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PRODUCTION OF P-FERTILIZER FROM DIGESTATE LIQUID FRACTION THROUGH STRUVITE CRYSTALLIZATION

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Nutrient and organic matter recovering from wastes to reduce the use of agrochemicals and closing waste cycle

ABSTRACT

- Phosphorus is an **essential element** in the food production chain, even though it is a **non-renewable resource** [1]
- Livestock effluents may cause **eutrophication** due to their high phosphorus and nitrogen concentration [2]
- This study focuses on **phosphorus recovery as struvite** from the liquid fraction of digestate
- The **struvite** ($NH_4MgPO_4 \cdot 6H_2O$) is a mineral (Fig. 1) acting as **slow release fertilizer** [3]

Figure 1. Struvite crystals

MATERIALS AND METHODS

Crystallization reaction [4]: $$Mg^{2+} + NH_4^+ + PO_4^{3-} + 6H_2O \rightarrow MgNH_4PO_46H_2O$$

- Liquid fraction of **digestate as** PO_4^{3-} and NH_4^+ source
- Seawater bittern (**SWB**), a by-product of salt production, **as Mg** source
- The samples have been analyzed to assess their optimum quantity for phosphorus precipitation
- **pH 8.5** is the optimum value for the struvite precipitation [5]
- Hydraulic retention time (**HRT**) = **24 h**, i.e. 6.9 L^{-1} (Fig. 2)
- Crystals quality has been evaluated by **SEM-EDS**
- Crystals composition has been evaluated by **XRD**
- Others **precipitation tests** in batch

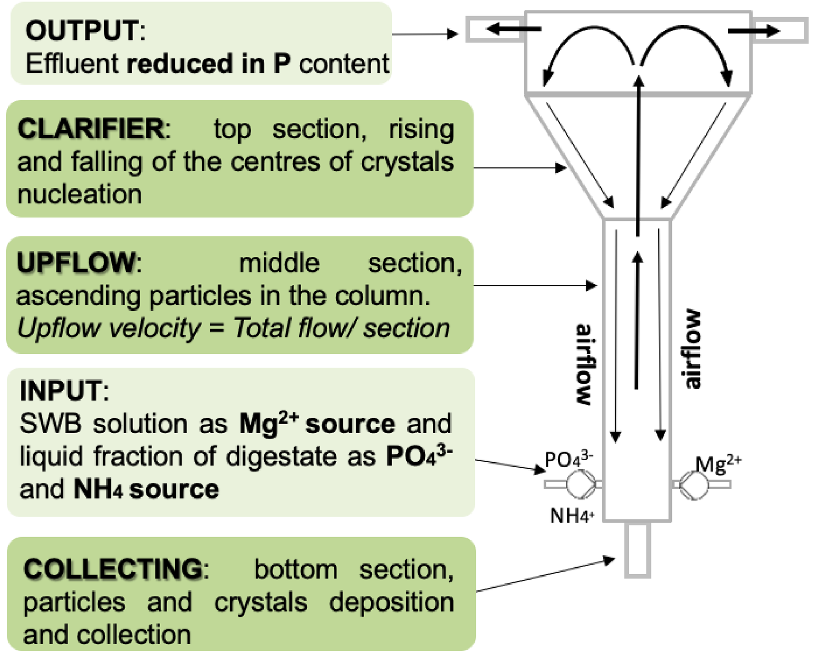

Figure 2. Scheme lab-scale crystallizer

RESULTS AND DISCUSSION

- The ICP-Ms analyses show (Fig. 3) a **P-recovery up to 99%** in the collector output and a **P abatement up to 89%** in the effluent
- In the collector output there is a **high concentration of crystals** with **various structure** (Fig. 4)
- The precipitation of phosphorus occurs in **clumps** and **patina** of **amorphous crystals** (Fig. 5)
- Although the presence of struvite wasn't confirmed by X-Ray Diffraction composition analyses, **P-assimilable concentration** (Table 1) of phosphorus precipitate (PP) is **higher** than poultry manure (PM) a common organic phosphorous fertilizer
- In fact, plants fertilized with PP show higher growing of shoots than PM (Fig. 6 and Table 2)

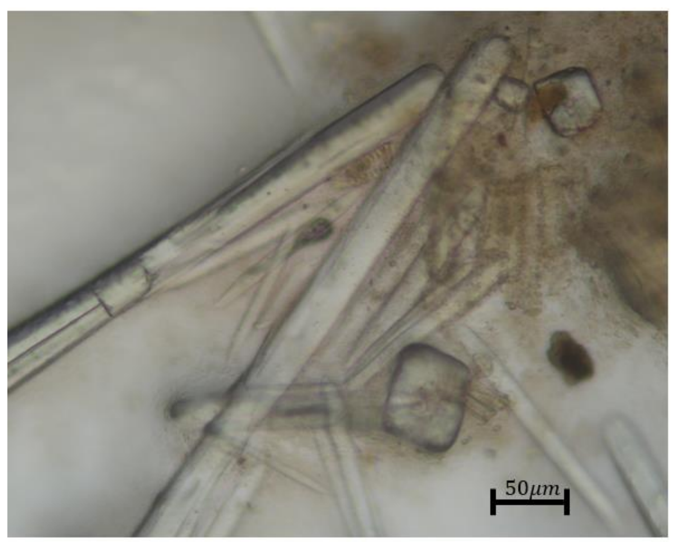

Figure 4. Crystals observed through optical microscope

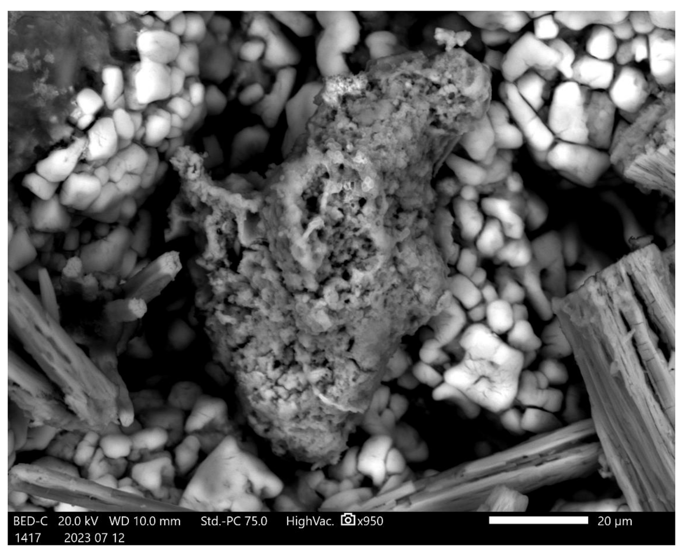

Figure 5. Clump observed through SEM

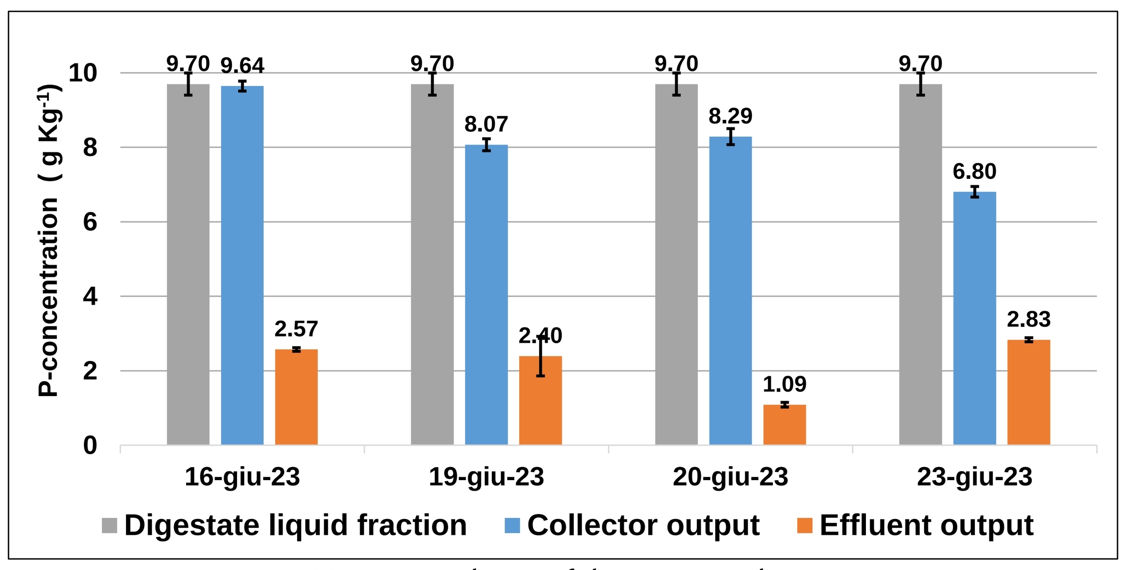

Figure 3. ICP-Ms analyses of digestate and outputs

Sample	P_2O_5 (mg kg^{-1})	P_2O_5 tot (%)
PM	3149 ± 420	3
PP	5018 ± 190	1,63

Table 1. P-assimilable content.

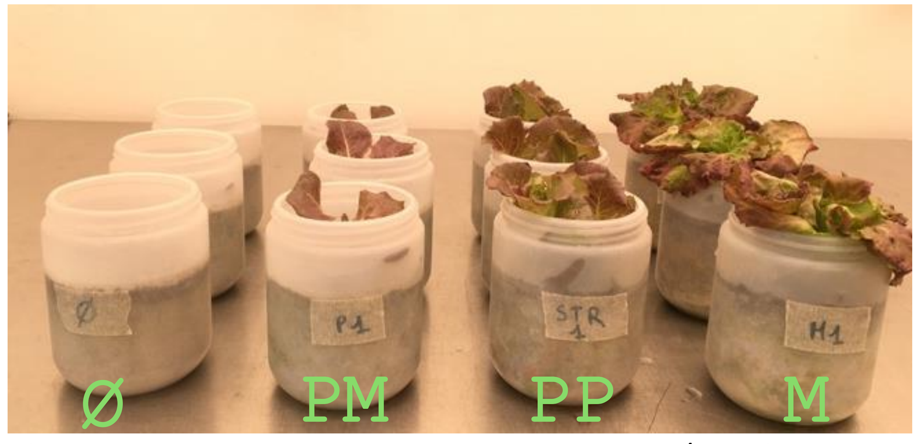

Figure 6. Agronomic test on *Lactuca sativa*. Ø: no fertilizers; PM: fertilized with poultry manure; PP: fertilized with phosphorous precipitate; M: fertilized with mineral fertilizer.

Sample	Plant shoots		Substrates
	Fresh weight (g)	Dry weight (g)	P_2O_5 tot (mg kg^{-1})
Ø	0,31 ± 0,10 a	0.20 ± 0.08 a	23.18 ± 4.73 a
PM	0,63 ± 0,10 ab	0.26 ± 0.07 ab	22.19 ± 6.05 a
PP	2,18 ± 0,10 b	0.64 ± 0.09 b	37.74 ± 7.55 b
M	5,79 ± 0,10 c	1.46 ± 0.33 c	57.03 ± 8.54 c

Table 2. Agronomic test on *Lactuca sativa*. Ø: no fertilizers; PM: fertilized with poultry manure; PP: fertilized with phosphorous precipitate; M: fertilized with mineral fertilizer.

- The struvite formation **was obtained**, as confirmed by X-Ray Diffraction (Figure 7), in a controlled environment (batch test) with a different liquid fraction of digestate.
- SEM microscopic analyses showed the precipitation of phosphorous occurred in **crystals of struvite** (Figure 8).

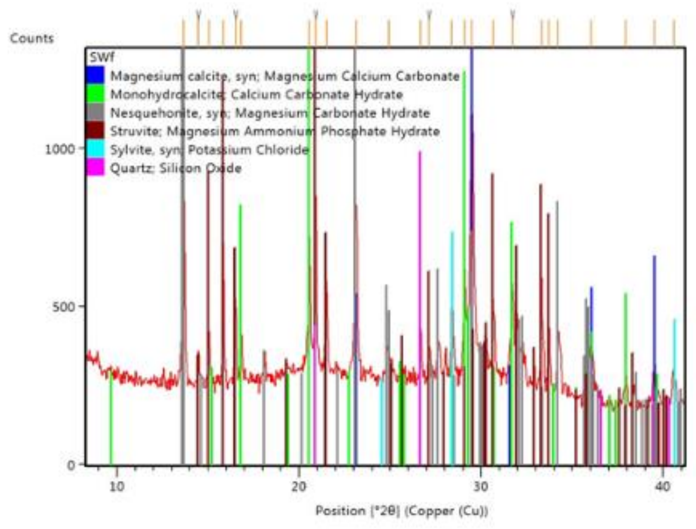

Figure 7. XRD of the product recovered from batch tests

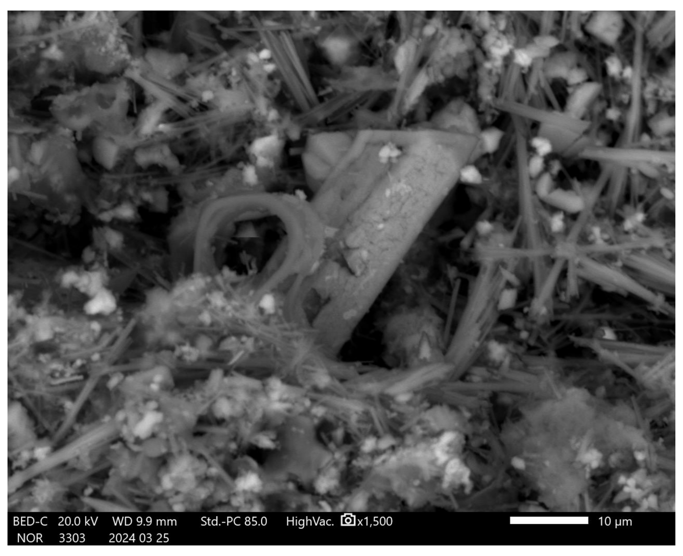

Figure 8. Struvite crystal observed through SEM

These results highlight the possibility to recover phosphorous from digestate through a crystallization process. Although the P precipitate obtained from the prototype wasn't struvite, it gave better performances as a fertilizer than poultry manure. However, struvite was obtained with a different stream in batch tests. Thus, the next goals of the project are to improve the crystallization process in order to guarantee the formation of struvite crystals, to repeat the experiments with new products to solidify the data and publish the results. To achieve these goals, the crystallizer prototype will be adapted based on batch test parameters to resolve problems which could have inhibited struvite formation previously. Finally, the agronomic growth test with the new crystallization products will be repeated.

REFERENCES

[1] S. Daneshgar, A. Callegari, A. Capodaglio, e D. Vaccari, «The Potential Phosphorus Crisis: Resource Conservation and Possible Escape Technologies: A Review», Resources, vol. 7, fasc. 2, p. 37, giu. 2018, doi: 10.3390/resources7020037.

[2] T. Pepè Sciarria, S. Zangarini, F. Tambone, L. Trombino, S. Puig, e F. Adani, «Phosphorus recovery from high solid content liquid fraction of digestate using seawater bittern as the magnesium source», Waste Manag., vol. 155, pp. 252–259, gen. 2023, doi: 10.1016/j.wasman.2022.11.008.

[3] B. Li et al., "The effect of slow-release phosphate fertilizers from digestates on maize rhizosphere soil microbial community and nutrient cycling: Response and activation mechanism," Appl. Soil Ecol., vol. 201, p. 105528, Sep. 2024, doi: 10.1016/j.apsoil.2024.105528.

[4] S. Zangarini, T. Pepè Sciarria, F. Tambone, e F. Adani, «Phosphorus removal from livestock effluents: recent technologies and new perspectives on low-cost strategies», Environ. Sci. Pollut. Res., vol. 27, fasc. 6, pp. 5730–5743, feb. 2020, doi: 10.1007/s11356-019-07542-4.

[5] Y. Jaffer, T. A. Clark, P. Pearce, and S. A. Parsons, "Potential phosphorus recovery by struvite formation," Water Res., vol. 36, no. 7, pp. 1834–1842, Apr. 2002, doi: 10.1016/S0043-1354(01)00391-8.

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