efficiency and choice of membrane / material. An upgrading unit is under construction and will be tested in pilot scale in 2019.

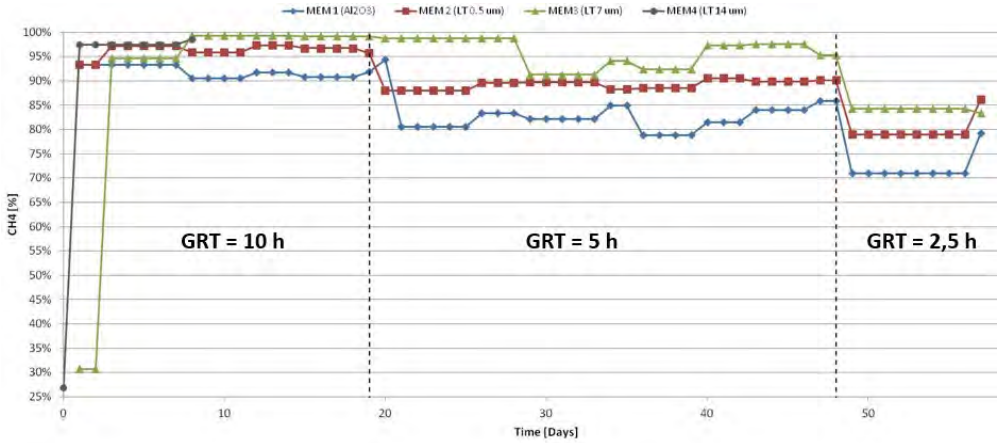

Figure 1.1 Methane levels in upgraded biogas using 4 different ceramic membranes for hydrogen dispersion.

A newly started development project (January 2019) is a spin-off from VARGA and will further examine production of high value end-product from biogas. The project is called FUBAF and the main aim is to produce Single Cell Proteins (SCP) from biologically upgraded biogas. Up to now, the concept of producing SCPs using methane oxidizing bacteria (MOB) has been demonstrated at industrial scale using natural gas and synthetic media. As an example, The Danish company, Unibio, has commissioned a commercial scale methane to protein plant using their novel U-Loop technology (Petersen et al., 2017).

A novel technology for nutrient recovery from both digestate from anaerobic digestion of source-separated organic waste from households and reject water from sludge dewatering is demonstrated in this project. It is a Electrochemical System (ES) and it is described in Zhang & Angelidaki (2015a and 2015b). The efficiency of the system is depending on various parameters as for example, substrate characteristics (i.e. total solids and ammonia content), applied current density and type of electrode. The technology has been patented by the Technical University of Denmark and further optimization and upscaling is now taking place.

This 2nd generation production concept where both recovered nutrients and upgraded biogas streams from anaerobic digestion of urban biowastes is used for production of SCPs has not yet been developed. The sustainability of the concept will be evaluated using circular economy principles.

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