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Struvite precipitation from processed dairy wastes

ABSTRACT

Thermochemical treatment of sludge from dairy industries was applied to obtain products designated as STRUBIAS (struvite, biochar, and ash), which are commercially accepted as fertilizing products. The technologies hereby used include lower temperature incineration to produce a P rich ash and hydrothermal carbonization (HTC) that produces hydrochar, a prototype of biochar, and a nutrient rich process water. The P and N in resulting hydrothermal process water were purified through struvite precipitation. The multiple optimization method was used to find the proper process conditions. These were evaluated on processed cheese wastewater where the desirability function enabled the minimizing effect of foreign ions while enhancing struvite precipitation from calcium rich whey. The approach was improved by addition of clinoptilolite natural zeolitic materials for struvite precipitation combined with ammonium sorption. This enhanced the ammonium removal, process thermodynamic and obtaining a fertilizer formulation encapsulating more nitrogen in the sorbent active sites, thus a managed nutrient release.

The particular attention was given to chemically produced dairy sludge with iron salts as coagulants. Such a sludge is characterized with very low P availability to plant, while high level of iron becomes threatening to some plants. On one side of the study, the incineration ashes were leached with phosphoric acid supplemented with hydrochloric acid followed by struvite precipitation after ammonium and magnesium dosage. For better cost effectiveness, the study with ash has combined the magnesite and dairy sludge ash co-leached together in acidic solution followed by struvite precipitation. The combination of dairy sludge ash and magnesite were as effective in struvite crystallization as the magnesium chloride use.

The HTC process leaves a bigger volume of nutrient-rich liquor. The recovery of phosphorus (P) by direct precipitation was criticized for product quality. The product iron content was 17.96%, a value higher than accepted limits for purity of phosphate fertilizers. Thus, the HTC liquor P extraction followed by struvite precipitation was studied. The use of oxalic acid extracted 86.7% of P from HTC liquor, while 86.6% of iron was removed. The process conditions of pH 9, and salt dosage of 1.73:1.14:1 for $Mg:NH_4^+:P$ mole ratio for struvite precipitation were obtained with a P recovery of 99.96%, and the effluent P concentration below 2 $mg \cdot L^{-1}$.

The quality of products as fertilizers was tested by both in-vitro and in-vivo assays. High iron content in the product demonstrated a negative effect on plant germination, whilst the precipitation product from P extract demonstrated an advantage of P purification into struvite for plant macro and micronutrient availability. The used method of P extraction followed by struvite precipitation is useful for both P and iron recovery into two separate products with agricultural and chemical applications, respectively.

Finally, a business model of sludge valorization into biochar and struvite was illustrated. The struvite precipitation cost effectiveness was evaluated on the hydrothermal carbonization liquor at full scale by adopting the use of fluidized bed reactors. The product cost was nearly 1.05 USD/Kg struvite. Along with that, the recovered iron oxalate byproducts can be commercialized as Fe and Ca sources for further chemical applications.