Refining Carbon From Wastewater To Ensure High Biogas Production And Low Emission Of Nitrous Oxide

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Refining carbon from wastewater to ensure high biogas production and low emission of nitrous oxide

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Introduction

During the last 10 years, wastewater treatment plants in Denmark have worked intensively with energy optimization by reducing energy consumption for wastewater treatment and increase biogas production from sludge. The biogas production have been increased by improving the primary separation; thus more carbon is removed from the main wastewater stream. It has on some plants been done very successfully and we are today talking about "energy producing wastewater treatment plants". During the same period, there have been less focus on the carbon footprint from wastewater treatment. Most focus have been on the balance between clean water and energy production (Fig 1a).

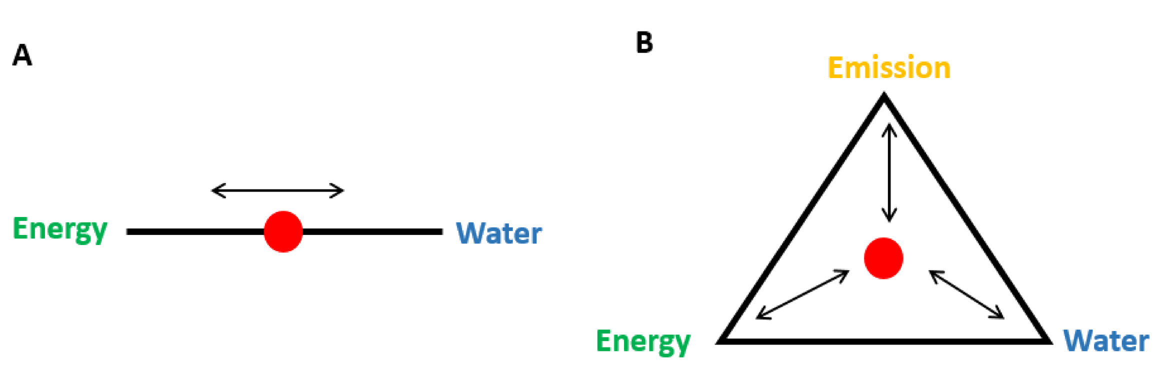

Figure 1: Operational prioritization A) Wastewater treatment plant today, B) Future climate-friendly wastewater treatment plant

However the carbon footprint have to be included in the design of future wastewater plants. The carbon footprint is often measured as CO_2 equivalents and includes the used chemicals, transport of wastewater, energy balance and also the emission of greenhouse gasses such as nitrous oxide. Nitrous oxide is a strong greenhouse gas, app. 300 as strong as carbon dioxide. Nitrous oxide is produced and released in the aerated tanks during secondary treatment. Literature data shows that the production of nitrous oxide increase, if the ratio between carbon and nitrogen is low (Kampschreur et al 2009). If more carbon is removed prior to the secondary treatment, it is therefore expected that more nitrous oxide is produced and released. Due to low amounts of carbon, it may further be necessary to add an external carbon source to the secondary treatment tank to ensure high removal of nitrogen and phosphorus and thereby ensure the quality of the effluent. The addition of external carbon source is expensive.

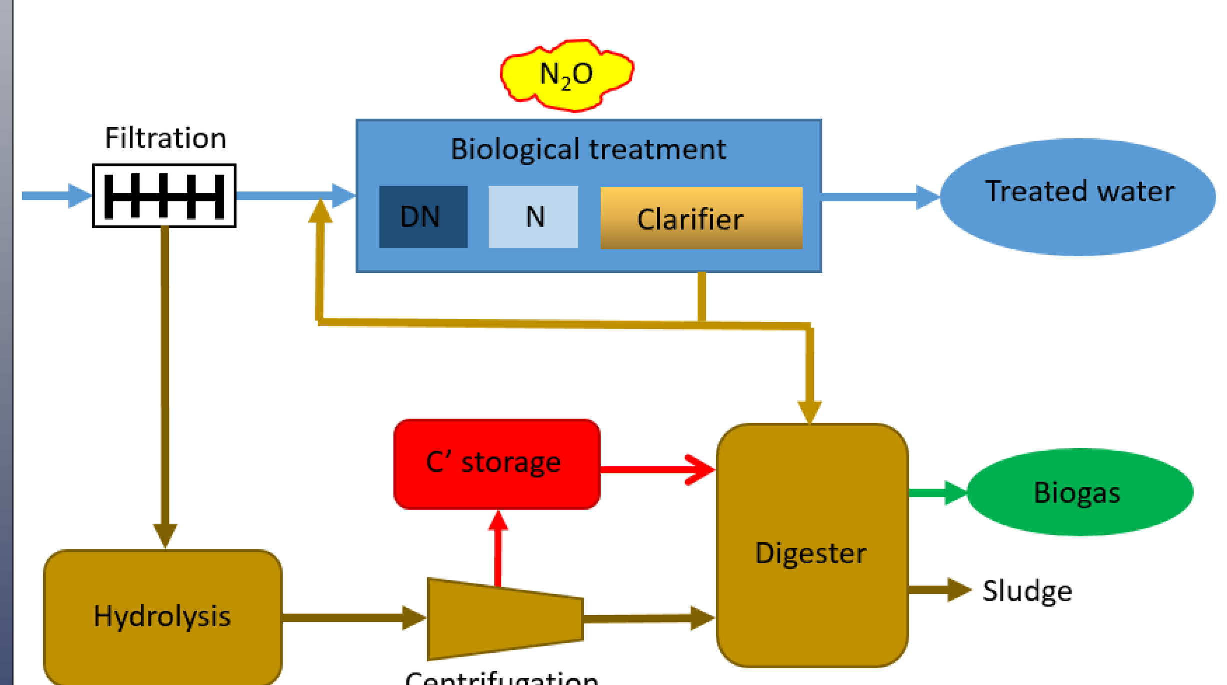

Figure 2: The climate-friendly wastewater treatment plant

Methods

A novel design of a wastewater treatment plan have been designed that minimize carbon footprint of the wastewater treatment plant with focus both on energy balance, water treatment and emission of greenhouse gas (Fig 1b and 2). A pilot-scale Hydrotech filter have been installed to remove as much carbon during the primary step as possible. A 3 m^3 hydrolysis tank have been installed with a thermostat and a pH- regulator. A pH-value of 5 or 7 was used and the residence time was 3 days. After hydrolyses, a decanter centrifuge was used for solid-liquid separation and the hydrolysate was tested by measuring TS, COD, total phosphorus, dissolved phosphorus, ammonia, total nitrogen, and specific denitrification rate using standard methods. Ion chromatography was used to measure concentration of volatile acids, with acetate and propionate as the most abundant. The concentration of saccharides, proteins and humic acids was measured using the Anthrone and the modified Lowry method.

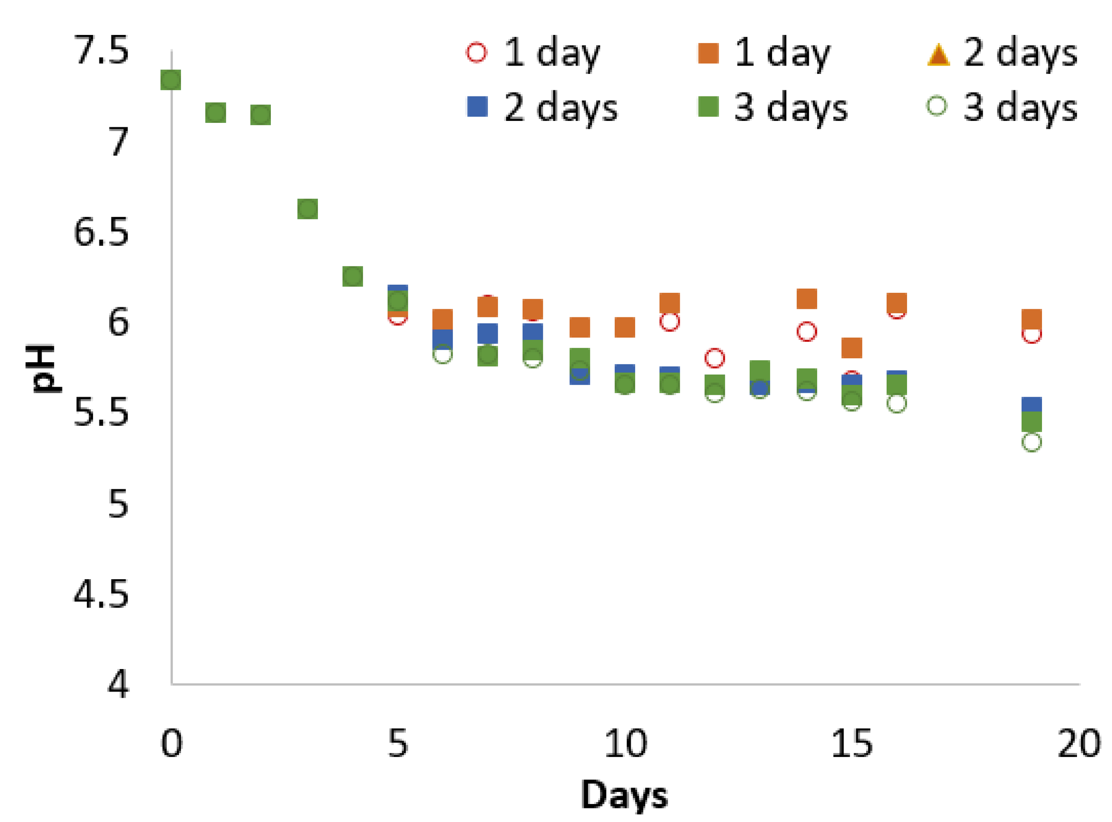

Figure 3: pH development in hydrolysis tank with resident time of 1, 2 and 3 days.

It was observed that pH decreased to pH 5-5.5 without pH adjustment and steady-state was established after app. 5 days (Fig. 3). The hydrolysate was centrifugated whereby 85-90% of the dry material could be removed.

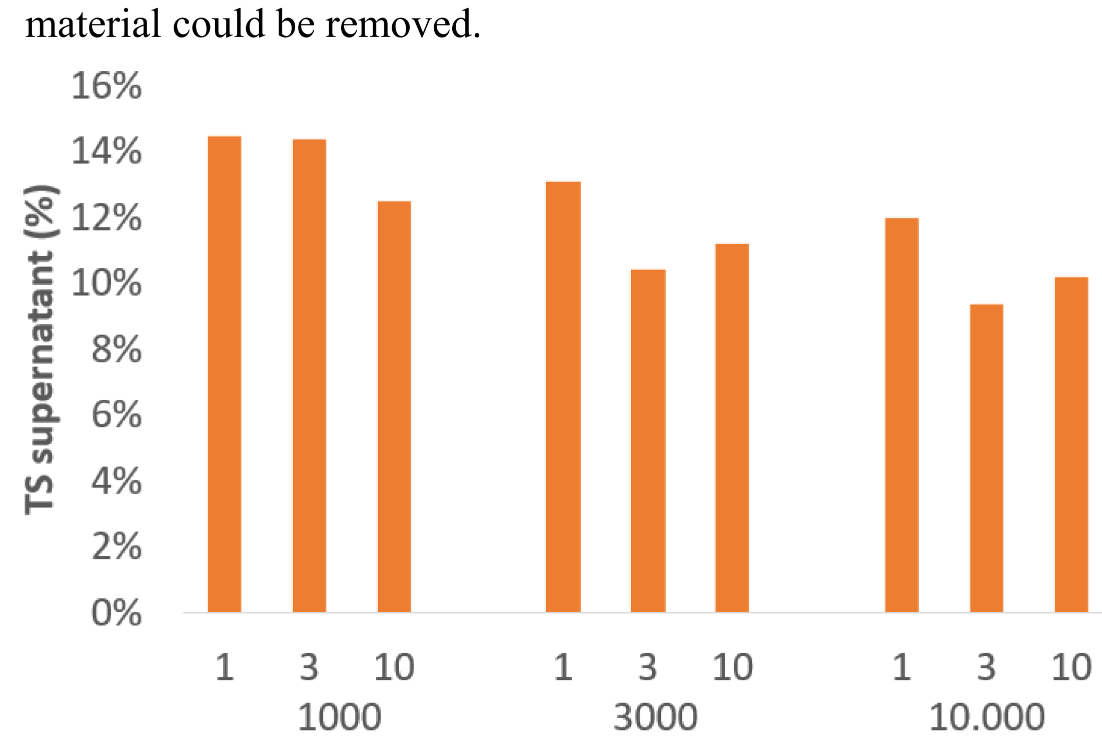

Figure 4: Total solid measured in supernatant after centrifugation at 1000, 3000 and 10.000 G for 1, 3 or 10 min.

Results

Hydrolysate was collected from the pilot-plant and analysed. The dry matter content after the primary treatment of the sludge was meausred to be 54 ± 1 g/L. The dry matter content in the hydrolysate after centrifugation was measured to be 3- 9 g/L, highest for hydrolysis done at high temperature and pH.

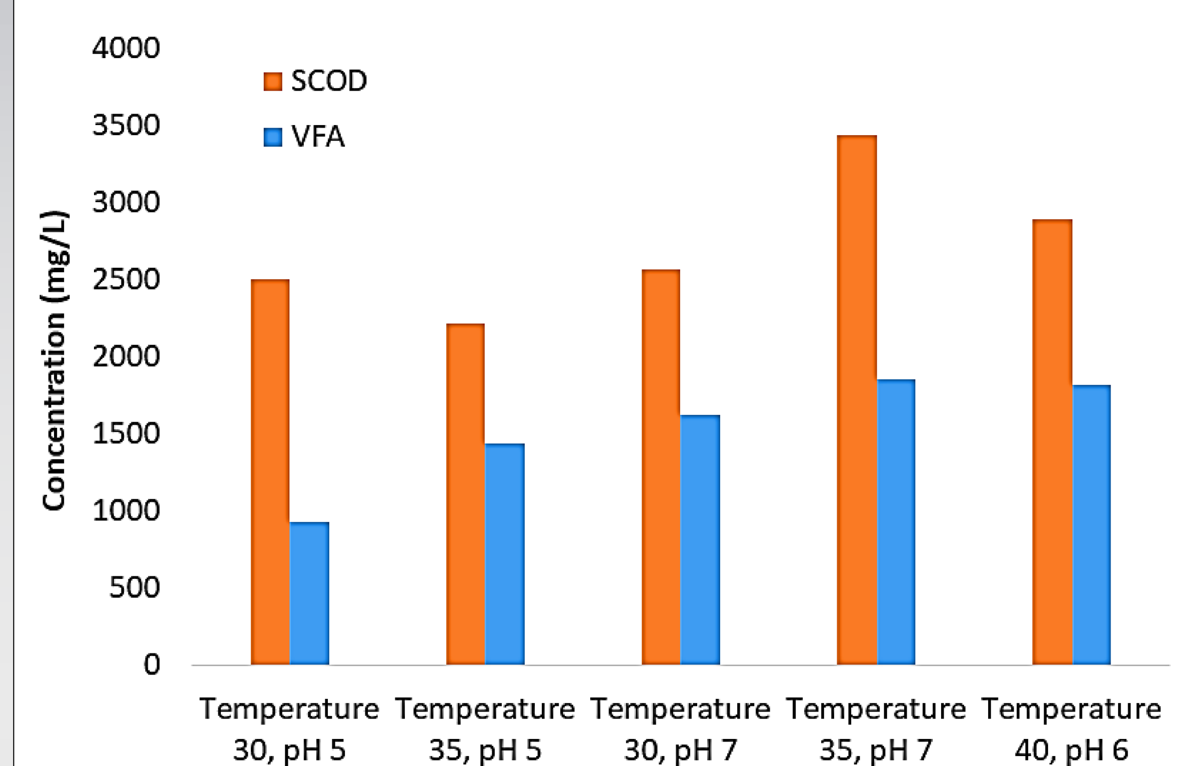

Figure 5: Concentration of soluble COD (SCOD) and volatile fatty acids (VFA) in hydrolysate.

No VFA was measured in the primary sludge, the concentration of VFA in the hydrolysate varied between 1000-1800 mg/l and increased with higher temperature and pH. The yield was measured to 30-35 g VFA per kg dry matter. Soluble hydrolysate mainly consist of acetate followed by propionate. Acetate production increased with temperature and pH. Proteins and saccharides contributes with less than 5 % to the COD (Fig 6).

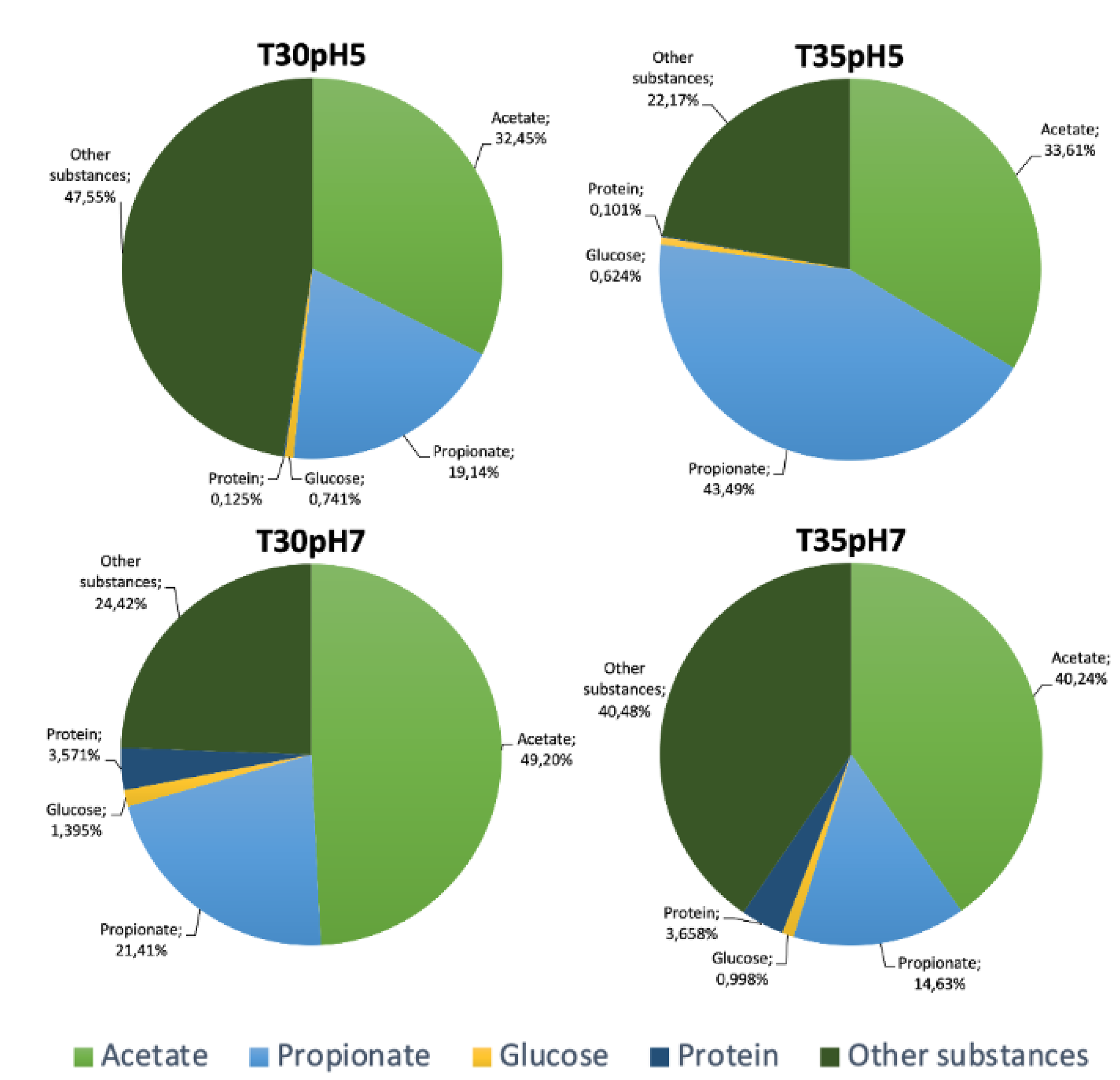

Figure 6: Soluble COD in hydrolysate

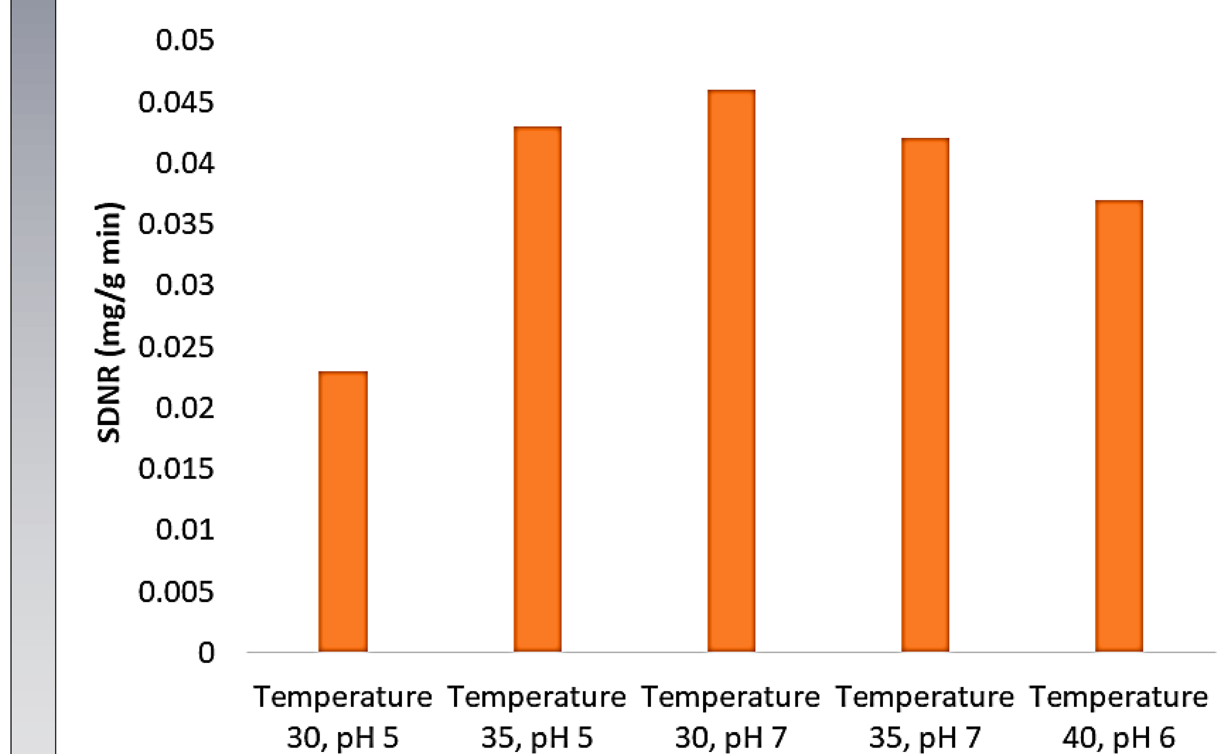

Figure 7: Specific denitrification rate measured with an initial concentration of nitrate of 30 mg/L and a COD/N ratio at 6.2

The specific denitrification rate was measured for acetate to 0.031 mg/g min, and similar values have been observed with the hydrolysate (COD/N ratio 6.2). For the hydrolysates produced at high temperature and pH, a maximal SDNR of 0.045 mg/g min was reached. This was presumable due to a mixture of organic compounds including acetate and propionate at high concentration. Small amount of ammonium are released, i.e. 2-4 g per kg VS. These data are comparable with the results from other studies (Bonzas et al 2002, Jönsson and Jansen 2006).

Conclusions

Hydrolysate was produced from primary sludge to produce a liquid cocktail with volatile fatty acids that can be stored and used either for the secondary treatment during wastewater treatment or for biogas production. The solid fraction after hydrolysis and centrifugation will be fed into the digester. The yield during hydrolyses was measured to **30-35 g VFA/kg dry material** or **40-65 g SCOD/kg dry material**. The specific denitrification rate was measured to be 0.02 – 0.04 mg/g min similar to values found for common used external carbon sources Hydrolysis at temperatures around 35°C and pH 7 gave the best result, but pH adjustment was required to keep a pH of 7. Without pH adjustment, pH drops to pH 5-5.5. The cost of external carbon is estimated to be 2.5 times as expensive as the produced volatile fatty acids.

Acknowledgement

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