Biomass-Derived Flocculants for Wastewater Treatment

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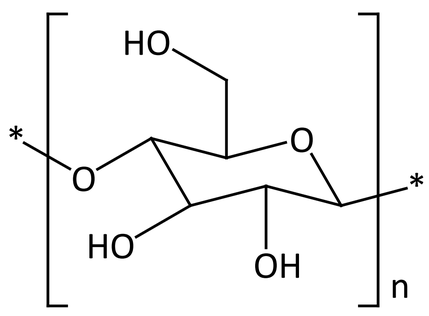
MOTIVATION

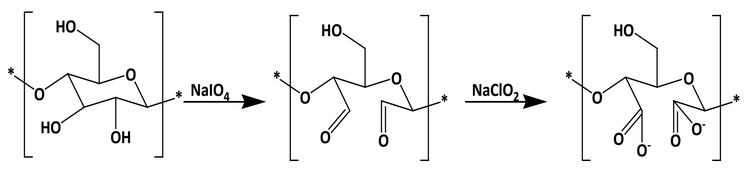
The growing interest in the valorisation of lignocellulosic residues from forestry industries addresses the urgent need for more sustainable solutions in the production of materials and functional agents. The abundance of resources such as Acacia wood, an invasive species in Portugal, presents a dual opportunity: to mitigate its environmental impact while obtaining renewable raw materials for high-value applications. At the same time, the treatment of industrial effluents, especially those containing microplastics and dyes, remains a global challenge. Conventional synthetic flocculants, although effective, raise concerns regarding their toxicity and environmental persistence. In this context, the development of cellulose-based bioflocculants emerges as a green and efficient alternative aligned with the principles of sustainable chemistry and circular economy.

Cellulose

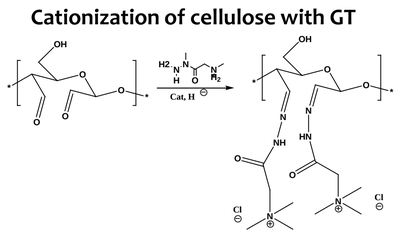


Synthesis routes

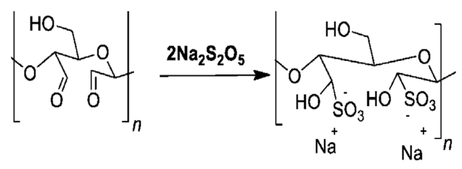
Periodate–chlorite oxidation



Cationization of cellulose with GT

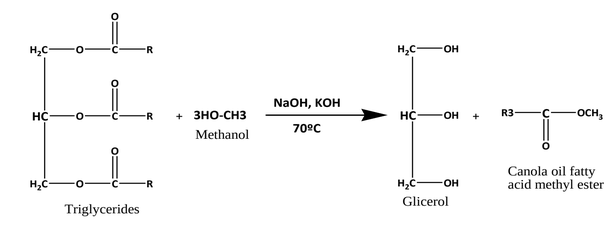


Anionization of cellulose with $Na_2S_2O_3$

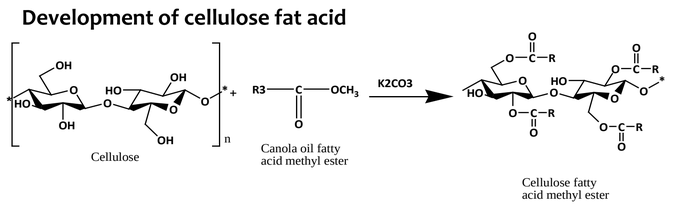


Hydrophobization

Grafting of fat acids

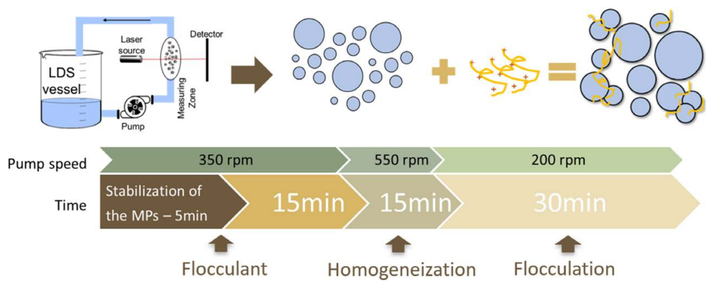


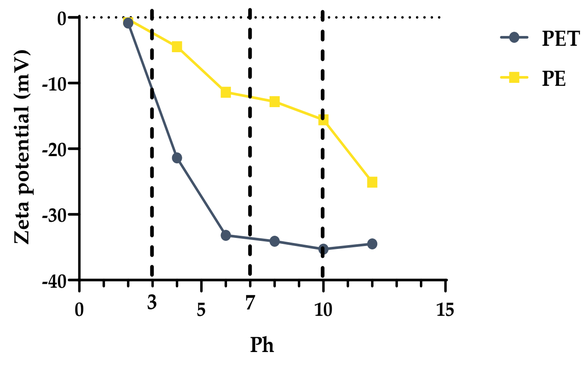
Development of cellulose fat acid



Flocculation Performance

Method

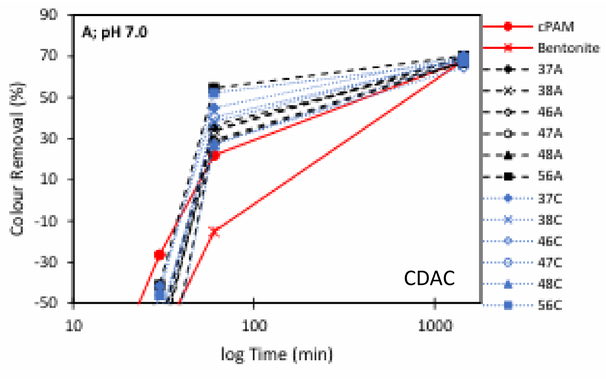


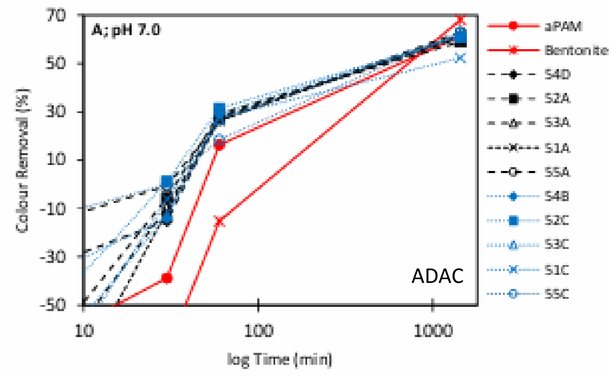


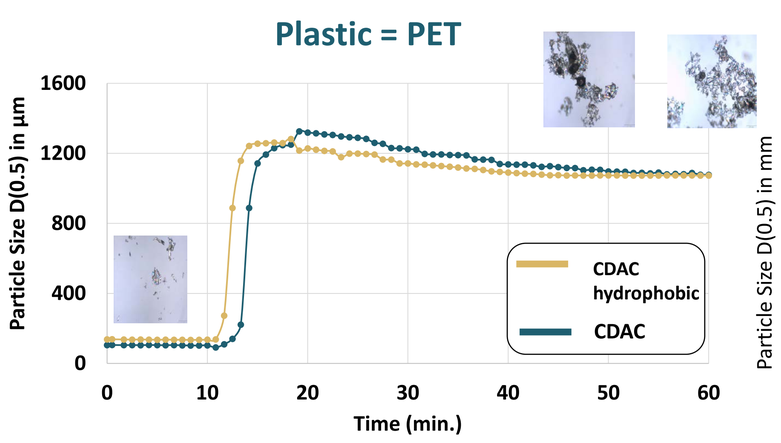
pH	Zeta potential (mV)	
	PET	PE
3	-9.5 (±0.81)	-2.0 (±1.08)
7	-34.2 (±0.69)	-12.5 (±1.12)
10	-35.3 (±1.01)	-15.6 (±0.82)

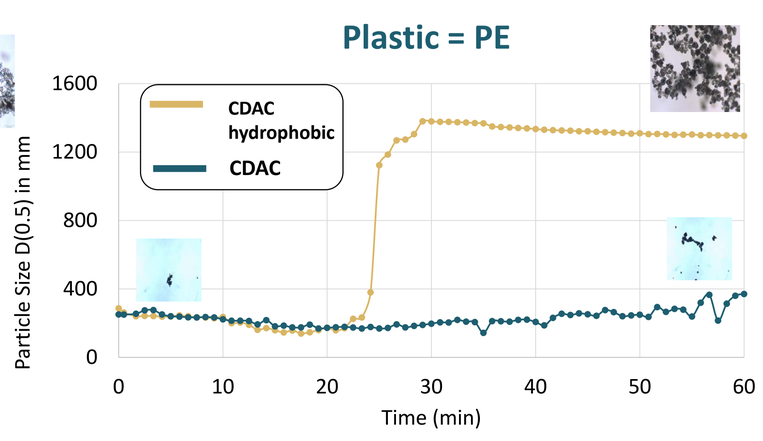
Results

- *Both CDAC and ADAC cellulose-based flocculants significantly outperformed the synthetic references and bentonite, especially over longer settling times;*
- *Initial colour removal was modest for all systems;*
- *CDAC maintained consistent performance across all tested variants;*
- *ADAC also showed strong and similar performance among tested samples;*









- *Hydrophobization is not relevant in the case of PET;*
- *PE flocculation requires hydrophobization of the cellulose;*
- *This behaviour can be correlated with the different charge density of the two plastics;*

Conclusions

Biomass-derived cellulose flocculants demonstrated high efficiency for colour and microplastic removal from industrial effluents, matching or surpassing conventional synthetic agents under several test conditions.
Tailored chemical modifications (cationic and anionic) allowed robust flocculation performance even at neutral pH, where traditional effluents display higher stability.
Both polymer families exhibited rapid colour reduction kinetics and effective charge neutralization, confirming their suitability for eco-friendly wastewater treatment.
These results validate the potential of modified cellulose polymers as sustainable, high-performance alternatives to polyacrylamide-based flocculants, contributing to decreased environmental impact and the utilization of renewable resources.