7th International Conference
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FUNCHAL, MADEIRA - VIDAMAR HOTEL
3 — 5 SEPTEMBER 2025

CIRCULAR ECONOMY SYNERGIES: LEVERAGING AGRIFOOD WASTE FOR SUSTAINABLE SHOE MATERIALS

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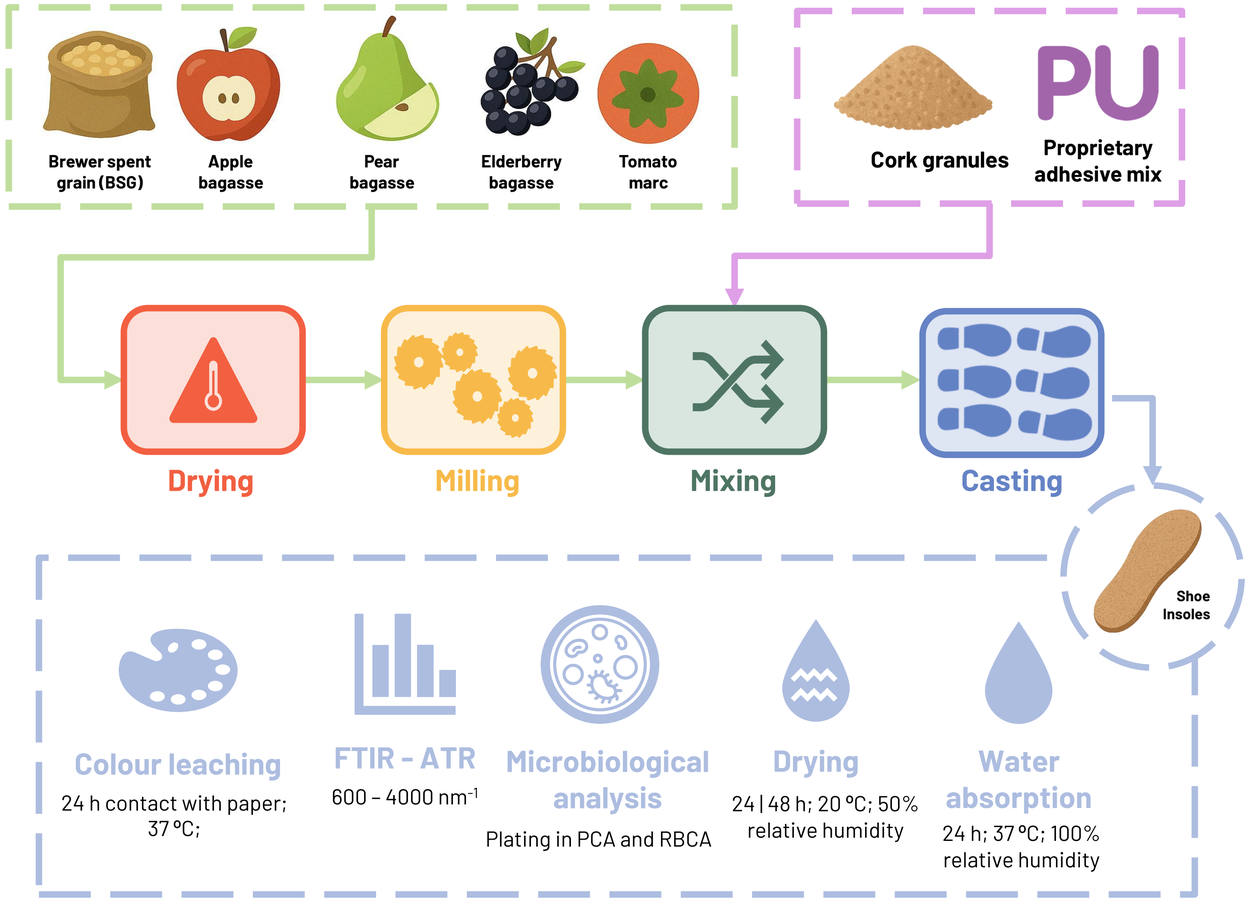
Introduction

The shoe industry needs more sustainable practices to reduce its environmental impact not only in terms of processes and generated waste but also in its dependence on virgin raw materials. To address the last, there is an unconventional synergy that can prove to be disruptive. A synergy with the agrifood sector. While cascading use and food first principles mean that priority should be given to food and feed applications, there are several wastes generated by this sector that are not suitable for either application, and these are the ones that could be of particular interest for use to reduce raw material dependence by the shoe industry. Cork is a sustainable material commonly used in the footwear sector due to its lightweight, cushioning, and thermal insulating properties. However, there is increasing interest in enhancing it by incorporating additional materials derived from industrial byproducts. Beyond sustainability benefits, these modifications can potentially improve moisture absorption, alter microbial survival, and aesthetic design features, making them ideal for shoe insoles and similar applications where comfort and hygiene are critical. Thus, this study explores the potential of incorporating diverse industrial byproducts into cork-based shoe materials to improve both functional and design aspects, contributing to sustainability strategies within the footwear industry.

Materials & Methods



Results

Microbiological analysis

Table 1. Microbiological load of the different composites expressed in log CFU/g composite

		Time (days)				
		0	15	30	60	90
Control	Yeasts & Molds	nd	nd	nd	nd	nd
	Total Mesophiles	nd	nd	nd	nd	nd
Tomato marc	Yeasts & Molds	nd	nd	nd	nd	nd
	Total Mesophiles	4.82 ± 0.04	4.83 ± 0.02	4.94 ± 0.03	5.00 ± 0.02	5.04 ± 0.05
Elderberry pomace	Yeasts & Molds	nd	nd	nd	nd	nd
	Total Mesophiles	nd	nd	nd	nd	nd
BSG	Yeasts & Molds	nd	nd	nd	nd	nd
	Total Mesophiles	nd	nd	nd	4.50 ± 0.03	4.53 ± 0.03
Pear pomace	Yeasts & Molds	nd	nd	nd	nd	nd
	Total Mesophiles	nd	nd	nd	nd	nd
Apple pomace	Yeasts & Molds	nd	nd	nd	nd	nd
	Total Mesophiles	nd	nd	nd	nd	nd

nd, not detected

Colour leaching

Figure 1. Photograph of white paper squares after 24 hours of incubation in contact with the different composites under a moistened cotton layer. a) control composite; b) composite containing elderberry bagasse; c) composite containing tomato marc; d) composite containing BSG; e) composite containing pear bagasse; f) composite containing apple bagasse.

Water absorption

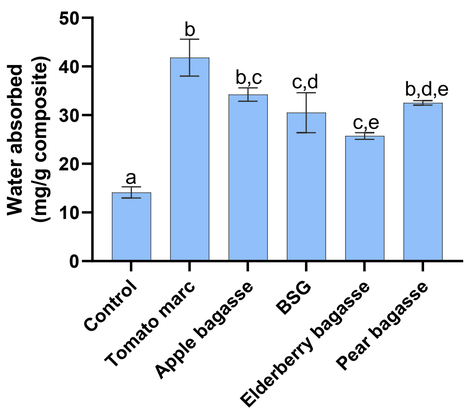


Figure 2. Average amount of water absorbed by cork composite cubes with incorporated by-products, after 24 h of exposure to an atmosphere with 100% relative humidity at a temperature of 37 ° C. Different letters indicate statistically significant differences ($p < 0.05$ One-Way ANOVA + Turkey's post-hoc test).

Drying

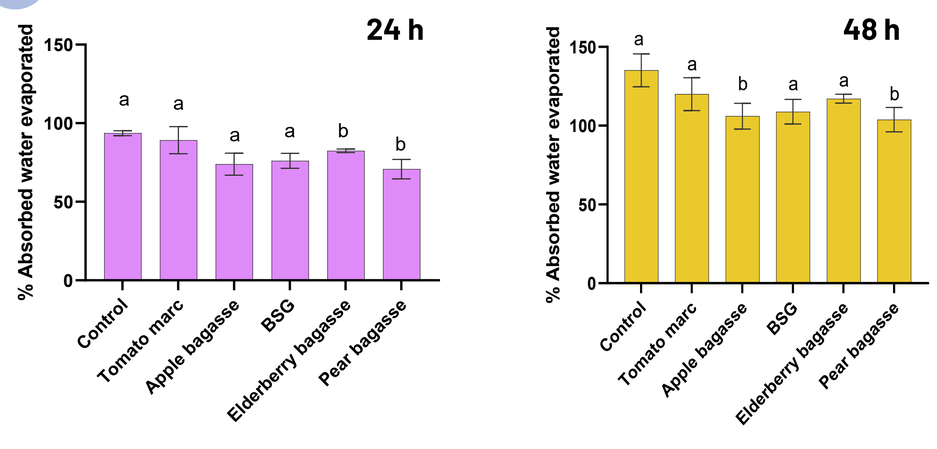


Figure 3. Percentage of absorbed water lost by cork composite cubes with incorporated by-products, after 24 h of exposure to an atmosphere with 50% relative humidity at a temperature of 20 ° C. Different letters indicate statistically significant differences ($p < 0.05$ One-Way ANOVA + Turkey's post-hoc test).

Figure 4. Percentage of absorbed water lost by cork composite cubes with incorporated by-products, after 48 h of exposure to an atmosphere with 50% relative humidity at a temperature of 20 ° C. Different letters indicate statistically significant differences ($p < 0.05$ One-Way ANOVA + Turkey's post-hoc test).

FTIR - ATR

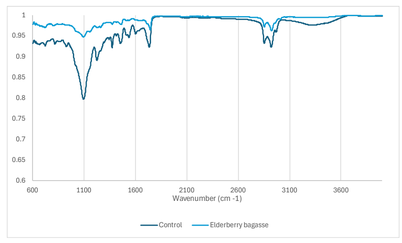


Figure 5. FTIR-ATR spectra of the control composite and the composite containing elderberry bagasse.

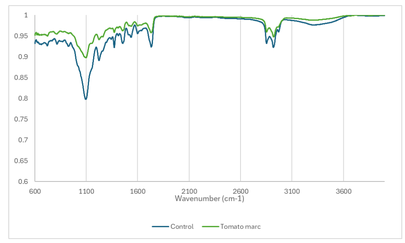


Figure 6. FTIR-ATR spectra of the control composite and the composite containing tomato marc.

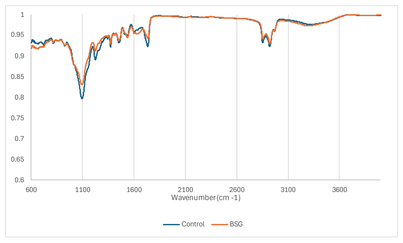


Figure 7. FTIR-ATR spectra of the control composite and the composite containing BSG.

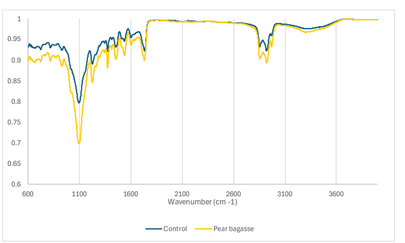


Figure 8. FTIR-ATR spectra of the control composite and the composite containing pear bagasse.

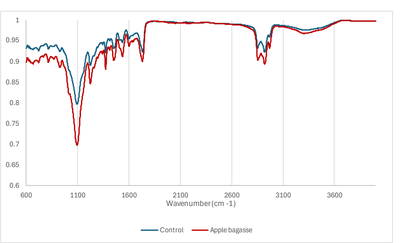


Figure 9. FTIR-ATR spectra of the control composite and the composite containing apple bagasse.

Major conclusions

- **Feasible** | Byproduct incorporation into cork composites was technically viable.
- **Water behaviour** | All composites absorbed more water and most exhibited drying behaviours statistically similar to the control.
- **Chemical interactions** | Elderberry bagasse was the most disruptive; tomato marc, BSG, and apple bagasse exhibited spectra similar to the control.
- **Microbiological stability** | Most materials remained stable for 90 d incubation.
- **Colour leaching** | Composites containing apple bagasse exhibited similar leaching to the control. Other composites exhibited less colour transference.

Acknowledgments

This work was supported by National Funds from FCT - Fundação para a Ciência e a Tecnologia (project UIDB/50016/2020), by project BioShoes4All (project 2375 call 02-C12-i01.01-2022.P1 co-financed by component 12 – Promotion of a Sustainable Bioeconomy, integrated in the Climate Transition Dimension of the Recovery and Resilience Plan within the scope of the Recovery and Resilience Mechanism (MRR) of the European Union (EU), framed in the Next Generation EU.

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