Advanced treatment of wastewater from fish industry to produce bioenergy and microbial proteins

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Introduction: Addressing the risks related of natural ecosystems imbalances involves upcycling wastewater streams by reshaping industrial systems. Fishmeal production by extrusion and extraction processes typically produces high volumes of COD- and nutrient-rich wastewaters. A novel, potentially low-carbon and low-cost upcycling streamline for wish processing wastewater entails (1) anaerobic digestion (AD) for biogas production and ammonification; (2) electrochemical ammonia extraction either *in situ* or *ex situ*; (3) microbial protein production by hydrogen oxidizing bacteria (HOB) fed with the extracted ammonia as the nitrogen source, CO_2 from flue gases and renewable H_2 as energy source. Major challenges for process upscaling are (a) assessing the stability and biomethane yield of AD; (b) optimize the AD biomethane and ammonia recovery by increasing the organic loading rate while controlling ammonia liquid concentration by adjustment of voltage and electrodialysis cell configuration; (c) assess and optimize microbial protein production by HOB . Our aim was to partially address these challenges by assessing the bench scale performance of fish wastewater AD and ammonia extraction by electrodialysis.

Methods and data: Fish processing wastewater was collected from a fishmeal production facility located in Jutland, Denmark. The biomethane potential (BMP) of fish processing wastewater was determined in mesophilic batch assays setting the inoculum-to-substrate ratio (on VS basis) equal to 3. Furthermore, mesophilic AD of fish wastewater has been carried out in a continuous CSTR reactor (active volume 1.9 L). The biomethane yield and productivity, as well as the reactor performance stability, were assessed at hydraulic retention time (HRT) down to 15 d and at organic loading rates (OLR) between 0.62 and 1.2 $g \cdot L^{-1} \cdot d^{-1}$. Ammonia was extracted from the produced digestate in an electrodialysis cell designed with three separate chambers (each with a volume of 300 mL), respectively for anode, cathode, and the digestate feedstock. The cell chambers were separated by a cation exchange membrane. Anode (IrO_2) and cathode (stainless steel) had a projected area 8 cm^2. A voltage of 5 V was applied. Sodium carbonate was chosen as catholyte, and 48 h was set as the catholyte retention time.

Results: Fish processing wastewater yielded significant amounts of biomethane (557 $mL \cdot g_{VS}^{-1}$) with respect to cellulose (441.3 $mL \cdot g_{VS}^{-1}$) in batch tests. This result may be consequence of the high VFA concentration (17 $g \cdot L^{-1}$) and other soluble organic compounds in the feedstock. The averaged biomethane productivity of the continuous AD reactor, which was operate for 65 days, increased with increasing OLR: 223 $mL_{CH4} \cdot L^{-1} \cdot d^{-1}$ at OLR 0.62 $g_{VS} \cdot L^{-1} \cdot d^{-1}$; 389 $mL_{CH4} \cdot L^{-1} \cdot d^{-1}$ at OLR 0.93 $g_{VS} \cdot L^{-1} \cdot d^{-1}$; 509 $mL_{CH4} \cdot L^{-1} \cdot d^{-1}$ at OLR 1.2 $g_{VS} \cdot L^{-1} \cdot d^{-1}$. On the other hand, the biomethane yield remained stable over the whole reactor operating period at a value of 385 ± 30 $mL_{CH4} \cdot g_{VS}^{-1}$. The pH remained on average equal to 7.75 over the full operational period. Offline ammonia extraction yielded 0.3 $g \cdot L^{-1}$ total-N over 48 h in the catholyte solution having an Initial Total-N concentration of 1.5 $g \cdot L^{-1}$ in the digestate produced by continuous processing wastewater AD.

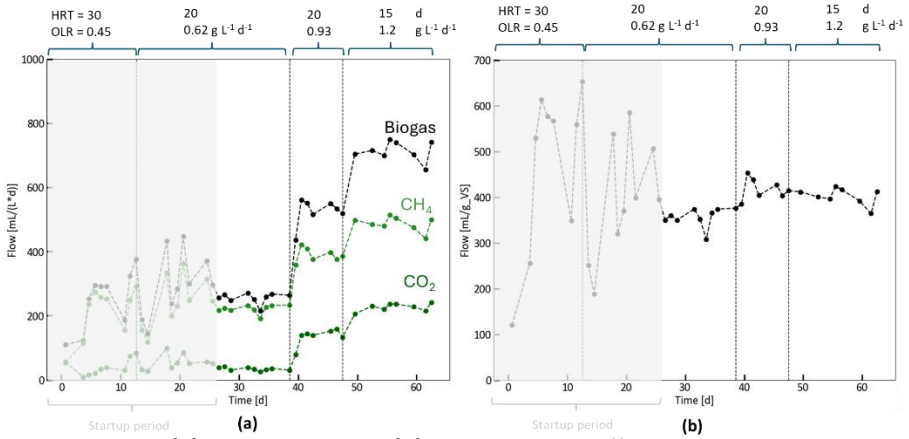

Figure 1: **(a)** gas productivity; **(b)** CH_4 yield over different operational stages.

Market potential: This study provided a first assessment of the biomethane yield and performance of continuous fish wastewater AD at bench scale showing high potential for energy and nitrogen recovery. Future work will focus on optimizing continuous microbial protein productivity and quality as a function of the gas-liquid mass transfer rate and gas impurities concentrations.

Discussion and take-home message: Fish processing wastewater was shown to be a high biomethane yielding substrate both in batch and continuous enabling stable AD operation. The resulting digestated was proven to be a valuable N source within an electrodialysis extraction setup. Ongoing work aims to maximize biomethane and ammonia productivity by tailoring the OLR and the operational variables affecting online nitrogen extraction.