

Circular Economy in Food Industry Waste Management (BIVALIA Workshop2 - 2026)

Editors: Elena Díaz Nieto; Francisco Heras Muñoz; Juan Antonio Melero Hernández; Manuel Gertrudix
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C. Álvarez^{1*}, M.P. García-Aparicio¹, A. González¹, A.D. Moreno¹, M.J. Negro¹

1: Advanced Biofuels and Bioproducts Unit, Energy Department, CIEMAT, Madrid, Spain

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P.I.4 — Sequential enzymatic and hydrothermal fractionation of brewer's spent grain for selective prebiotic XOS production

C. Álvarez^{1*}, M.P. García-Aparicio¹, A. González¹, A.D. Moreno¹, M.J. Negro¹

¹ Advanced Biofuels and Bioproducts Unit, Energy Department, CIEMAT, Madrid, Spain

*Correspondence: cristina.alvarez@ciemat.es

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The growing interest in functional food ingredients has intensified the search for sustainable sources of prebiotic xylooligosaccharides (XOS) with a low degree of polymerization (DP2–DP5). These compounds are particularly attractive due to their selective stimulation of beneficial gut microorganisms and their associated health benefits [1]. Yet, producing these compounds efficiently remains challenging, especially when working with complex lignocellulosic residues. Among agro-industrial residues, brewer's spent grain (BSG) is one of the most relevant. It accounts for approximately 85% of the total solid waste generated during beer production [2]—specifically during the mashing stage—and represents an abundant but underexploited feedstock. Although rich in hemicellulose, proteins, and phenolic compounds, its heterogeneous composition often limits its direct conversion into high-value fractions.

This study addresses these limitations by implementing a two-stage valorisation strategy designed to enhance BSG processability and maximise the selective release of XOS. First, a tailored enzymatic sequence—combining amylase, glucoamylase, and protease—was applied to remove starch and proteins, mitigating issues such as gel formation and Maillard-type reactions during thermal processing, and also allowing for the recovery of the protein. This step substantially increased the relative xylan content of the solid residue, creating a more suitable substrate for subsequent fractionation. The pretreated biomass was then subjected to liquid hot water processing at 185 °C, a catalyst-free approach that promotes controlled solubilisation and depolymerisation of arabinoxylans.

The integrated process yielded 13.8 g/L of XOS, corresponding to 8.7 g per 100 g of dry BSG, with nearly half of the recovered oligosaccharides falling within the low-DP range associated with enhanced prebiotic functionality. Degradation products remained minimal, highlighting the selectivity of the method. Beyond XOS, the process generated additional streams of biotechnological interest, including protein- and sugar-rich liquors and a cellulose-enriched solid fraction with improved digestibility.

Overall, this work demonstrates that BSG can be transformed from a low-value residue into a versatile feedstock for producing high-quality prebiotic ingredients, reinforcing its role within advanced biorefinery and circular-economy strategies.

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References

- [1]. R. Hutkins, J. Walter, G. R. Gibson, C. Bedu-Ferrari, K. Scott, D. J. Tancredi, A. Wijeyesekera, and M. E. Sanders, "Classifying compounds as prebiotics – scientific perspectives and recommendations," *Nature Reviews Gastroenterology & Hepatology*, pp. 54–70, 2025. <https://doi.org/10.1038/s41575-024-00981-6>
- [2] A. Zeko-Pivač, M. Tišma, P. Žnidaršič-Plazl, B. Kulisic, G. Sakellaris, J. Hao, and M. Planinić, "The Potential of Brewer's Spent Grain in the Circular Bioeconomy: State of the Art and Future Perspectives," *Frontiers in Bioengineering and Biotechnology*, vol. 10, art. no. 870744, 2022. <https://doi.org/10.3389/fbioe.2022.870744>