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DESIGNING AND 3D PRINTING FOOD PRODUCTS FUNCTIONALIZED WITH BIOACTIVE COMPOUNDS OBTAINED FROM APPLE POMACE THROUGH THE APPLICATION OF NOVEL TECHNOLOGIES

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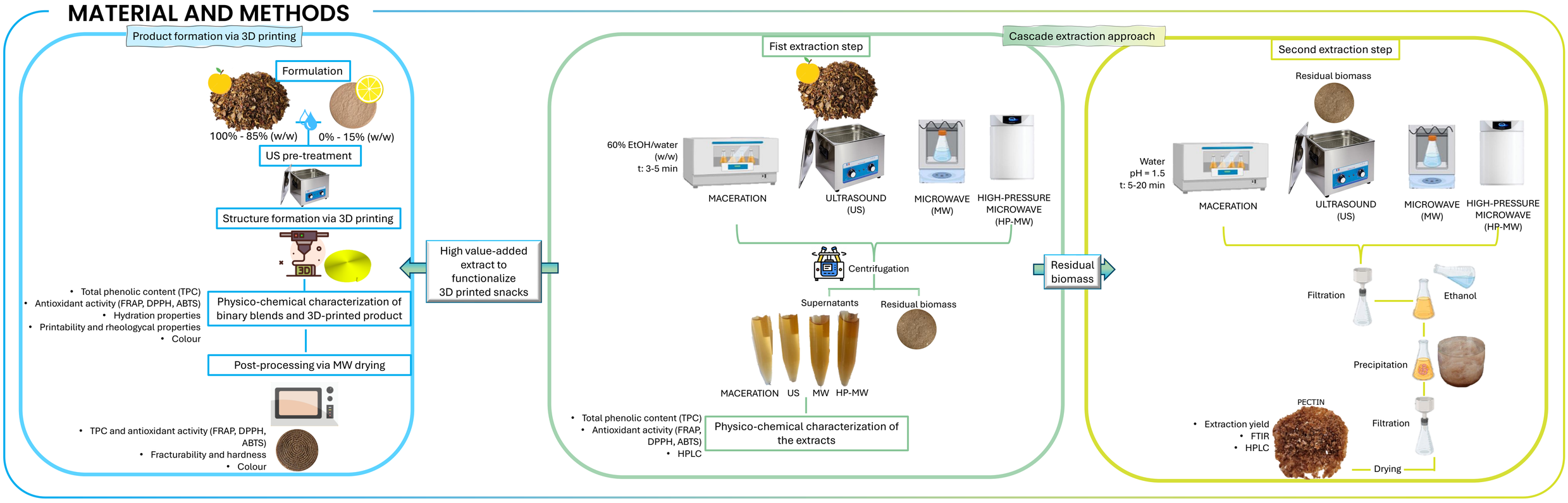
SPOKE, WP AND TASKS

SPOKE 8: New models of circular economy in agriculture through the recovery and recycling of waste.
WP 8.1: Producing new products to upgrade waste value.
TASK T8.1.1: Valorization of the waste by green chemistry to obtain high value molecules or new products.
TASK T8.1.3: Valorization of the waste to obtain biomaterials.

INTRODUCTION AND AIM OF THE WORK

Using natural sources, like agrifood residues, to create high-value products can meet the growing consumers' demand for eco-friendly options. Residues from agrifood industry represent an environmental burden and an opportunity to contribute to the economic and social benefit, because still rich in valuable compounds, which can be efficiently valorized if adequately recovered [1]. Extraction processes assisted by US, MW and HP-MW are novel processes with the potential to unlock plant intracellular active compounds and modulate functional and physical characteristics [2,3]. Nevertheless, although great advances have been made in terms of extraction and formulation of bioactives from agrifood by-products, there is a lack of proof of concept for their final application in food products. Among digital technologies, 3D printing has rapidly gained attention as a promising strategy for developing personalized, healthy foods as nutraceutical carriers, with novel design, low costs, and targeted health-benefits [4,5]. The direct trapping of extracts with complex composition, recovered from agri-food residues, as not yet studied, can be expected to be challenging.
This study aimed to develop 3D-printed snacks using apple pomace and lemon albedo flours, pre-treated with ultrasound (US). The obtained snack was, then, functionalized by adding the extract richest in bioactive compounds recovered from apple pomace (1% dw) via US, microwave (MW) and high-pressure-MW (HP-MW) extraction processes. Via a cascade approach, the same technologies were applied to recover pectin from the residue derived from the first extraction step. The effect of US pre-treatment and the functionalization of the snack on the techno-functional properties of the binary blends and the final product was assessed in terms of color, texture and rheology, total phenolic content and antioxidant activity.

MATERIAL AND METHODS



RESULTS

Fist extraction step

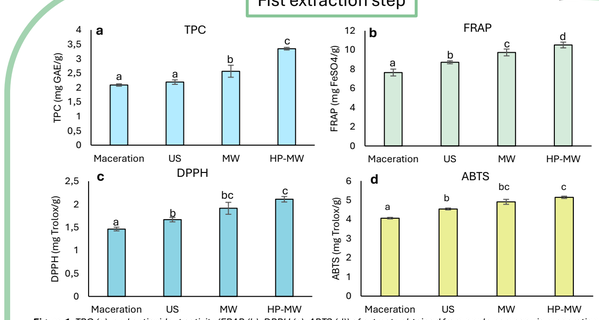


Figure 1. *TPC (a), and antioxidant activity (FRAP (b), DPPH (c), ABTS (d)) of extracts obtained from apple pomace via maceration, US, MW, and HP-MW.*

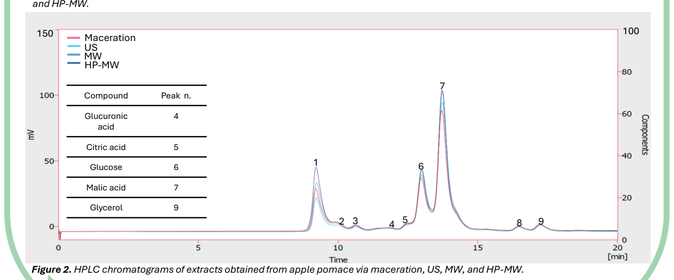


Figure 2. *HPLC chromatograms of extracts obtained from apple pomace via maceration, US, MW, and HP-MW.*

- HP-MW was the most efficient technology in recovering phenolic compounds from apple pomace. It induced an increase in TPC and antioxidant activity of 40% on average compared to maceration.

Cascade extraction approach

Second extraction step

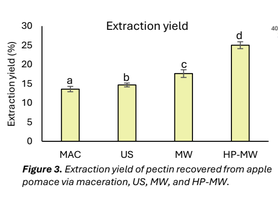


Figure 3. *Extraction yield of pectin recovered from apple pomace via maceration, US, MW, and HP-MW.*

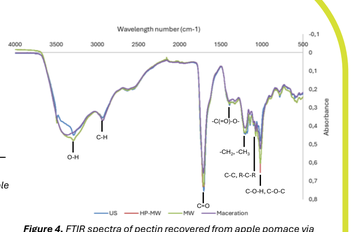


Figure 4. *FTIR spectra of pectin recovered from apple pomace via maceration, US, MW, and HP-MW.*

- FTIR spectra of the obtained pectin was consistent with the FTIR spectra of commercial pectin from apple.
- Differences in intensity were observed. A higher absorption peak indicates a higher concentration of the corresponding functional group or bond.

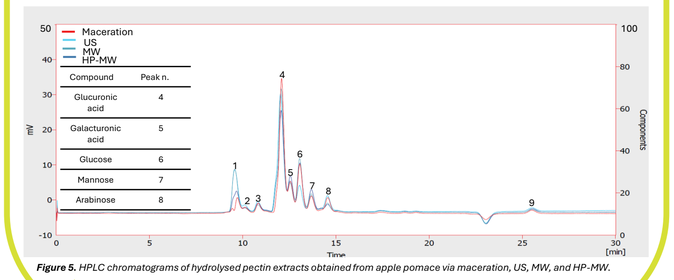


Figure 5. *HPLC chromatograms of hydrolysed pectin extracts obtained from apple pomace via maceration, US, MW, and HP-MW.*

- Glucuronic acid was the predominant compound identified in the pectin hydrolysate.

Product formation via 3D printing

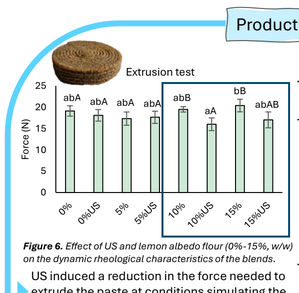


Figure 6. *Effect of US and lemon albedo flour (0%-15%, w/w) on the dynamic rheological characteristics of the blends.*

- US induced a reduction in the force needed to extrude the paste at conditions simulating the 3D printing process, improving its printability.

Table 1. *Effect of US and lemon albedo flour (0%-15%, w/w) on the dynamic rheological characteristics of the blends.*

Albedo flour (%) Factor 1	US Factor 2	G' (Pa)		G''(Pa)		tan (δ)		τ_{max} (Pa)	
0%	0	2340,2	aA	672,04	aA	0,294	aAB	120,29	aC
	1	3036,8	bA	1155,4	aA	0,399	aB	240,11	aA
5%	0	6884,8	aB	2410,5	aB	0,365	aB	549	aA
	1	6553,9	aB	2353,2	aB	0,375	aB	455,56	aA
10%	0	11020	aBC	3889,9	aC	0,368	aA	1700,60	aB
	1	16662	bD	6029	bD	0,378	aB	1782,11	aC
15%	0	8866,2	aC	3162,8	aBC	0,372	bA	1264,61	aB
	1	13451	bC	3719,1	aC	0,284	aA	1312,98	aB
100%	0	22269	bD	5908	bD	0,272	aA	2280,12	bC
	1	18909	aD	4839,8	aC	0,261	aA	2052,65	aD
Factor 1		***		***		***		***	
Factor 2		***		*		ns		ns	
Factor 1X2		***		***		***		ns	

- US improved τmax values, elastic and viscous moduli of the blends.

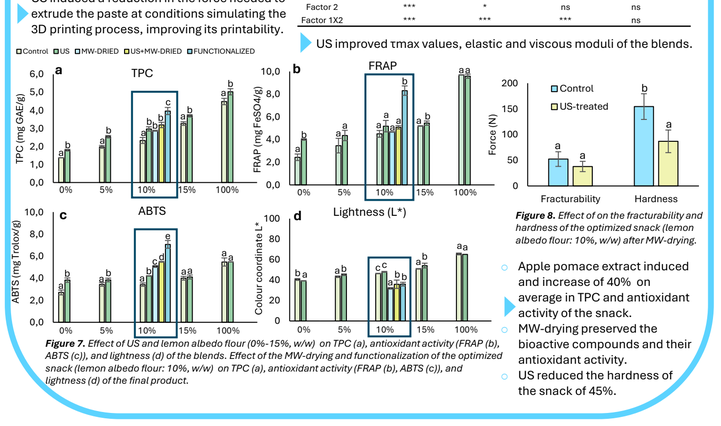


Figure 7. *Effect of US and lemon albedo flour (0%-15%, w/w) on TPC (a), antioxidant activity (FRAP (b), ABTS (c)), and lightness (d) of the blends. Effect of the MW-drying and functionalization of the optimized snack (lemon albedo flour: 10%, w/w) on TPC (a), antioxidant activity (FRAP (b), ABTS (c)), and lightness (d) of the final product.*

Figure 8. *Effect of on the fracturability and hardness of the optimized snack (lemon albedo flour: 10%, w/w) after MW-drying.*

- Apple pomace extract induced and increase of 40% on average in TPC and antioxidant activity of the snack.
- MW-drying preserved the bioactive compounds and their antioxidant activity.
- US reduced the hardness of the snack of 45%.

- US pre-treatment improved the texture and rheological properties of the blends.
- The 3D-printed snack formulated with 10% lemon albedo flour showed the best techno-functional characteristics.
- The addition of apple pomace extract, obtained via HP-MW, to the formulation induced a significant increase in TPC and antioxidant activity of the snack.

CONCLUSIONS
FUTURE PERSPECTIVES

- Consumers' acceptability via sensory analysis.
- In vitro digestibility of the 3D printed snack.
- Further characterization of the pectin to identify potential applications.
- Potential assessment for scaling up the process.

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