Politecnico di Torino

PONTIFICIA UNIVERSIDAD CATÓLICA DE VALPARAÍSO

Alginate beads with humic acids extracted from anaerobic digestate of sewage sludge

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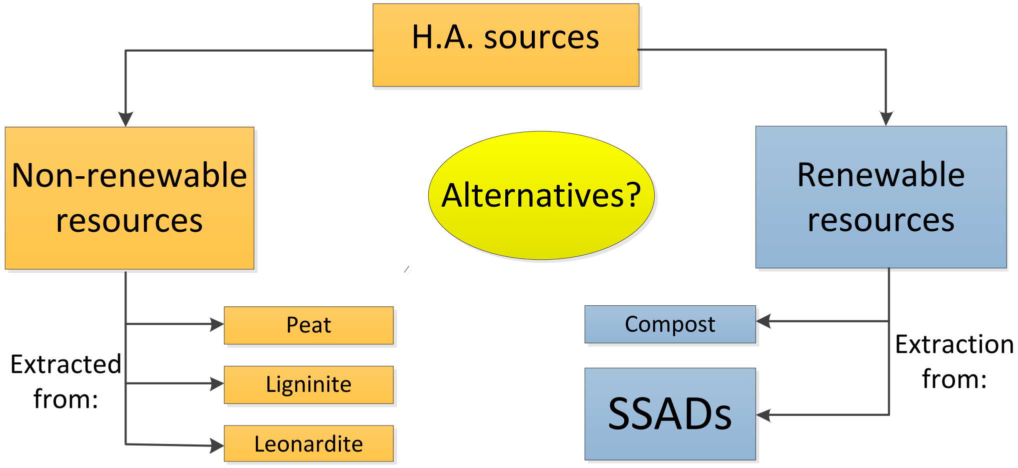
Valparaiso and PoliTo for bioproducts and waste streams reuse in a Circular Economy approach

VALPO4CIRCULAR ECONOMY

Compagnia di San Paolo

Introduction of the work

- Previous studies on fertilizer effects of anaerobic digested sewage sludge (SSAD) on plant growth and soil properties
- Important role of organic matter (>60%)
- Organic matter composed also by humic acids (HA)
- HA: humic substances (HS) soluble in water at pH greater than 2 (after alkalinization)
- HS: biopolimers derived by microbial biodegradation of organic matter



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Research article

Anaerobic digestates from sewage sludge used as fertilizer on a poor alkaline sandy soil and on a peat substrate: Effects on tomato plants growth and on soil properties

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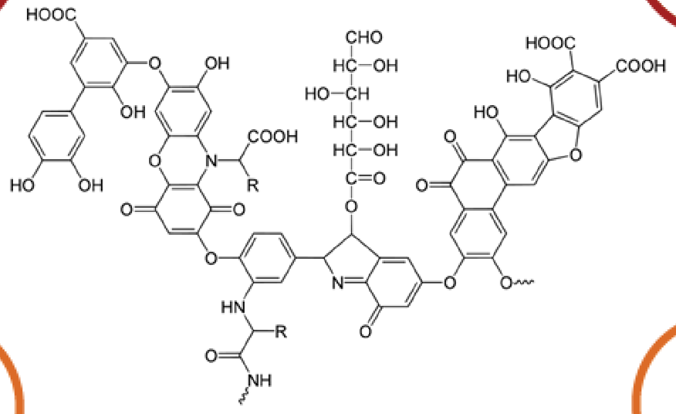
The “black gold”

Roots development

Porosity

Water retention

Fertility



Erosion

Solar radiation

CEC

Salinity

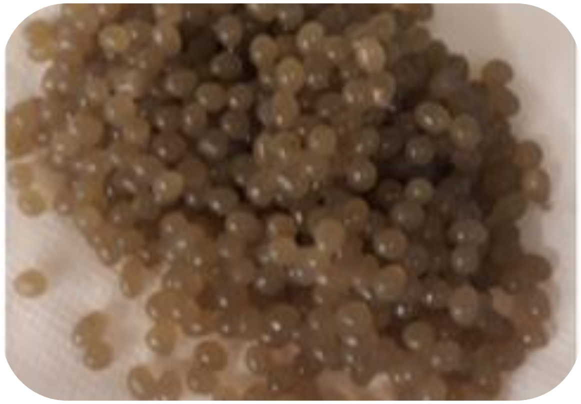
Population and microbial activity

Additive effect

Four objectives of the work

HA
quantification

HA
extraction



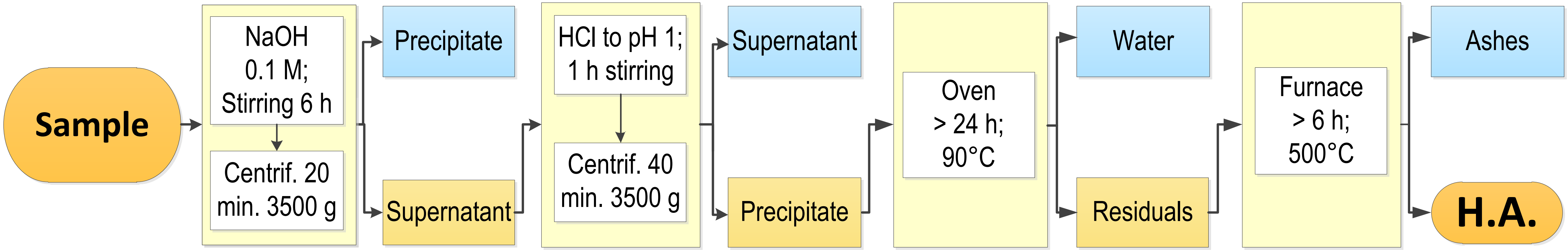
HA
encapsulation

Greenhouse
test

Quantification of HA

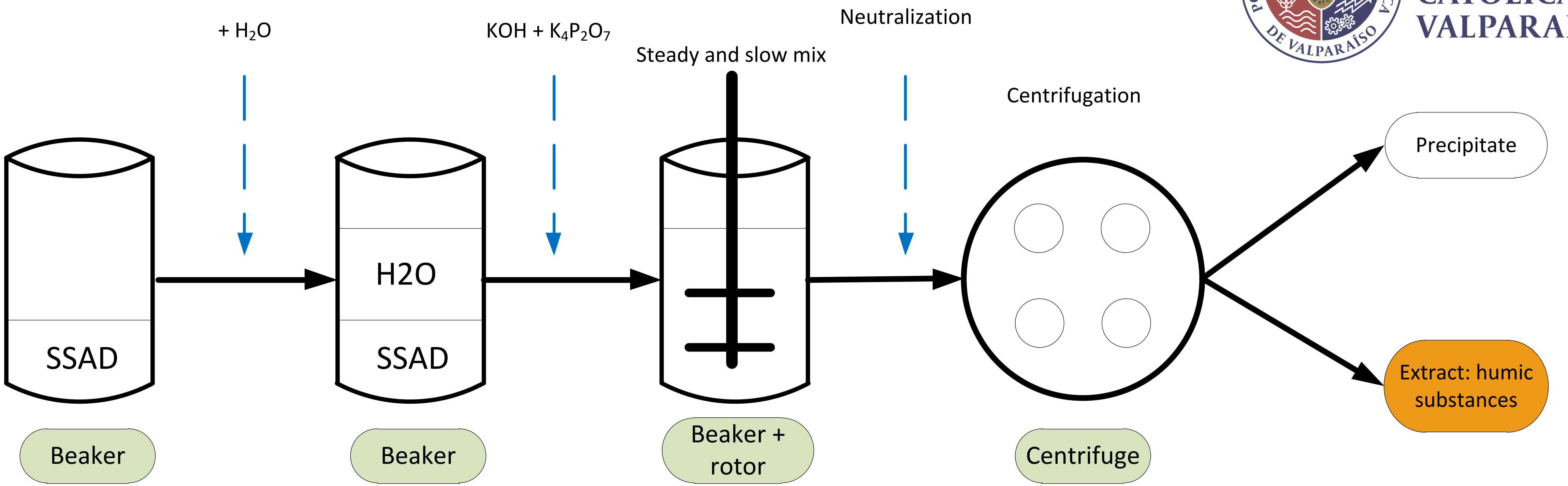
Lamar method

- Humic Products Trade Association (HPTA)
- International Humic Substances Society (IHSS)



Lamar, R. T., Olk, D. C., Mayhew, L., & Bloom, P. R. (2014). A new standardized method for quantification of humic and fulvic acids in humic ores and commercial products. *Journal of AOAC International*, *97*(3), 721-730.

Extraction of HA



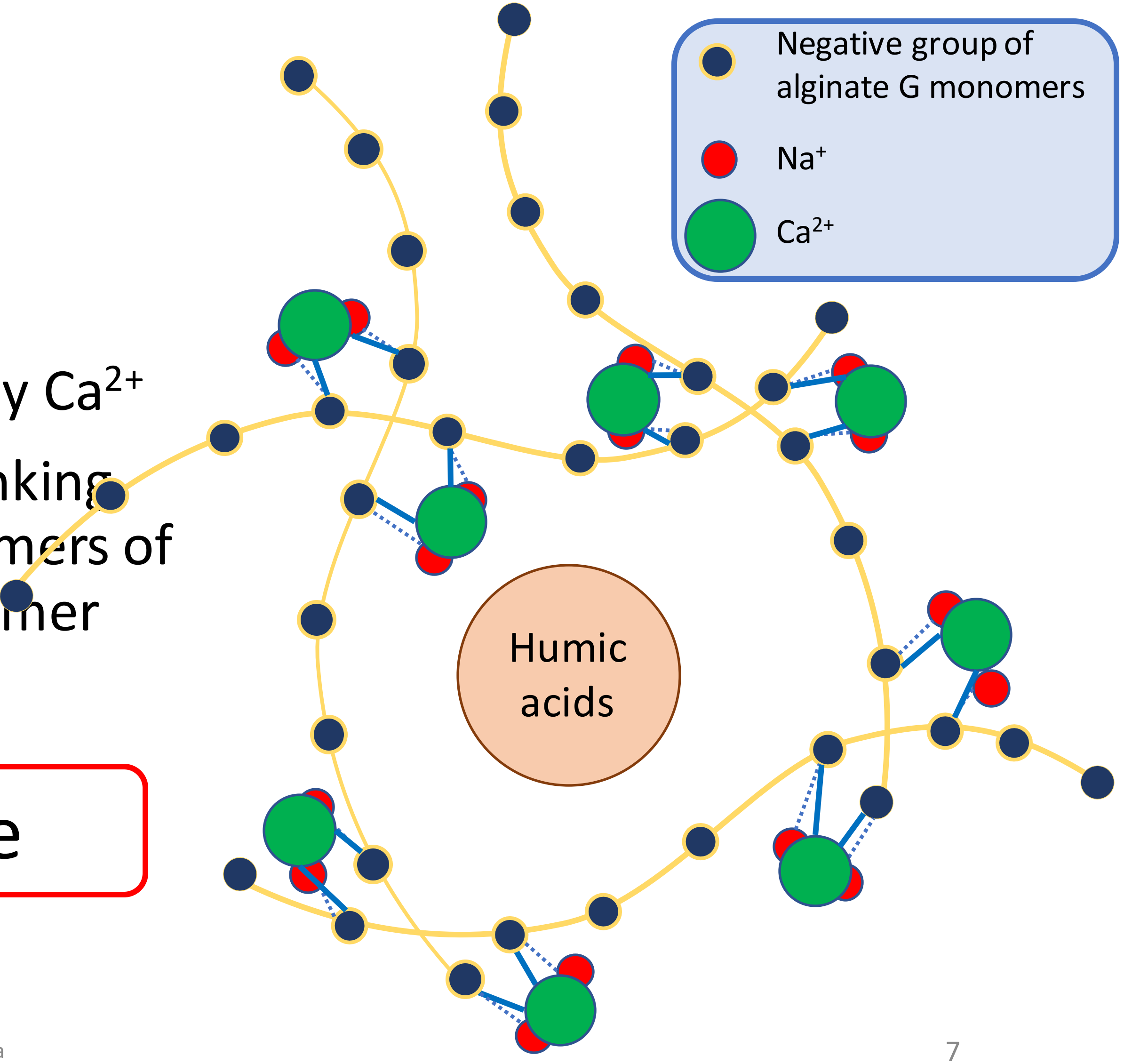
Encapsulation of HA

Sodium alginate

- Natural polysaccharide:
  - (1,4)-β-D-mannuronic acid (M)
  - (1,4)-α-L-guluronic acid (G)
- From brown algae

1. Alginate
2. Alginate$^-$ Na^+
3. Na^+ substitution by Ca^{2+}
4. Ca^{2+} ionic cross-linking between G monomers of two different polymer chains

Slow release



Greenhouse test

Treatments

Soil (Control)

Soil + HA beeds

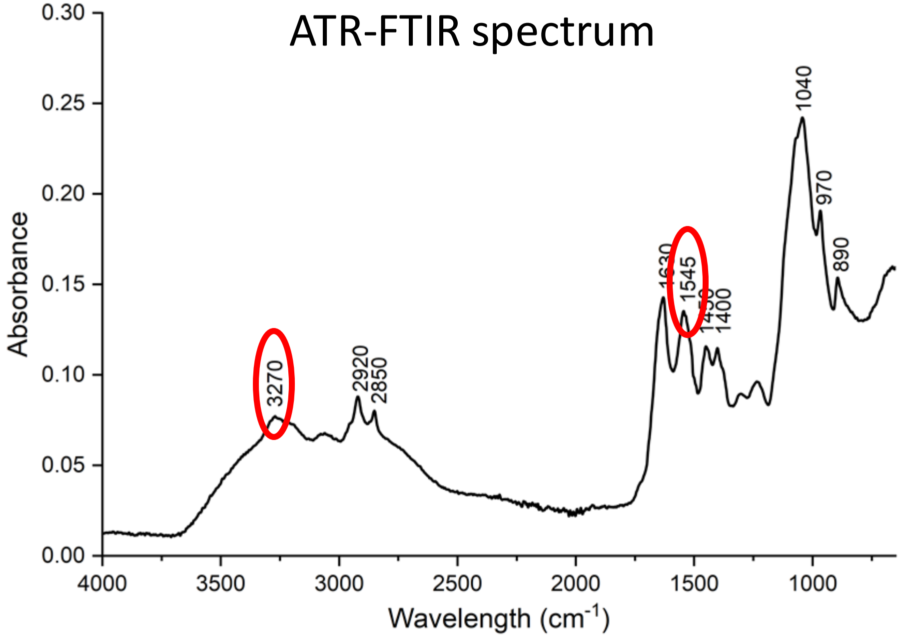
Greenhouse conditions:

- Pot: Ø 30 cm
- Dosage: 8.7 kg ha^{-1} of HA
- Drip irrigation
- 9 replicates
- Lettuce plants
- Epigean and hypogean biomass measure after 70 days

Results – quantification and characterization

HA quantification

Parameter	Dry matter %		% H.A. (d.m.b.)	
	Mean value	Standard dev.	Mean value	Standard dev.
SSAD	25.58	± 0.49	12.53	± 1.60
Extract	1.13	± 0.02	26.87	± 0.35
Commercial H.A.	83.95	± 0.08	77.87	± 1.46



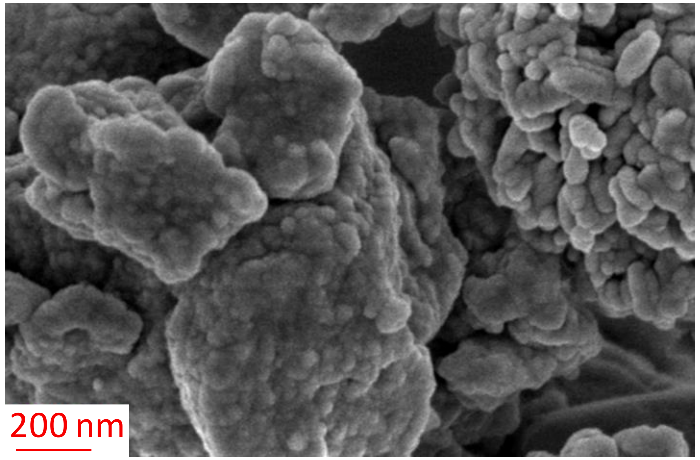
Spectrum:

- 3270: H-bonded O-H stretching of carboxylic acids, phenols, and alcohols
- 1545: C=N stretching of amides

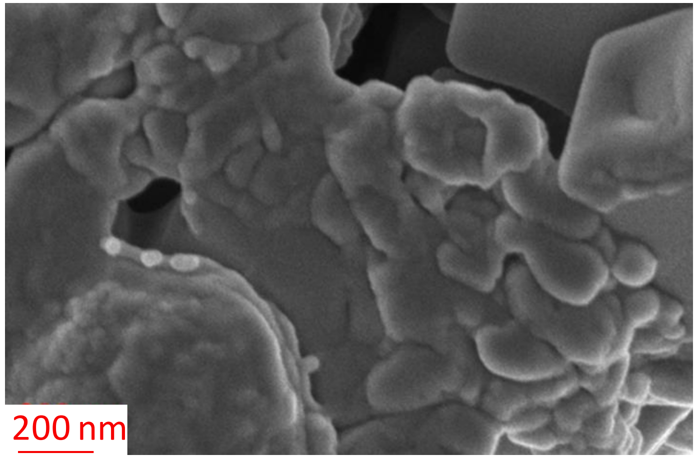
Results – characterization

FESEM Images

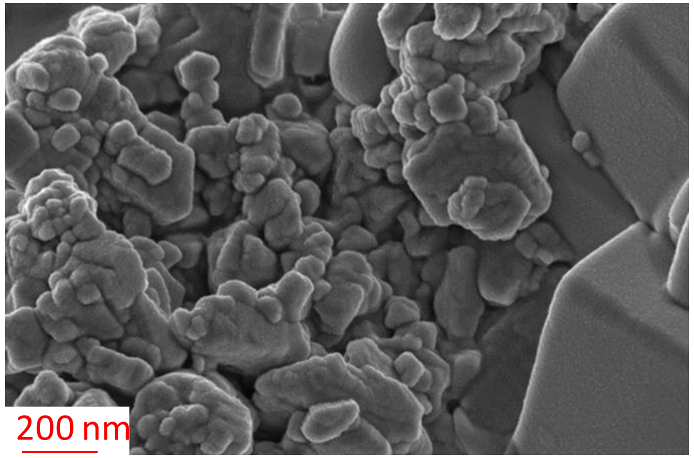
Commercial humic acids (powder)



Humic acids extract (lyophilized)

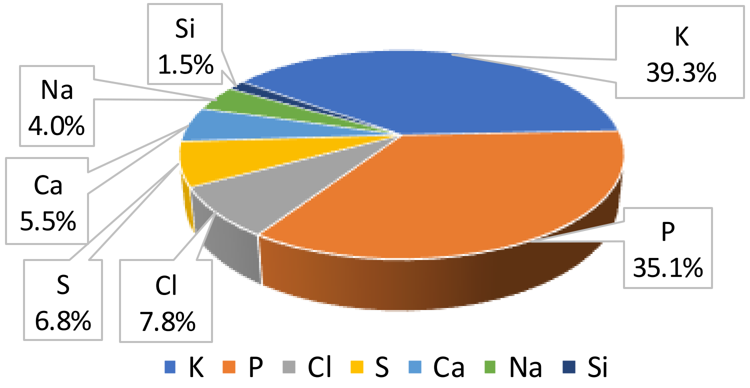


Humic acids beads

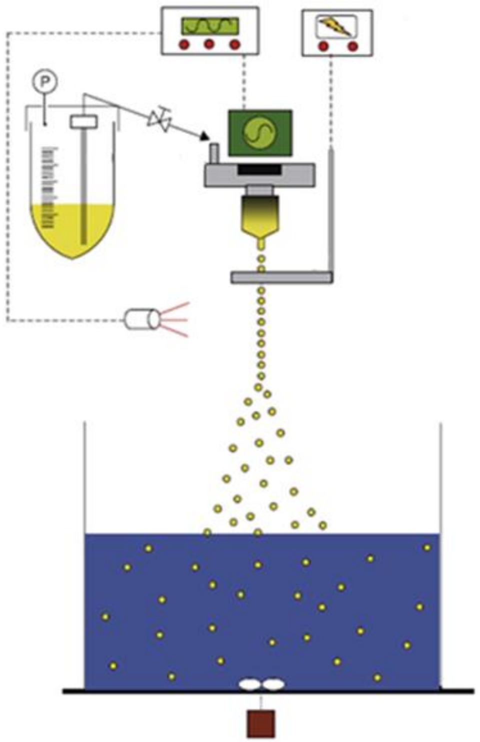


- FFESEM images shown similar structures between commercial HA, lyophilized extracted HA and HA beads
- C, O, N, H excluded from EDX analysis
- Beads free of heavy metals

EDX Analysis



Results - encapsulation

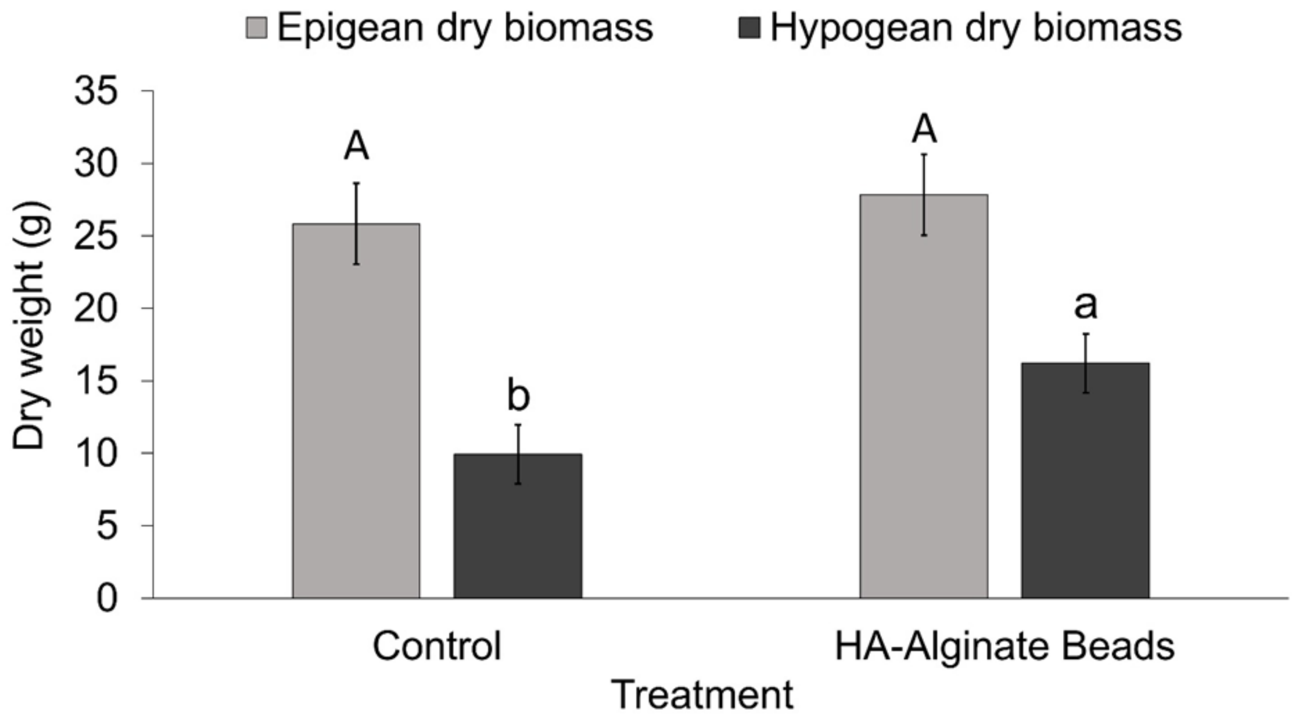


Encapsulation parameters:

Parameter	U.M.	Range		Selected values
		min.	max.	
1 - Alginate concentration	%	1.2	4	2.3
2 - Nozzle diameter	mm	0.8	1.5	1
3 - Frequency	Hz	0	750	40
4 - Voltage	V	0	2500	250
5 - $CaCl_2$ concentration	M	0.06	6	0.6
6 - Beads permanence	hours	0	24	0.1
7 - Pressure	mbar	0	800	400-500
8 - Agitation	rpm	0	1000	≅ 100
Beads diameter (wet)	mm	0.2	6	2.4 ± 0.4
Beads diameter (dry)	mm	0.1	2.7	1.1 ± 0.1

Results – test

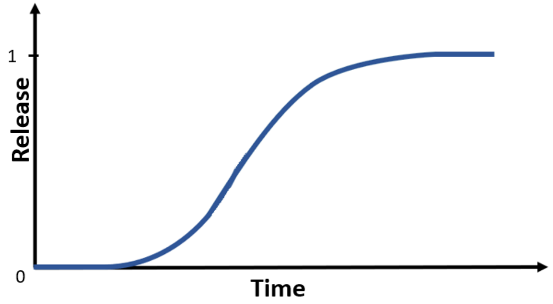
Greenhouse test - biomass

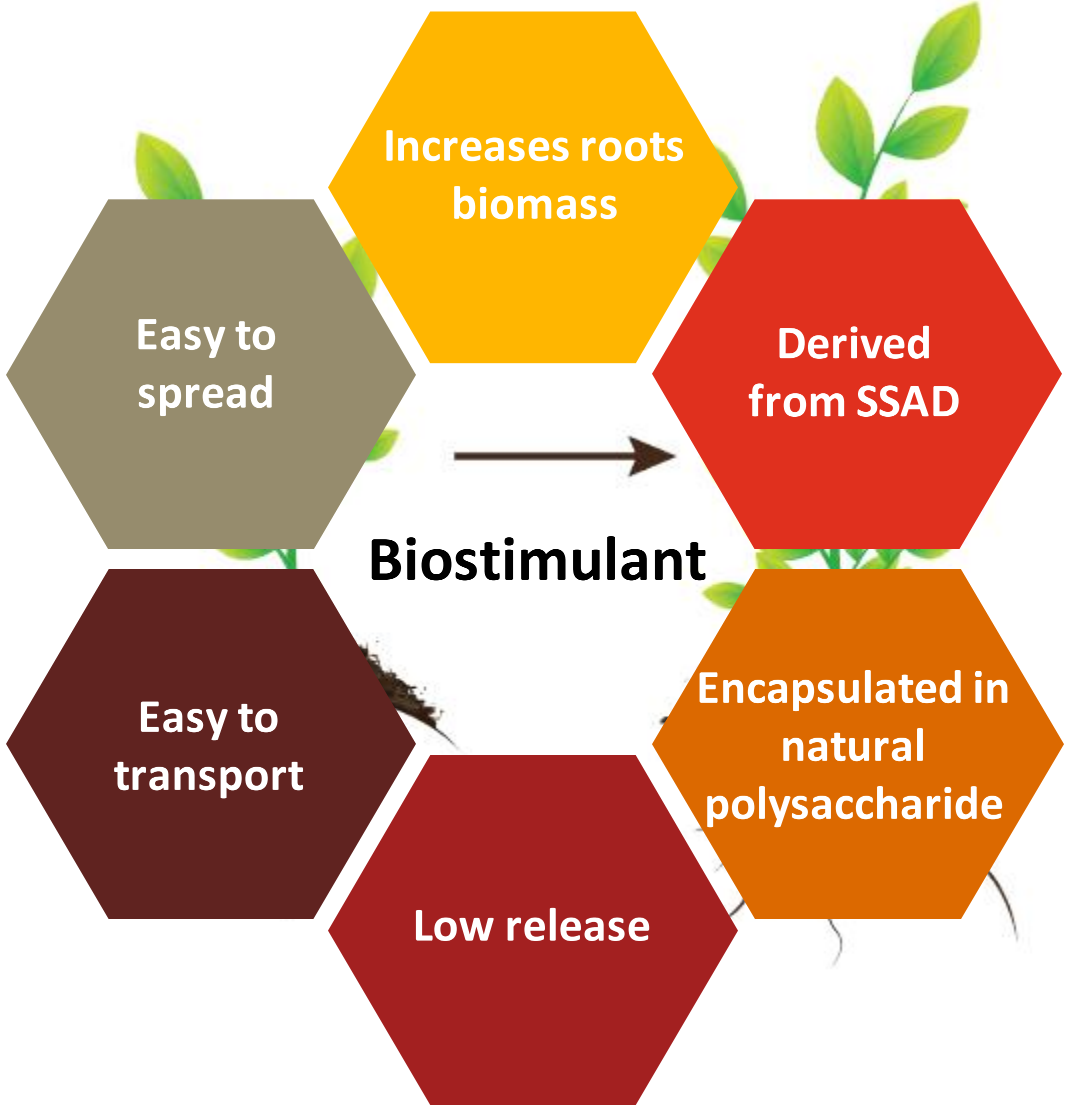


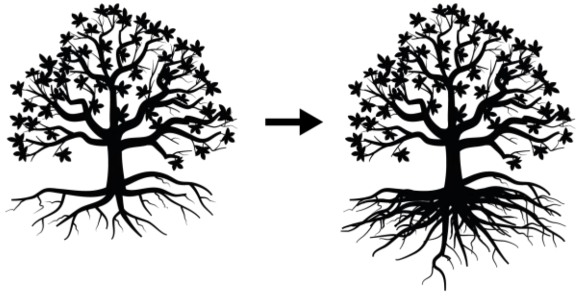
- No differences on epigean biomass
- Higher roots biomass with HA-Alginate beeds (+63%)

Data analysis: One-way ANOVA, Tuckey post-hoc test $p < 0.05$;
Tuckey post-hoc test: different letters indicate significant differences between treatments.

The biostimulant product

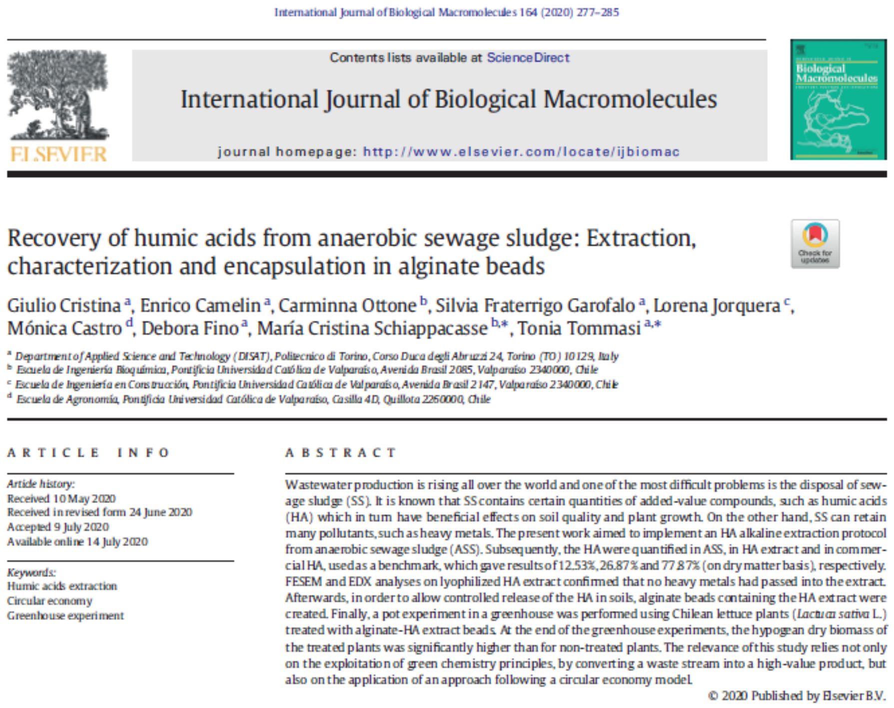






Conclusions

- Quantification of HA in SSAD
- Extraction of HA
- Two-fold enrichment of HA in extract 12.5% → 26.9%
- Encapsulation → creation of biostimulant
- Beads free of heavy metals
- Beads enhanced on roots growth (+63%)
- High value compounds derived from SSAD



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Recovery of humic acids from anaerobic sewage sludge: Extraction, characterization and encapsulation in alginate beads

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ABSTRACT

Wastewater production is rising all over the world and one of the most difficult problems is the disposal of sewage sludge (SS). It is known that SS contains certain quantities of added-value compounds, such as humic acids (HA) which in turn have beneficial effects on soil quality and plant growth. On the other hand, SS can retain many pollutants, such as heavy metals. The present work aimed to implement an HA alkaline extraction protocol from anaerobic sewage sludge (ASS). Subsequently, the HA were quantified in ASS, in HA extract and in commercial HA, used as a benchmark, which gave results of 12.53%, 26.87% and 77.87% (on dry matter basis), respectively. FESEM and EDX analyses on lyophilized HA extract confirmed that no heavy metals had passed into the extract. Afterwards, in order to allow controlled release of the HA in soils, alginate beads containing the HA extract were created. Finally, a pot experiment in a greenhouse was performed using Chilean lettuce plants (*Lactuca sativa* L.) treated with alginate-HA extract beads. At the end of the greenhouse experiments, the hypogean dry biomass of the treated plants was significantly higher than for non-treated plants. The relevance of this study relies not only on the exploitation of green chemistry principles, by converting a waste stream into a high-value product, but also on the application of an approach following a circular economy model.

Thank You for Your Attention

Giulio Cristina

25/06/2021