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Publication date:
2021

Document Version
Publisher's PDF, also known as Version of record

From digestates to proteins – how to valorize struvite and PCP into microbial feeds

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Microbial protein is regaining popularity as a promising alternative dietary supplement to traditional protein sources, being methane oxidizing bacteria (MOB) being an attractive option for its production. First-generation production processes relying on fossil resources are currently used in commercial applications, but there is an increasing trend of using recovered residual streams to achieve a more circular production process. Research has mostly focused on recovered nitrogen and methane sources, with little attention to phosphorus, also crucial for protein production and essentially a non-renewable resource. This study aims to understand the challenges in providing residual phosphorus to MOB, as well as their phosphorus requirements, thus allowing an optimized use of the phosphorus recovered at wastewater treatment plants. Struvite and precipitated calcium phosphate (PCP) were the residual phosphorus sources studied. Firstly, dissolution of struvite and PCP was optimized as they cannot be dissolved in water and therefore are not bioavailable for MOB growth (Figure 1). Two temperatures (25 and 37 °C), pH levels (2 and 5) and acids (H_2SO_4 and HCl) were tested. pH showed a larger effect than temperature on phosphate dissolution. The optimum dissolution conditions were 4 h at 37 °C at pH 2 for struvite and 30 min at 25 °C and pH 2 for PCP. HCl was chosen as the preferred acid since the high contribution of H_2SO_4 to the medium's ionic strength has a detrimental effect on MOB growth. To evaluate MOB growth and protein quantity and quality, batch experiments were carried out with struvite and PCP as phosphorus sources, and ammonia and nitrate as nitrogen sources. Both struvite and PCP were good phosphorus sources for microbial protein production via methanotroph cultivation. All treatments showed similar growth rates (**Figure *2***) and yields, ranging from 0.72 to 1.11 d^{-1} and 0.21 to 0.29 g CDW g CH_4^{-1}, respectively. There was also no effect of neither the phosphorus nor the nitrogen source observed on the amino acid composition (Figure 3). Struvite yielded the highest protein content (75 %), as can be seen in Figure 4, although it had high levels of cadmium and lead. PCP yielded the lowest (11 % with ammonium and 45 % with nitrate). Finally, PCP in high concentrations results in the formation of precipitates and induces microbial stress,

resulting in lower biomass yields and high conversion of methane into dissolved organic carbon (15 %), which requires treatment prior to discharge.

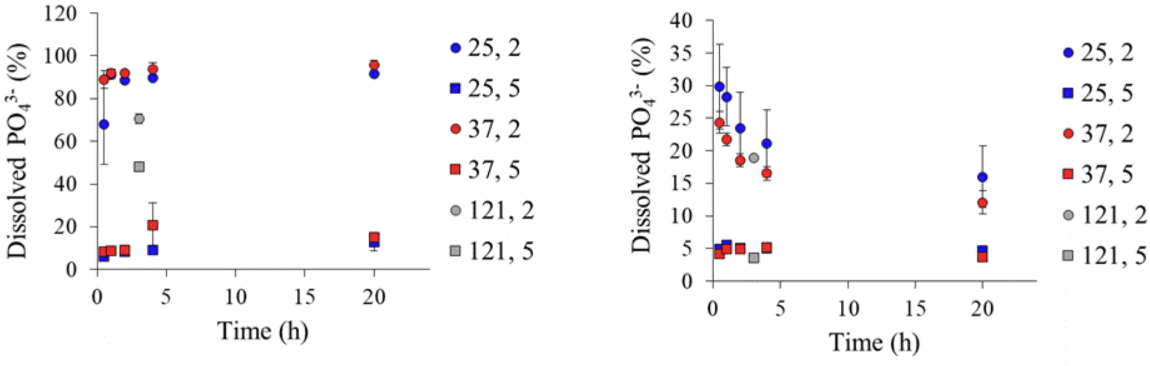

Figure 1. Dissolved phosphate concentrations in A) struvite and B) PCP solutions at temperatures 25 and 37 °C and at pH 2 and 5. Data are represented by means ± SEM.

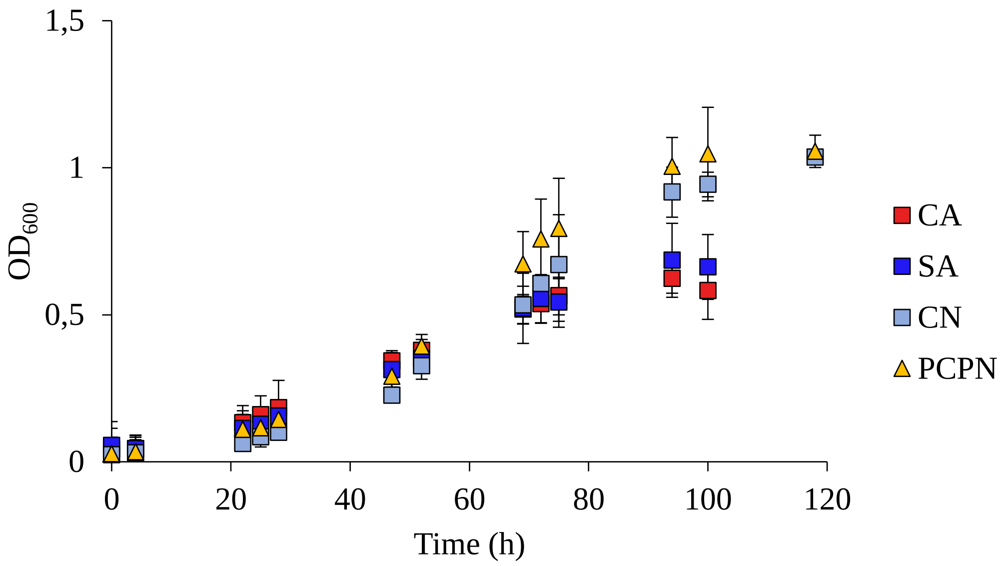

Figure 2. Growth curves using optical density (at 600 nm) as a proxy for growth for control dAMS medium (CA), struvite with ammonium (SA), PCP with ammonium (PCPA), control dNMS medium (CN) and PCP with nitrate (PCPN). Data are given as mean ± SEM.

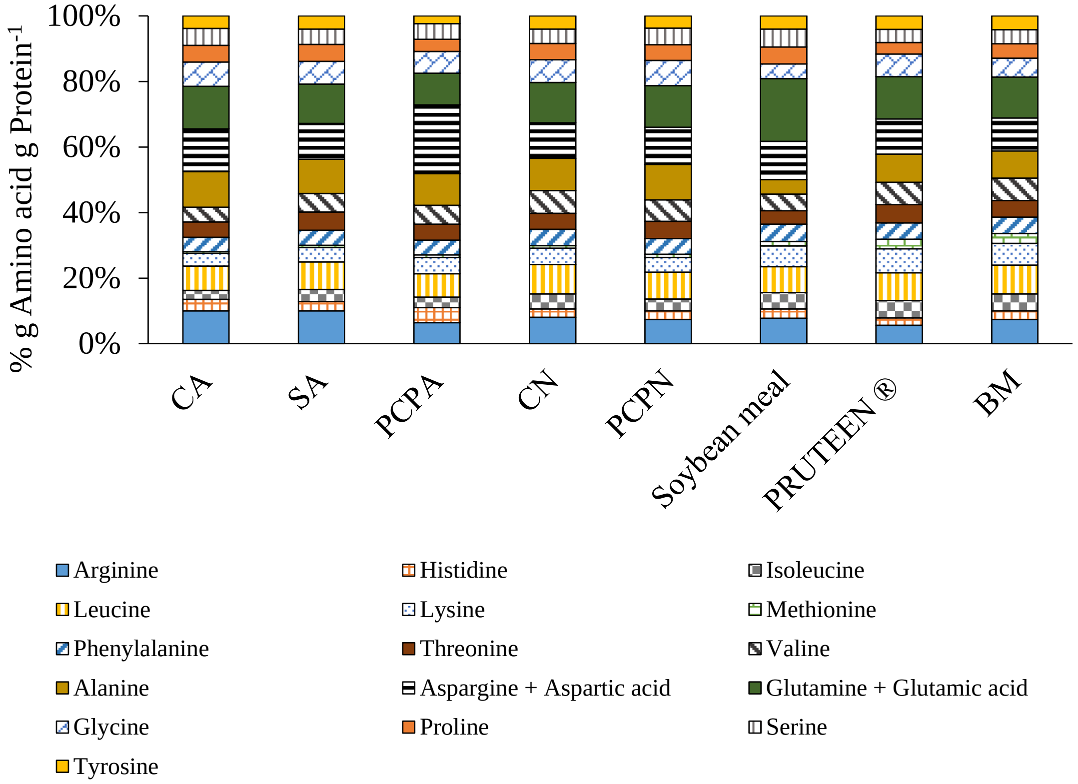

Figure 3. Amino acid profile as percentage amino acid weight per total protein content for control dAMS medium (CA), struvite with ammonium (SA), PCP with ammonium (PCPA), control dNMS medium (CN) and PCP with nitrate (PCPN), soybean meal (Schøyen et al., 2007), commercial microbial protein grown on methanol PRUTEEN® (Øverland et al., 2010), and microbial meal grown on natural gas by Øverland et al. (2010).

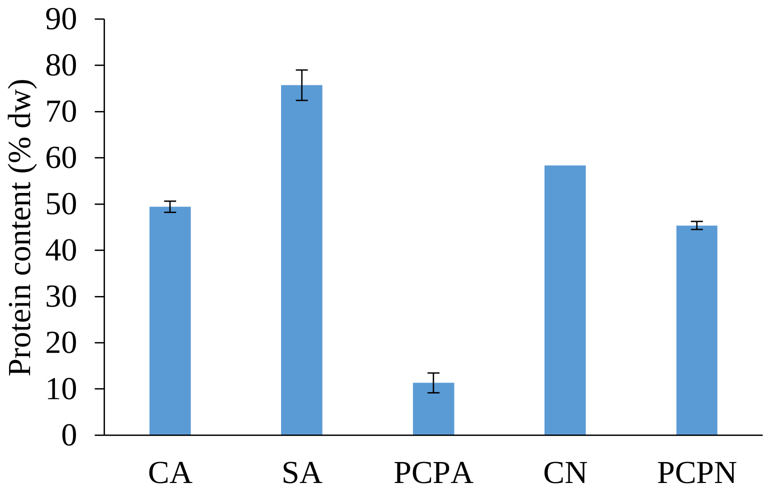

Figure 4. Protein content for control dAMS medium (CA), struvite with ammonium (SA), PCP with ammonium (PCPA), control dNMS medium (CN) and PCP with nitrate (PCPN). Data are given as mean ± SEM.