AGRO4AGRI

Nanocellulose-Based Advanced Fertilizer Systems for Controlled Nutrient Release in Sustainable Agriculture

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What is AGRO4AGRI?

AGRO4AGRI is an EU-funded project set to **revolutionise plant nutrition and protection** through cutting-edge nano and biotechnology.

48	12	€5.3M
months	**partners**	**budget**
(from May 2024 to April 2028)	(from 7 countries)	(fully EU-funded under Horizon Europe)

HORIZON Research and Innovation Actions | **Grant Agreement No. 101130890**

Call and topic 'HORIZON-CL4-2023-RESILIENCE-01-34

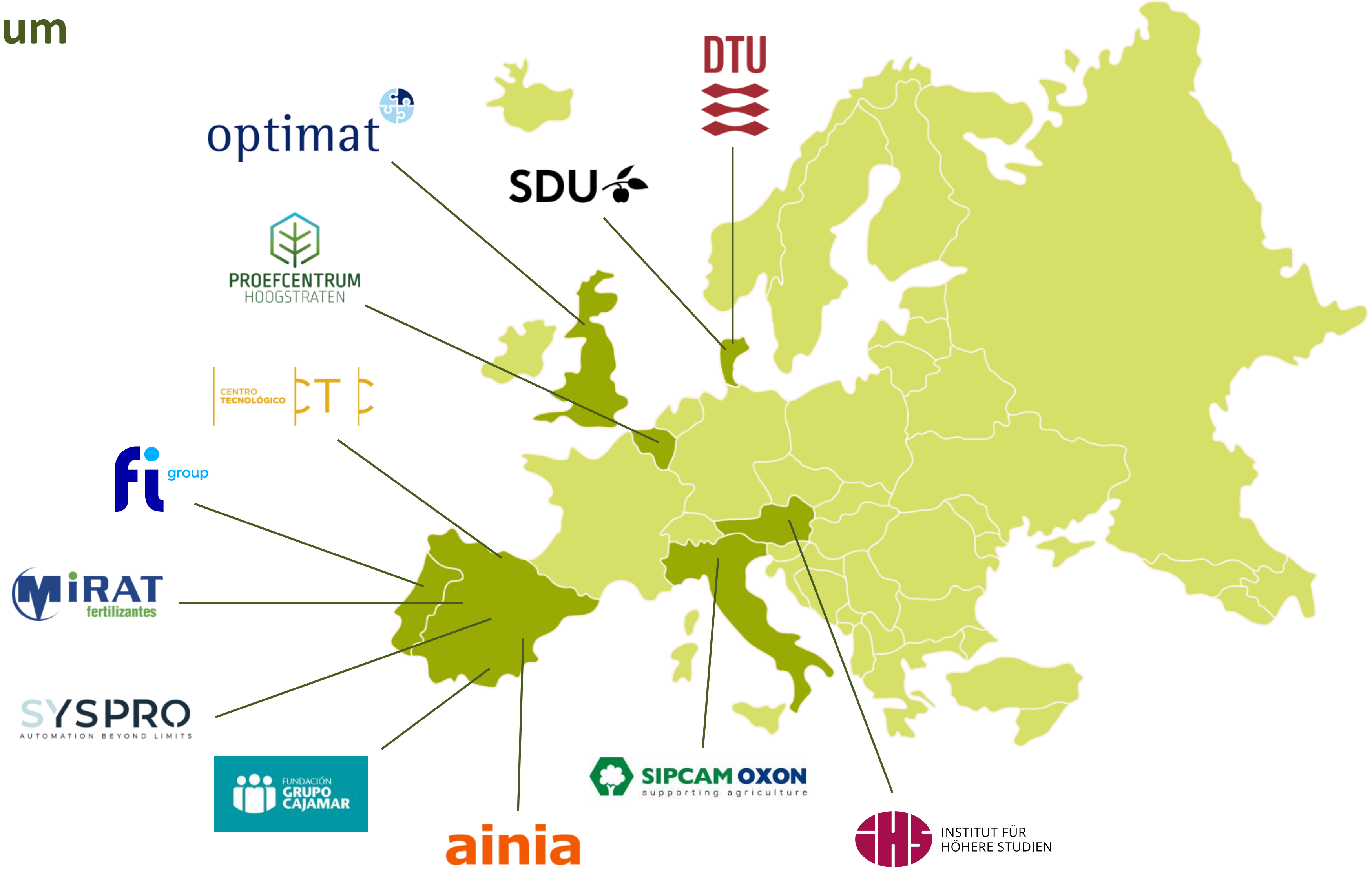
Advanced (nano and bio-based) materials for sustainable agriculture (RIA)'

The AGRO4AGRI Consortium

12 partners, 7 countries:

- 3 RTOs
- 3 academic research groups
- 3 industrial companies
- 1 multi-national company
- 1 SME
- 1 not-for-profit
- Represent agrochemical supply and value chain

Coordinated by AINIA (Valencia)



AGRO4AGRI strategic objectives

1 Develop advanced delivery systems of **fertilisers based on inorganic nanoparticles** (nanoclays and mesoporous silica)

2 Develop advanced delivery systems of **fertilisers from bio-based materials** (biochar and nanocellulose derivatives)

3 Develop **target-specific nematicides** based on dsRNA microencapsulated with bio-based coatings

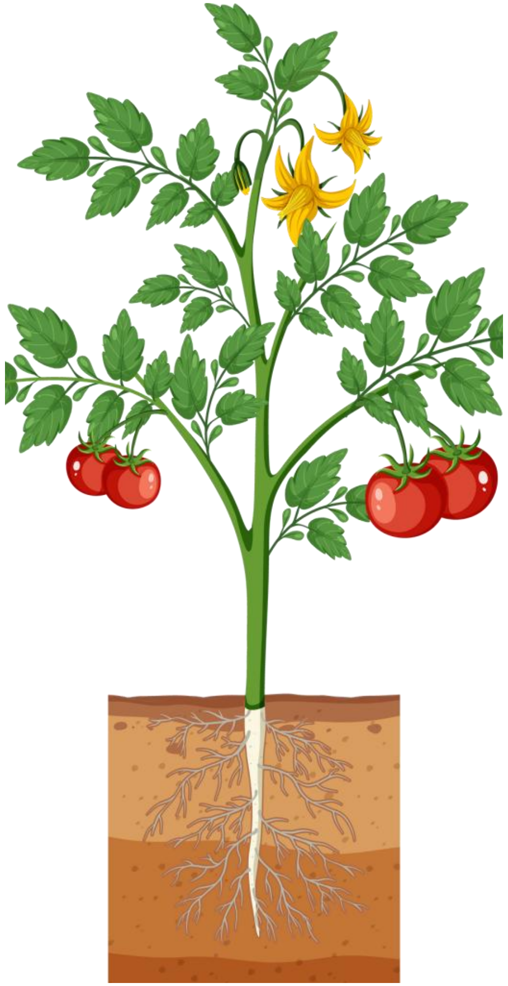
4 Validate several **SSbD agrochemical solutions** in real-life case studies (TRL5-6)

5 Demonstrate the **commercial viability** of project prototypes, to stimulate investment for the long-term growth of project

PROBLEM

Traditional agrochemical practices

- Large amounts of fertilisers and pesticides usage
- Intensive irrigation
- High human and ecotoxicity pesticides
- Bioaccumulation and bioconcentration



SOLUTION

AGRO4AGRI solutions

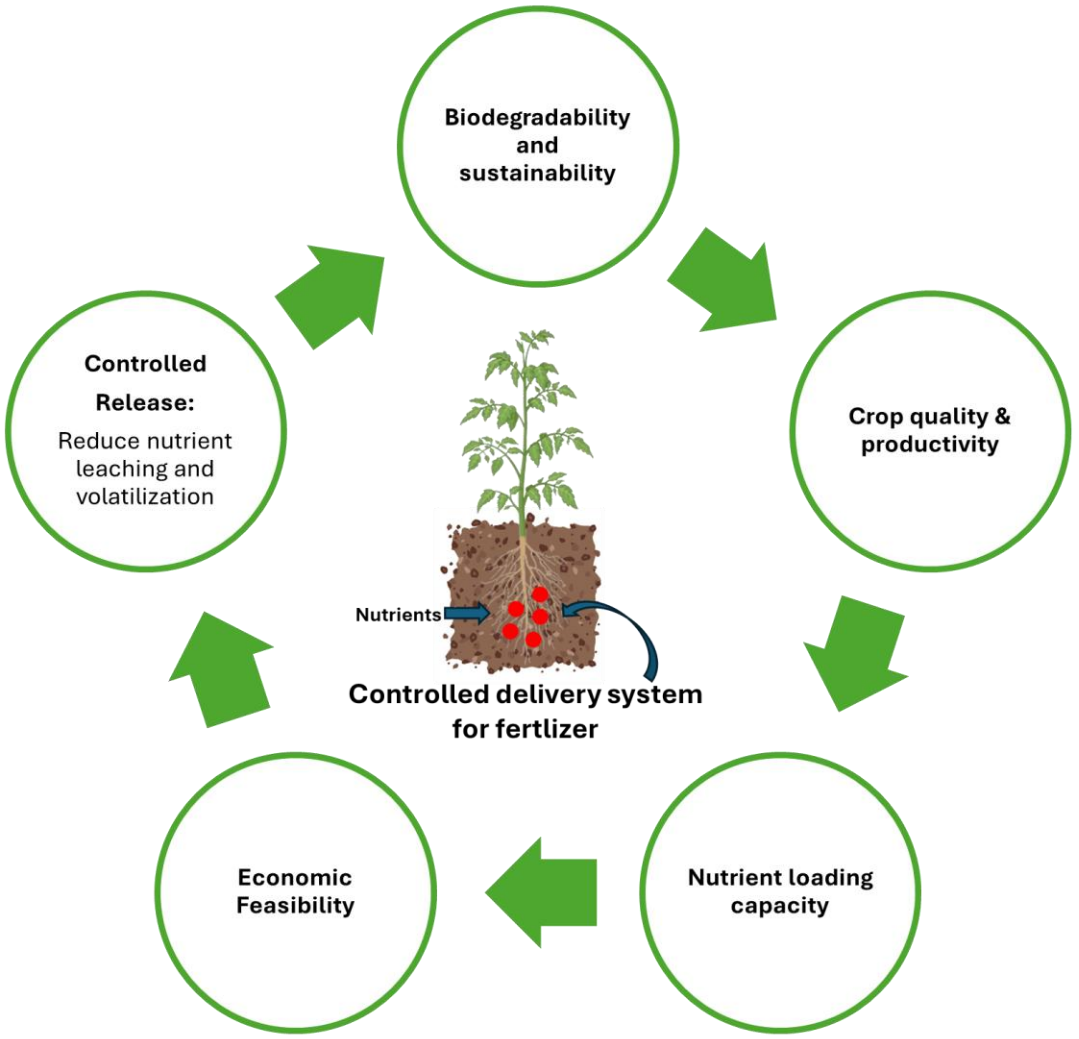
- Advanced delivery systems based on inorganic nanomaterials and biobased materials for controlled and slow release of the chemicals
- Low risk active substances for operators and environment
- RNAi-based biopesticides
- Nanocellulose hydrogels slow water delivery
- Reduced wash-off

What is a CRFS?

A **controlled release fertilizer system** is a technology designed to **gradually and precisely release nutrients over time**, according to the physiological needs of the plant and environmental conditions such as soil moisture, temperature, or pH. These systems use **polymeric matrices or coatings** – often biodegradable – to **regulate the rate of nutrient release**, minimizing losses through leaching, volatilization, or soil fixation.

Advantages:

- Maximize nutrient use efficiency (NUE)
- Reduce environmental impact
- Optimize timing and dosage of fertilization
- Support healthier and more productive crop growth



Commonly, CRFs can be classified into two sections by the matrix materials, **inorganic compounds** or **polymeric materials**. In recent years, **polymeric materials** have drawn more attention to the CRFs because of their **good mechanical properties** and **slow releasing rate**.

Common petroleum-based polymers used:

- Polyethylene (PE)
- Polypropylene (PP)
- Polyvinyl chloride (PVC)

→ Environmental Concern →

- Most petro-based polymers are **not biodegradable**
- Their use **introduces new pollutants** into the environment (e.g.microplastic, plastic additives etc.)

↓ Sustainable alternative ↓

Natural, biodegradable materials(Chitosan, starch derivatives, cellulose etc.)

Nanocellulose derivatives

Most abundant natural polymer

Biocompatibility and biodegradability

High reactivity

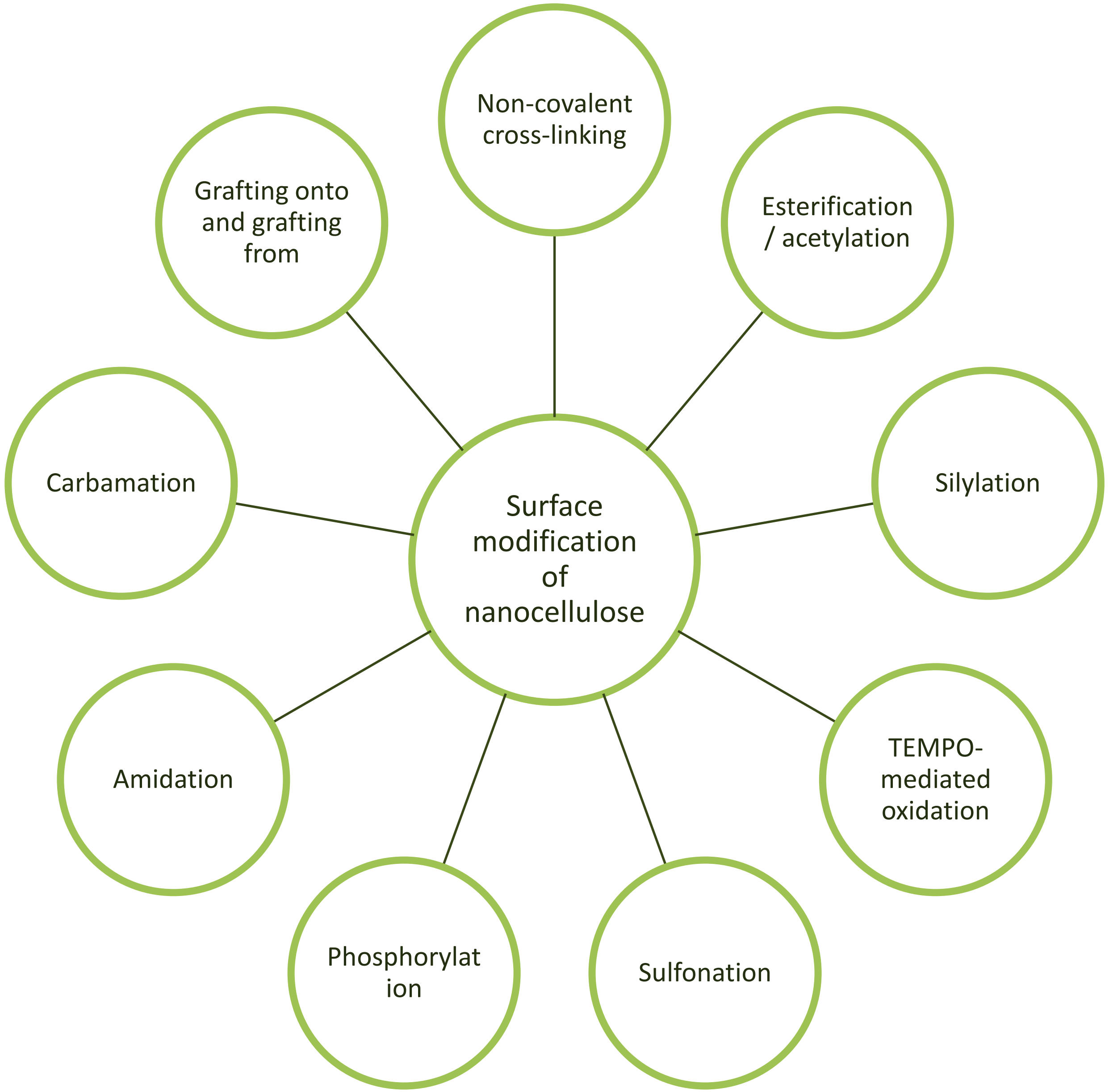
no toxicity

Water retention

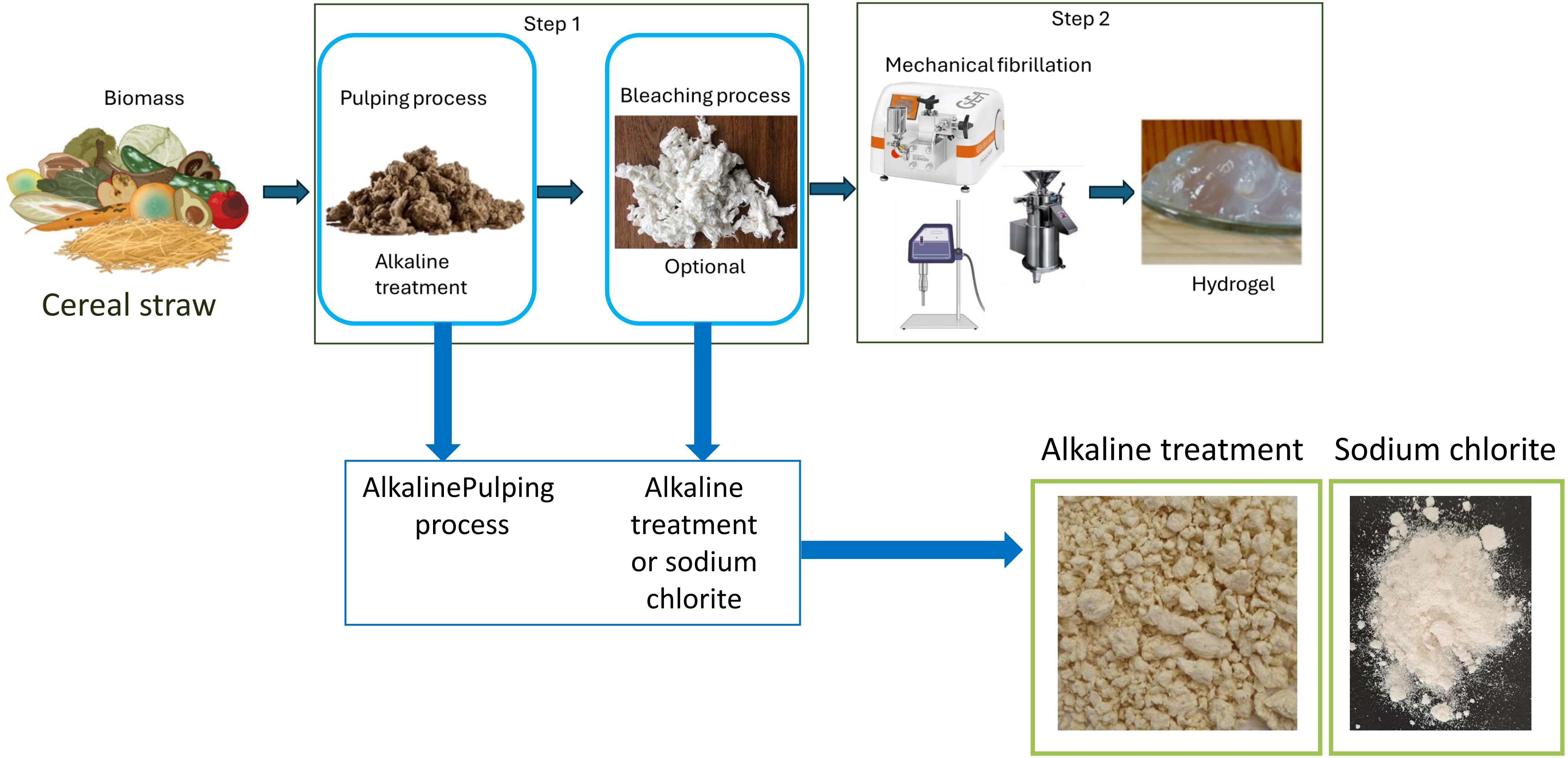
Fast release rate

↓

Chemical modification



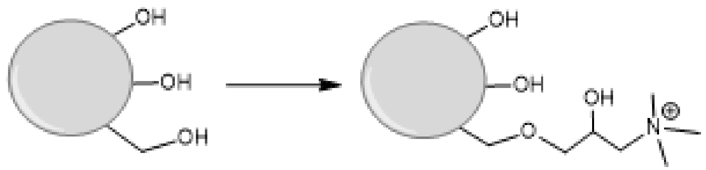
Optimization of the Nanocellulose Isolation Process



Chemical modification of nanocellulose

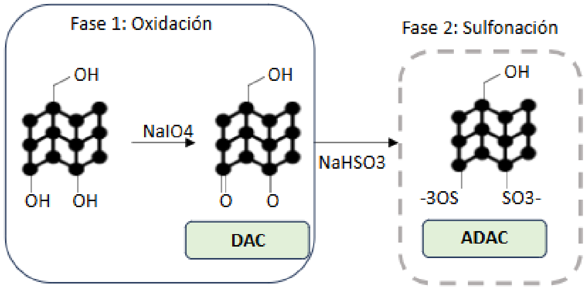
Cationic

Modification with epoxide



Anionic

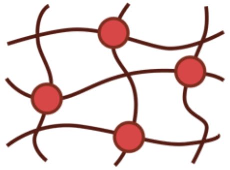
Sulfonation



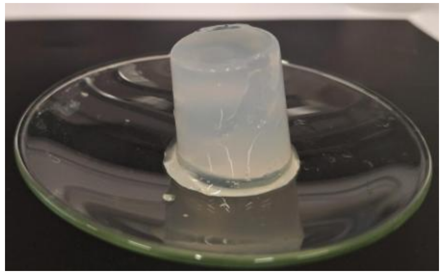
Oxidación:

- ✓ Introduction of ammonium group through oxidation reaction
- ✓ 2,2,6,6-Tetramethylpiperidin-1-yl oxyl (**TEMPO**)

Aerogels or hydrogels → Crosslinking with sodium alginate

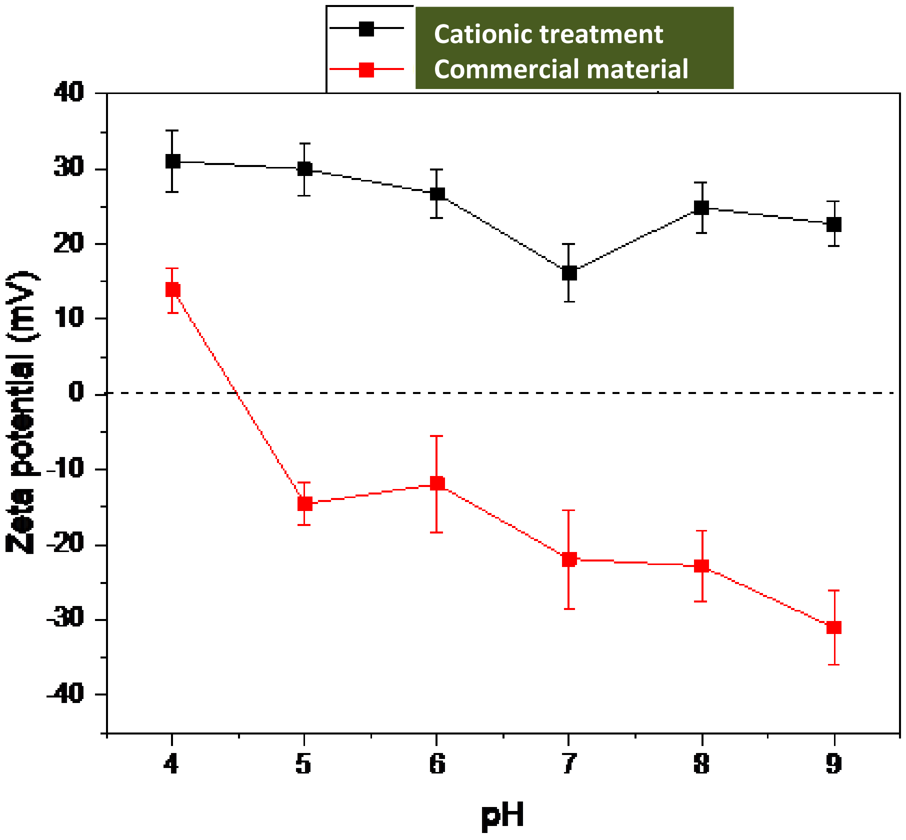


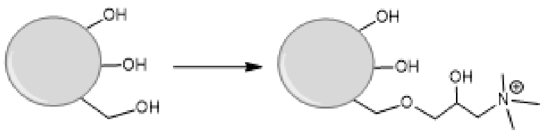
Hidrogel

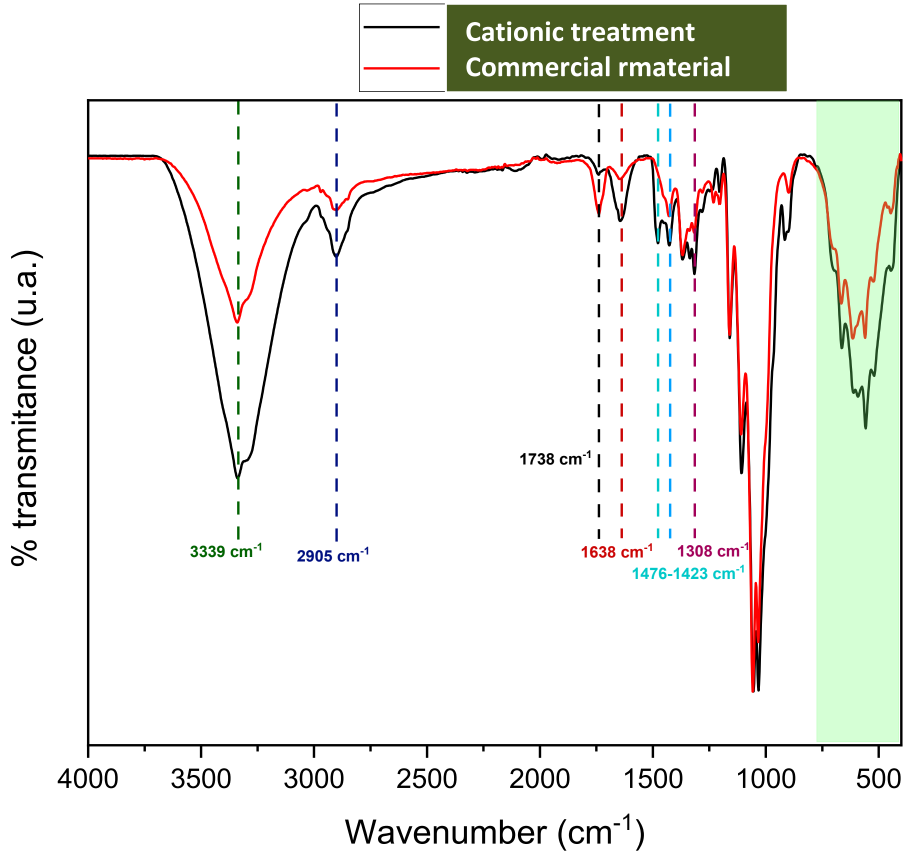


Aerogel

Cationic nanocelulose: Modification of nanocellulose from cereals straw

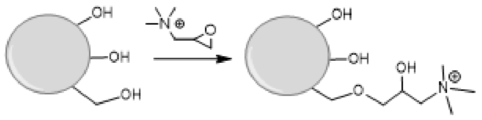






Sample	Zeta Potential	Elemental analysis (%N)
Cationic nanocellulose	24.9 ± 3.31	2% ± 0.22
Commercial nanocellulose	-22.83 ± 4.67	0%

Cationic nanocelulose: Modification of nanocellulose from cereals straw



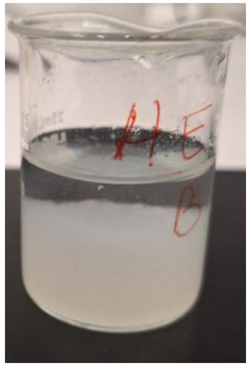
Sample	Bleaching	NaOH treatment
Cereal straw	Yes	
	No	No
	No	Yes
	Yes (Hydrogen peroxide)	No
	Yes (Hydrogen peroxide)	Yes
	Yes (Sodium chlorite)	No

Sample	Zeta Potential	Elemental analysis (%N)
Cationic nanocellulose	+13.7 ± 0.7	0.5% ± 0,07
Biomass	-16.6 ± 1.3	0%

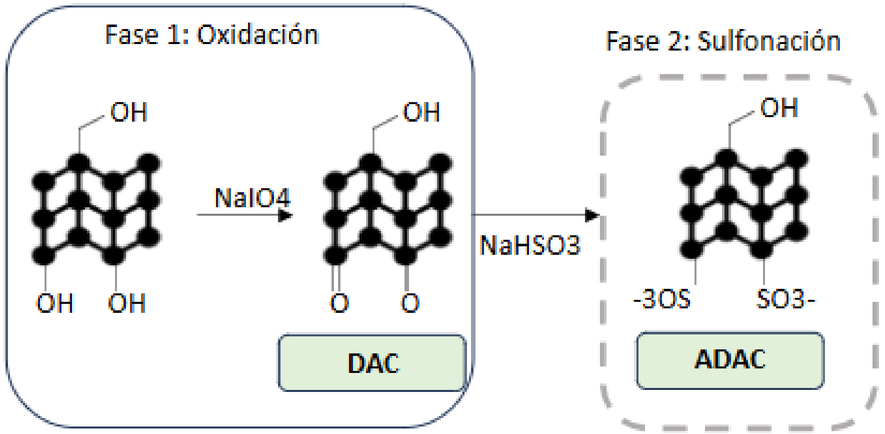
The reaction proceeded successfully, most likely because bleaching with sodium chlorite is more effective and removes a greater amount of lignin, which would otherwise interfere with the reaction.

Problem

Low stability



Anionic cellulose: Sulfonation

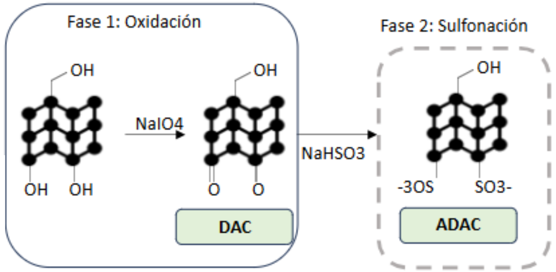


Sample	Mass balance	
Comercial cellulose	Low mass balance due to loss of soluble product during purification and depolymerization	High oxidant concentration
	90-96%	Lower oxidant concentration

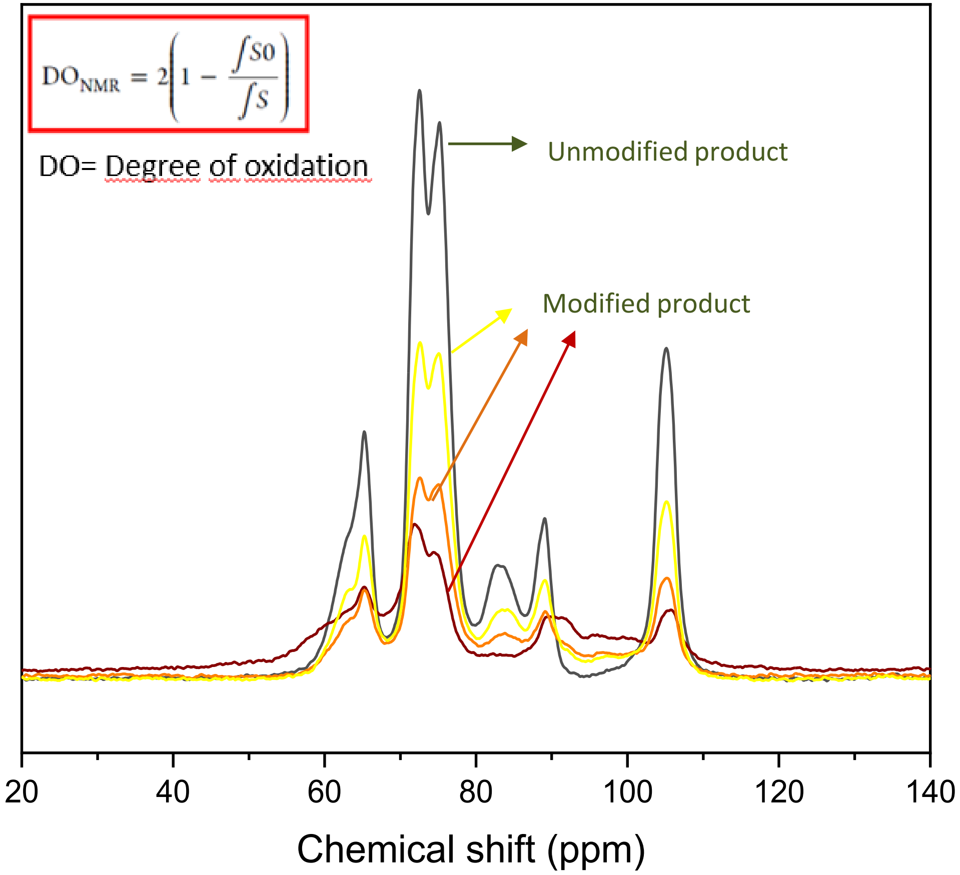
Excessive modification of the functional group results in **increased solubility** of the final product, leading to **losses of the product** during the purification process.

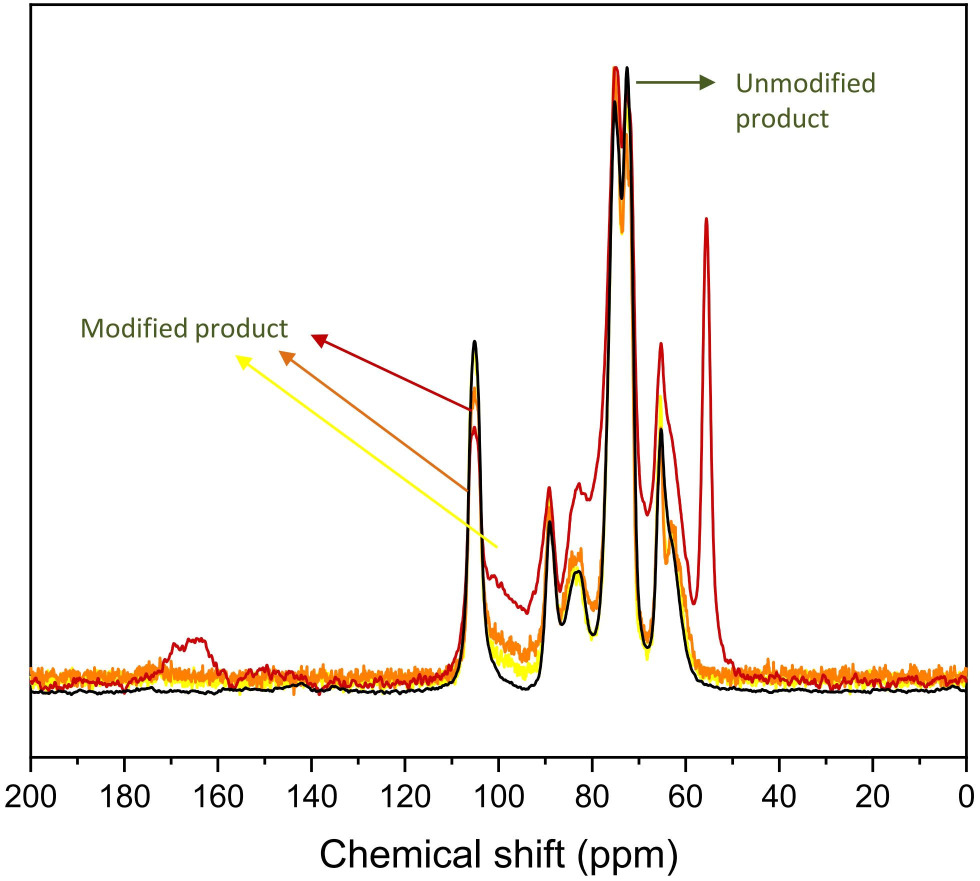
Control of the degree of oxidation

Anionic cellulose: Sulfonation

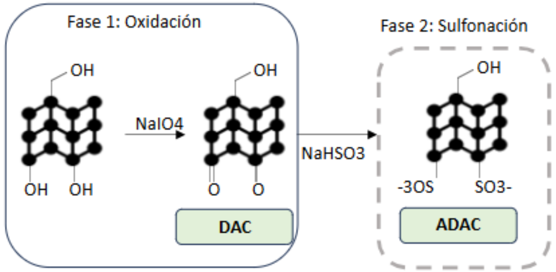


Commercial nanocellulose

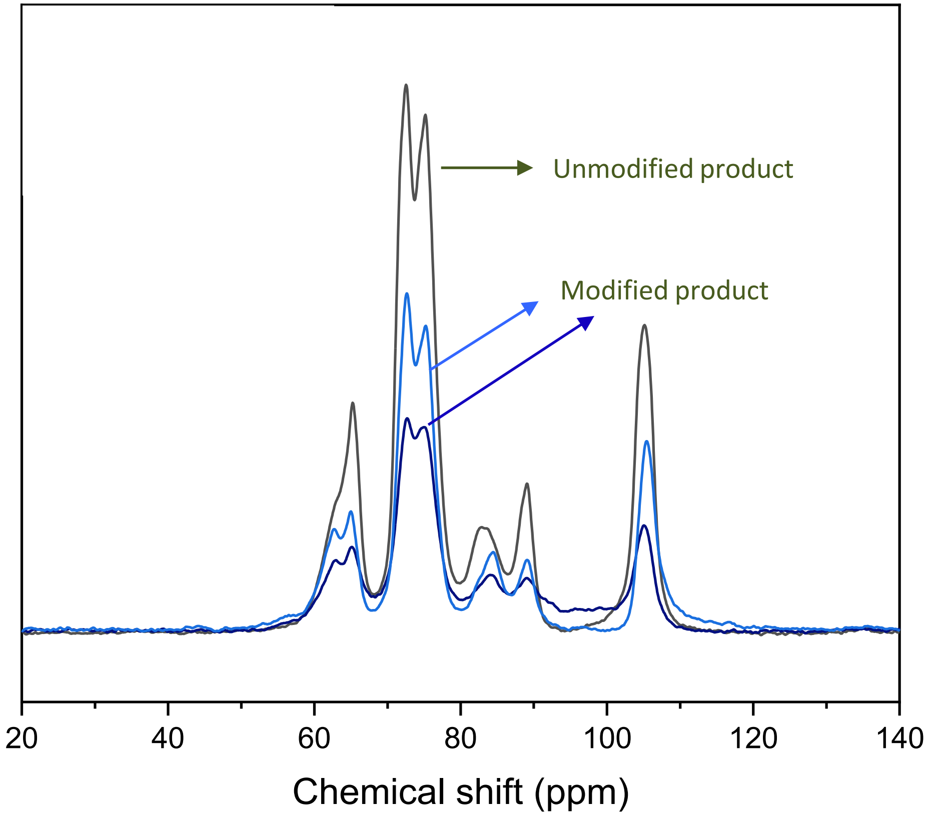


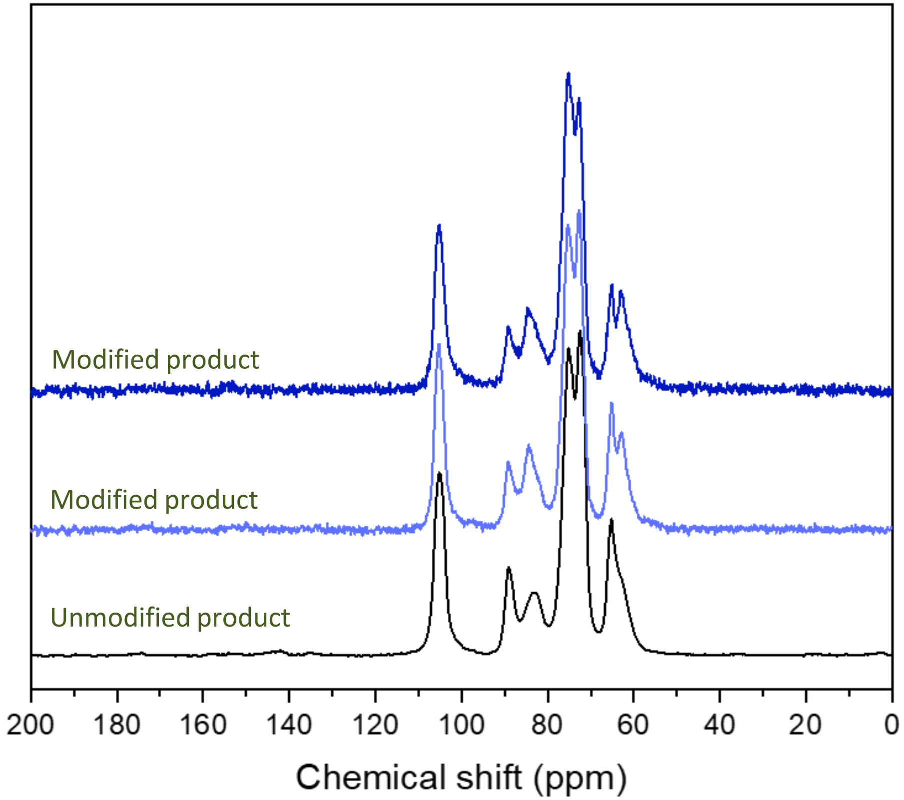


Anionic cellulose: Sulfonation

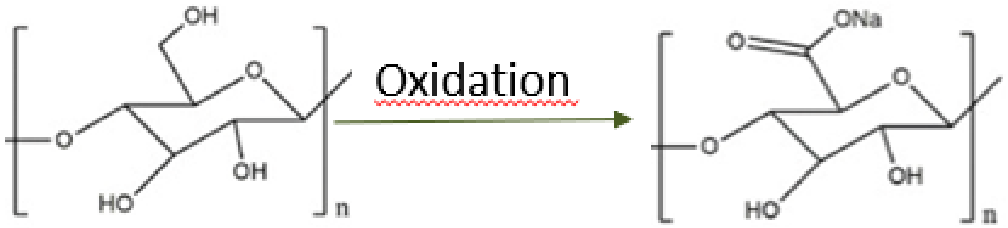


Cereal straw





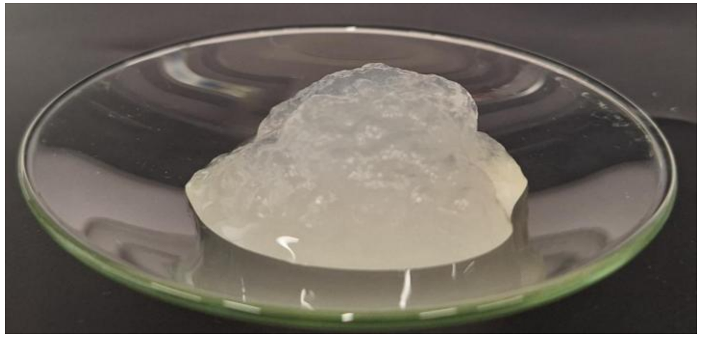
Anionic cellulose: Selective oxidation with ammonium persulfate

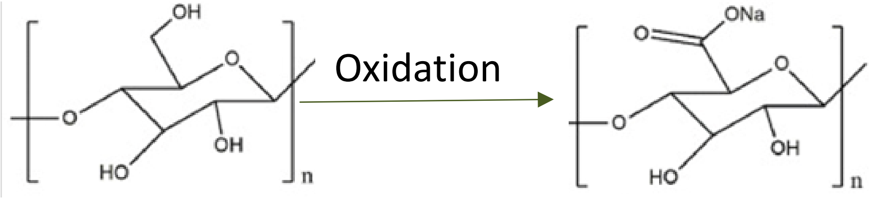


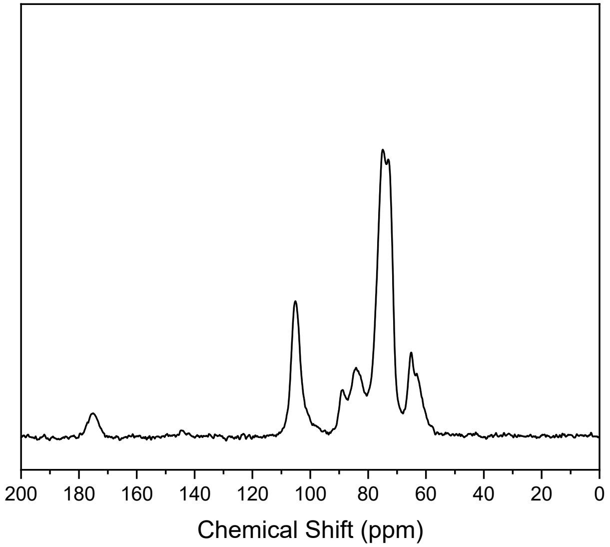
Sample	Bleaching	NaOH treatment
Cereal straw	Yes	
	No	No
	No	Yes
	Yes (Hydrogen peroxide)	No
	Yes (Hydrogen peroxide)	Yes
	Yes (Sodium chlorite)	No

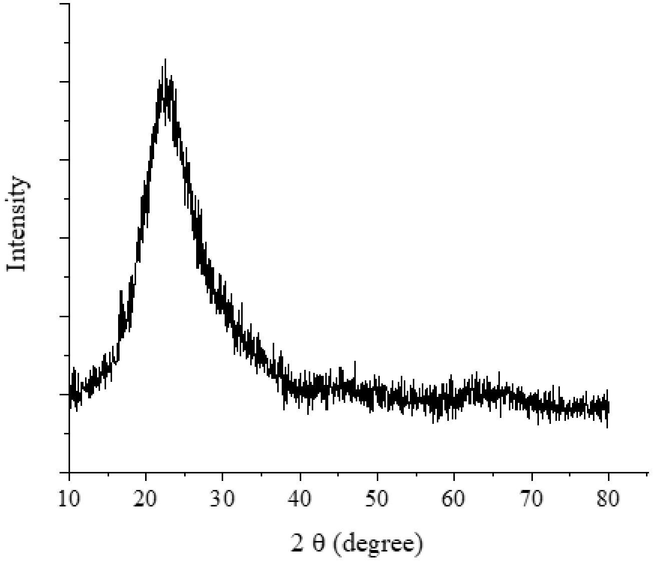
→ The reaction does not work

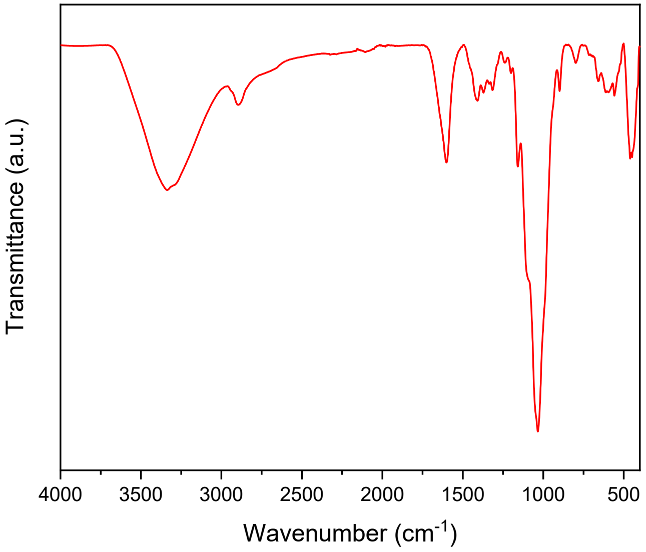
Anionic cellulose: Selective oxidation with TEMPO



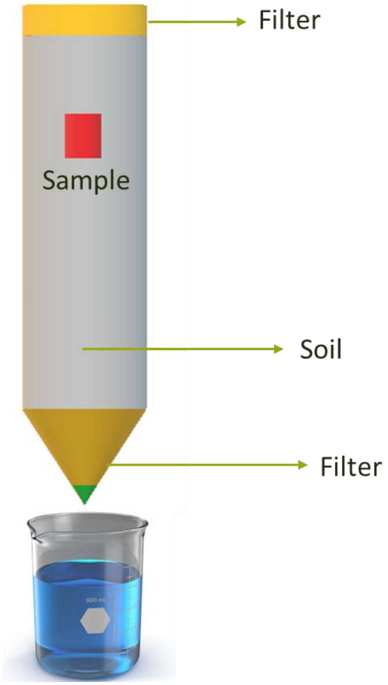








Release fertilizer test: Soil column



Sample	Fertilizer	Characterization technique	Time
Sulfonated nanocellulose	KCl/Urea	• KCl: ICP (plasma atomic emission spectrometry) and conductivity test • MAP: Photometric test and conductivity test • Urea: coloriimetric test	30 days
	Monoammium phosphate (MAP)		
TEMPO oxidized nanocellulose	KCl/Urea		
	Monoammium phosphate (MAP)		

Conclusion

This study outlines a comprehensive approach toward the development of a sustainable fertilizer delivery system using nanocellulose derived from cereal straw. Key steps included:

Raw material selection: use of cereal straw as a renewable, abundant, and low environmental impact resource.

Chemical modification of nanocellulose: identification and application of the most effective strategies to enhance interaction with fertilizer compounds.

Process optimization: definition of optimal reaction conditions using commercial cellulose as a model system during the early development stages.

Evaluation of modifications: selection of the most promising functionalizations based on reaction efficiency and material stability.

Development of advanced matrices: production of aerogels and hydrogels as innovative carriers for controlled nutrient delivery.

Soil release testing: optimization of release experiments to assess system performance, release kinetics, and long-term stability.

Next Presentations

- **Engineering Forest-Derived Biochar as a Nanoplatform for Sustainable Nutrient Delivery in Plants**
  I. Ortiz
- **From Lab to Pilot: Process Design and Scale-Up of Wheat Straw Nanocellulose Production for Fertilizer Delivery Systems**
  A. Somoza, E. Usala, F. Vargas
- **Stakeholder-Aligned Pathways to Impact and Exploitation in Sustainable Agrochemistry**
  J. Beinaroviča

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Join AGRO4AGRI Stakeholders Database

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