Resource production in aerobic granular sludge on a simultaneous fill/draw SBR mode under saline stress

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Highlights:

- The osmotic pressure generated by salt did not stimulate EPS production but favored ALE recovery.
- Salt stress in simultaneous fill/draw reactors provides more stability in EPS production.
- The granules formed in a salt pulse were more resistant because they were more tightly aggregated.

Keywords: Aerobic granules; Biological treatment; Saline pulses.

INTRODUCTION

Wastewater treatment plants (WWTPs) are designed to meet standards for releasing treated effluent into water bodies, focusing on reducing environmental pollution. However, in several regions worldwide, many WWTPs have design, construction, and operation deficiencies, resulting in increased costs, reduced efficiency, and the inability to reuse treatment by-products. In this scenario, sustainable WWTPs emerge, are designed, and operated according to the circular economy and sustainable development precepts, considering the economic, social, and environmental dimensions (Jassal et al., 2023). Thus, raw sewage is seen as an input for a production process, generating resources that can be reused, such as biogas, cellulose, bioplastics, phosphate, and other resources with high added value, such as alginate-like exopolymers (ALE).

Given this, some emerging treatment technologies have introduced the precepts of sustainable WWTPs into their schematics and processes, as with Aerobic Granular Sludge (AGS) systems. In these systems, there is the possibility of recovering biopolymers from extracellular polymeric substances (EPS), which are produced during the process of microbial aggregation in stress situations. It has been reported that salt stress can favor resource production (Chen et al., 2024). Furthermore, the reactor configuration is a parameter that also affects the granulation process, and one of the strategies investigated in the literature to favor the granule stability and retain more biomass is simultaneous fill/draw reactors. The filling and discharge phases occur simultaneously in this configuration, followed by the reaction and sedimentation phases. Therefore, this work aims to evaluate the effect of stress caused by adding salt in simultaneous fill/draw reactors in the EPS matrix, which is the basis for reusing resources, such as ALE (the main constituent of EPS). According to Zahra et al. (2022), there is a growing interest on ALE recovery, as it represents more than half of the recovery of high-value-added materials that WWTPs can produce. Furthermore, ALE can be employed in various industrial applications, such as a coating material and biosorbent for dyes and phosphate.

METHODOLOGY

The aerobic granules were cultivated in two similar simultaneous fill/draw SBR systems under the same conditions for 78 days, differing only in salinity: R1, without salt addition; R2, with saline pulses, i.e., the feeding alternated between the control solution and a solution containing 5 g/L of salt. The sedimentation time was reduced by characterizing Phase I (15 min) and Phase II (5 min). Each cycle lasted 6 hours and consisted of anaerobic feeding (20 min), anaerobic reaction (100 min), aerobic reaction (214-224 min), anoxic reaction (10 minutes), sedimentation (15-5 min), and discharge (1 min). The engineering aspects, analytical methods, synthetic effluent composition and inoculum source are described in Frutuoso et al. (2024).

RESULTS AND CONCLUSIONS

In general, confirming the initial hypotheses, the production of proteins (PN) was greater than that of polysaccharides (PS) in both reactors (Figure 1). This condition is desirable in biological reactors, as PN is responsible for aggregating granules and PS for mechanical stabilization (Rollemberg et al., 2018). In the reactor without added salt, a decrease in total EPS production is verified after 20 days of operation, while in the reactor with a salt pulse, stability in EPS production is observed, with slight reductions in EPS throughout the operation. Reducing sedimentation time was essential to intensify EPS production and maintain stability. Furthermore, the adopted reactor configuration provides greater stability of the formed granules by retaining more biomass (Rollemberg et al., 2019). However, at the end of the experiment, there was a noticeable lower EPS production in R2 due to operational problems that caused biomass washout. However, this was not enough for the average EPS production to be lower than R1.

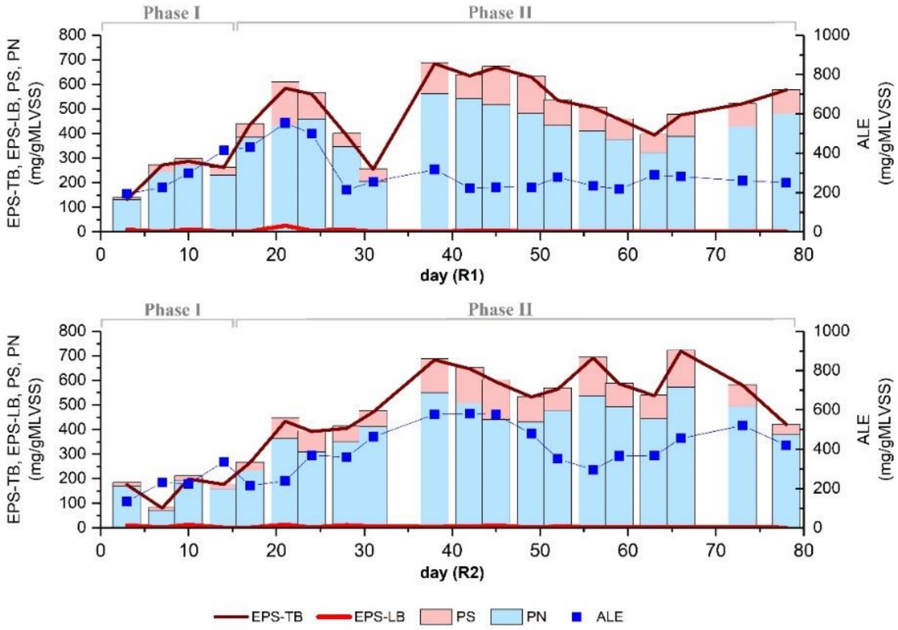

Figure 1 – Average quantification of extracellular polymeric substances (EPS) and alginate (ALE) in reactors.

From statistical analysis, it was not possible to verify significant differences between the two reactors regarding the production of PN, PS, and total EPS throughout each phase. However, the scenario is different when analyzing the EPS-LB and EPS-TB fractions. According to da Silva et al. (2023), EPS produced by aerobic granules have a dynamic double-layer structure, being classified as EPS-LB (loosely bound) and EPS-TB (tightly bound). Both can unite neighboring cells and promote the formation of granules. However, the outermost layer is made up of the EPS-LB bond, which, as the name suggests, has a weaker bond and can be easily broken, unlike the EPS-TB, which are connected consistently and stably. During Phase I, while sedimentation time was high and there was still the presence of poor-quality sludge in the mixed liquor, no statistical differences were found between R1 and R2 with regard to EPS-TB and EPS-LB. For EPS-LB, there were also no significant differences in Phase II. However, in this last phase, it was possible to verify that R2 presented a significantly higher concentration of EPS-TB in its EPS matrix than R1 ($p = 0.04$). This allows us to infer that the granules produced in the salt-supplemented reactor were more strongly linked, i.e., they would present greater resistance to disintegration episodes.

Regarding alginate (ALE) recovery, no statistical difference was observed between R1 and R2 ($p = 0.67$) during Phase I. However, in Phase II, the saline pulse reactor favored ALE recovery and was significantly different from R1 ($p = 0.006$). According to Frutuoso et al. (2024), ALE production is proportional to improved biomass quality and sedimentation characteristics; therefore, reducing sedimentation time was essential to improve these characteristics, and the saline stress in simultaneous fill/draw SBR provided greater system stability.

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