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Valorisation of Spent Coffee Grounds for Double Emulsion-based Oil Preservation

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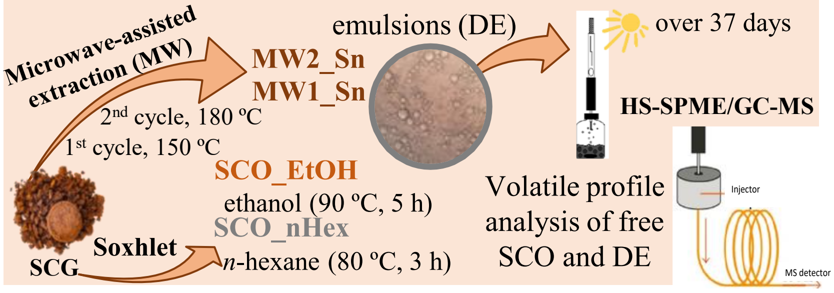
Introduction

Coffee industry generates substantial amounts of spent coffee grounds (SCG), a largely underutilized byproduct with promising potential for sustainable applications. This study explores the usage of SCG to produce double emulsions (DEs), for edible oil protection against oxidation, following the circular economy principles.

Materials/Methods



Results/Discussion

1. Yield and characterization of the recovered SCO

Table 1. Oil extraction yield, esterified fatty acids profile, density, total phenolics (TPC) and antioxidant potential (IC_{50}) of SCO recovered by Soxhlet with *n*-hexane and ethanol.

		SCO_nHex	SCO_EtOH
Yield (%)		13.2 ± 0.5	9.9 ± 0.7
Fatty acids (mol%)			
Palmitic	C16:0	37.6 ± 2.5	40.2 ± 5.0
Stearic	C18:0	6.8 ± 0.1	6.6 ± 0.1
Oleic	C18:1	10.3 ± 0.1	10.0 ± 1.5
Linoleic	C18:2	42.5 ± 2.3	41.2 ± 3.0
Linolenic	C18:3	1.3 ± 0.0	1.5 ± 0.0
Arachidic	C20:0	1.5 ± 0.0	0.5 ± 0.0
Density (g/mL, 25 ºC)		0.88 ± 0.1	0.89 ± 0.1
TPC (mg GAE/g SCO)		10.0 ± 0.5	49.8 ± 1.2
IC_{50} (mg TOC/g SCO)		360.0 ± 0.7	80.1 ± 0.1

Similar yield and triacylglycerides profile was obtained for both SCO, with **higher phenolics and antioxidant potential in SCO_EtOH**.

2. Yield and characterization of MW extracts

Table 2. Yield, carbohydrate content and profile and protein, caffeine and CGA contents of SCG and corresponding MW water-soluble extracts (Sn) obtained after MW at 150 ºC (MW1) and 180 ºC (MW2).

	SCG	MW1_Sn	MW2_Sn
Yield of extraction (%, w/w)*	-	16.5 ± 0.5	24.5 ± 3.5
Carbohydrates content (%, w/w)*	71.3	69.5	80.4
Monosaccharide composition (mol%)			
Ara	6.1	14.3	9.1
Man	47.2	36.5	36.6
Gal	19.3	48.6	54.3
Glc	18.5	-	-
Protein (%, w/w)*	12.5	13.0	12.0
Caffeine (% w/w)*	n.d.	1.6	0.7
CGA (mgCGA/g)*	n.d.	32.6	1.6
MBI	n.d.	0.00235	0.00528

MW-derived extracts showed similar galactomannan/arabinogalactan-rich profiles and protein levels, with MW1_Sn having more chlorogenic acids.

3. W/O/W double emulsions characterization

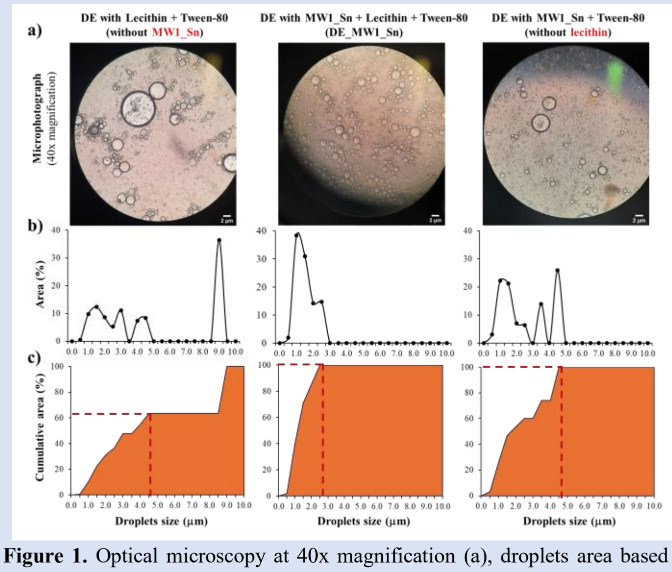


Figure 1. Optical microscopy at 40x magnification (a), droplets area based on their individual length (b), and cumulative area (c) for W/O/W double emulsions: only surfactants (left); DE_MW1_Sn (middle), and MW1_Sn + Tween-80 (right). Dashed lines indicate predominant droplet size.

DE_MW1_Sn yielded emulsions with higher droplet density and a more uniform and small size distribution, with **100% of droplets below 3 µm**, contrasting with irregular sizes and distribution when extract or surfactants were not present. The same for DE_MW2_Sn, although initial phase separation (not shown).

4. Release of SCO volatiles from W/O/W emulsions

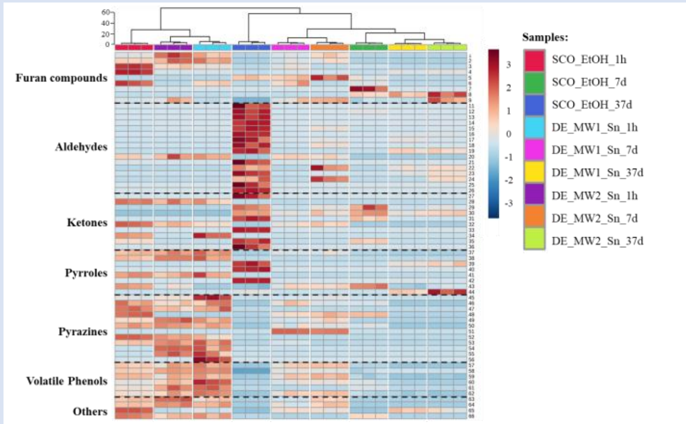


Figure 2. Heatmap representation of the 66 volatiles of SCO_EtOH, DE_MW1_Sn, and DE_MW2_Sn after 1h, 7 days, and 37 days of sunlight exposure. Relative content of each compound is illustrated through a chromatic scale (from dark blue, low values, to dark red, high values).

Emulsions protected SCO volatiles and limited oxidation products release over time.

Conclusion/Perspectives

This study demonstrates the feasibility of using SCG for double emulsions preparation, offering a sustainable method for edible oil preservation. This approach not only valorises coffee byproducts but also enhances the sensory quality of oil-based products. Future work may explore the application of this process in food formulations.

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