

From waste to biopolymers: sustainable valorization of secondary sludge via hydrothermal carbonization, acidogenic digestion and aerobic fermentation

Vittoria Stefanelli¹, Alisar Kiwan², Daniele Pirini², Davide Collini², Chiara Samori¹, Cristian Torri¹

¹Dipartimento di Chimica “Giacomo Ciamician”, University of Bologna, via Selmi 2, Bologna, Italy

²B-Plas S.b.r.l, via Lanfranco Gessi, 16, Lugo, Ravenna, Italy

Keywords: *Waste valorisation, hydrothermal carbonization, acidogenic digestion, volatile fatty acids, polyhydroxyalkanoates*

Presenting author email: vittoria.stefanelli2@unibo.it

The increasing generation of industrial wastewater sludge poses a significant environmental challenge, but it also presents an opportunity for sustainable resource recovery. This study explores an innovative multi-step process, developed by B-Plas, an pioneering start-up, to convert secondary sludge from an industrial wastewater treatment plant into polyhydroxyalkanoates (PHA), a family of biobased and biodegradable polymers.

The developed process includes hydrothermal carbonization (HTC) as a pretreatment to improve sludge dewaterability and enhance the solubilization of organic matter, thus improving its bioavailability for subsequent biological processes. Experimental results indicate that HTC at **200 °C for 30 minutes** leads to approximately **50% solubilization of the total COD** and a **65% reduction in total suspended solids (TSS)**, which facilitating the further step of acidogenic digestion (Figure 1).

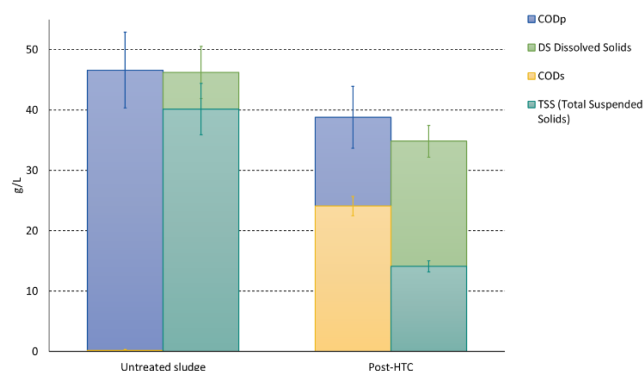


Figure 1. Composition of untreated thickened sludge and HTC-treated sludge in terms of total COD (CODt) and total solids (TS). CODt is the sum of particulate COD (CODp) and soluble COD (CODs), while TS consists of dissolved solids (DS) and total suspended solids (TSS). The HTC process increases soluble COD (CODs) and dissolved solids (DS), enhancing the availability of organic matter.

In the acidogenic digestion phase, performed in a Continuous Stirred Tank Reactor (CSTR), microorganisms convert the solubilized organic matter into volatile fatty acids (VFAs), which serve as building blocks for PHA synthesis. At an organic loading rate (OLR) of 5.3 ± 0.8 gCODs/L*d and a hydraulic retention time (HRT) of ~5 days, VFA production reached a yield of 2.0 ± 0.2 gCOD/L*d, with a conversion efficiency of $38.5\% \pm 0.1\%$. The main VFAs were ~40% acetic acid, ~25% propionic acid, ~15% isobutyric and butyric acids, and ~20% isovaleric acid. (Figure 2)

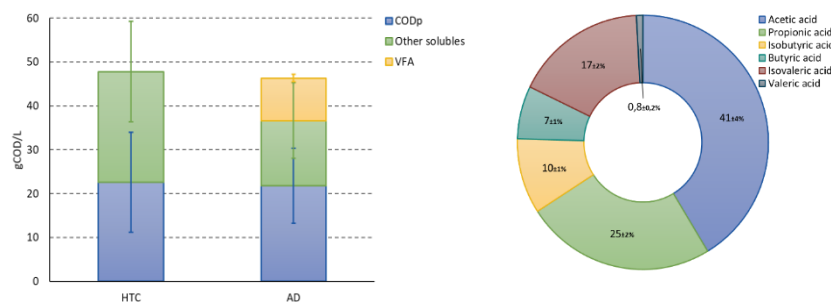


Figure 2. Results of the acidogenic digestion (AD) process. The bar chart shows the COD distribution in the liquid phase. The sum of the "other soluble" fraction and volatile fatty acids (VFAs) represents the soluble COD (CODs). The sum of particulate COD (CODp) and CODs represents the total COD (CODt) before (HTC-treated sludge) and after acidogenic digestion. The pie chart illustrates the composition of VFAs produced, showing the relative distribution of different acids.

Following acidogenic digestion, a solid-liquid separation process using a filter press yielded a **cake** with a **dry matter content of $45.3 \pm 1.6\%$** , effectively halving the input sludge volume.

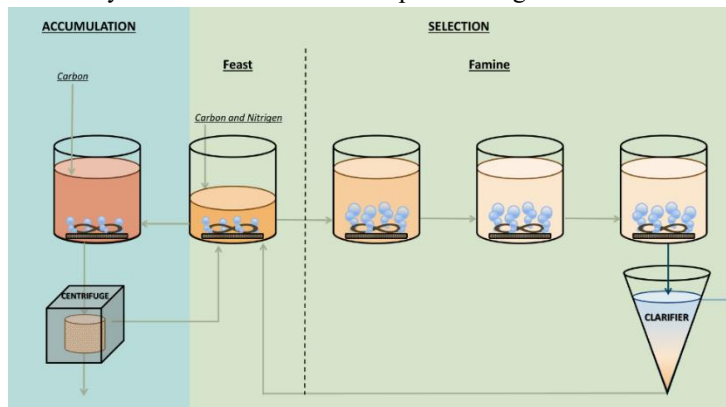


Figure 3. Schematic representation of the continuous process for the selection of PHA-accumulating bacteria. The system operates under a feast-and-famine regime to promote the enrichment of specialized microbial strains, followed by an accumulation step to maximize PHA storage.

Preliminary data from a synthetic feed mimicking the real substrate composition showed a PHA yield of **approximately 50-60% of cell dry weight**, demonstrating the potential of this approach. Further tests with the real acidogenic broth will be conducted to validate these results under actual operating conditions.

References