Transforming Agriculture and Industry: Unlocking the Potential of Bivalve Mollusk Byproducts for High-Value Innovations

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Keywords: biostimulant, abiotic stress, amino acids, sustainable agriculture
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Introduction

Annually, Spain discards approximately 25,530 tonnes of mussel byproducts, yet these could be transformed into high-value products such as biostimulants or functional food snacks. This repurpose could lead to a significant reduction in CO2 emissions, potentially decreasing up to 372,000 tonnes annually by reducing the production of mineral fertilizers.

Regarded as a leading region, Spain accounts for 21% of Europe's mussel production, with an output of 255,303 tonnes. However, the industry faces challenges with high rates of byproduct generation and waste, where losses due to shell breakage or small size of the bivalves range between 10% and 50% of total production. Traditionally, these byproducts have been used as compost or fertilizer, but more commonly, they are managed by certified disposal services, incurring an environmental and economic cost of approximately 400€ per tonne—translating to an annual expenditure exceeding 10 million euros for the national mussel sector.

To address these issues, this study has pioneered comprehensive integral valorization strategies of bivalve waste to create new bioproducts that replace fossil-based raw materials, thereby enhancing the bioeconomy. In an innovative approach, mussel meat has been transformed into an amino acid-based biostimulant, providing an alternative to conventional inorganic fertilizers. Moreover, functional food products based on mussels have been developed, offering health benefits in a snack format with unique characteristics.

A groundbreaking sustainable process has been developed using enzymatic hydrolysis to recover protein hydrolysate from mussel waste, resulting in an innovative biostimulant. The biostimulants created are rich in aspartic and glutamic acids, enhancing nutrient absorption and mitigating abiotic stresses in the crops where they are applied. To date, there are no biostimulants based on mussel protein, making the innovation of this product development highly significant.

Currently, there are no studies that have been conducted to transform protein from mussel meat waste into high-value products. Traditionally, only the shells have been utilized. However, this study demonstrates the comprehensive valorization of both the meat and shells of mussels through their transformation into high-value products using sustainable processes.

Results

To develop the biostimulant based on free amino acids, an innovative methodology was initially developed to mechanically separate the mussel shell from the meat. Once the mussel meat is separated, an enzymatic hydrolysis process is carried out in which the conditions have been optimized within the following ranges: pH (4-12), temperature (45-70°C), water ratio (1:4, 1:6, and 1:8), and type of enzyme (endo and exo activities). Additionally, the load of proteolytic enzyme used has been optimized in the range (0.5-2.5%), achieving a mass yield of (74-87%), a protein content of (33-43%), and a free amino acid content of (11.8-26%). Finally, the application of these hydrolysates as biostimulants based on free amino acids has been validated. The efficacy of the obtained protein hydrolysates as a biostimulant has been confirmed to enhance plant growth by more than 60% in the germination of Chinese cabbage seeds at concentrations ranging from 0.07-0.125% as shown in figure.

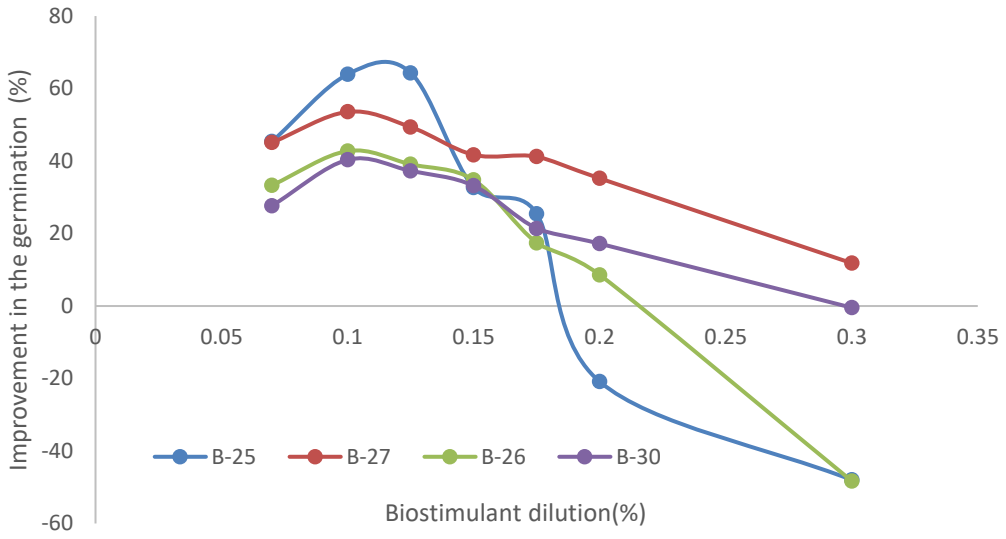

Figure 1. Comparison of the improvement in growth by germination of Chinese cabbage seeds with a hydrolysed product from different hydrolysis conditions.

Through the innovative use of enzymatic hydrolysis, this study successfully transforms mussel meat waste into valuable biostimulants, marking a major shift from traditional valorisation methods to sustainable resource utilization. The production of amino acid-based biostimulants not only offers an effective alternative to inorganic fertilizers, enhancing nutrient absorption and crop growth (over 60% improvement in growth), but also contributes to substantial reductions in CO2 emissions, with an estimated decrease of 372,000 tonnes annually.

Looking forward, this study could expand its impact by exploring additional applications of mussel-derived bioproducts in other sectors, such as cosmetics or pharmaceuticals, where the unique properties of these materials could offer further environmental and economic benefits. Additionally, scaling up production and extending market reach beyond Europe could magnify the environmental benefits and establish a global model for waste valorization in aquaculture. Implementing life cycle assessments to evaluate the overall sustainability of the production chain from waste to product could also provide deeper insights and drive continuous improvement.

References:

Pérez-Aguilar H., Hernández-Fernández C., Aran-Ais F. Protein recovery from animal by-product wastewater rich in protein for application as biostimulant in agriculture. Journal of Water Process Engineering, 2024, 66, 106120.

Pérez-Aguilar H., Lacruz-Asaro M., Arán-Ais F. Protein recovery of wastewater and animal by-products from the rendering and tanning industries for application as biostimulant in agriculture. Sustainable Chemistry and Pharmacy 38 (2024) 101434.

Pérez-Aguilar H., Lacruz-Asaro M., Arán-Ais F. Bioprocess to valorise fleshing produced in the tanning industry. Environ Sci Pollut Res (2023).

Pérez-Aguilar H, Lacruz-Asaro M, Arán-Ais F. Evaluation of Biostimulants Based on Recovered Protein Hydrolysates from Animal By-products as Plant Growth Enhancers. J Plant Sci Phytopathol. 2023; 7: 042-047.

Pérez-Aguilar H., Lacruz-Asaro M., Ruzafa-Silvestre C., Arán-Ais F. Protein recovery from wastewater animal processing by-products of rendering plants for biostimulant applications in agriculture. Sustainable Chemistry and Pharmacy 32 (2023) 101009.

Pérez-Aguilar H., Lacruz-Asaro M., Arán-Ais F. Towards a circular bioeconomy: High added value protein recovery and recycling from animal processing by-products. Sustainable Chemistry and Pharmacy, 2022, 28, 100667.