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Exploring simple and industrially viable methods for extracting oil from spent coffee grounds: evaluation of extracts' properties with economic feasibility analysis

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INTRODUCTION

- Spent coffee grounds (SCG), an abundant byproduct of instant coffee manufacturing and food service operations, represent a largely untapped resource rich in bio-actives and lipids [1].
- Despite their potential for valorization, SCG are primarily discarded as organic waste. Currently, only few high-value applications for SCG, including oil extraction, are applied industrially.

AIM

- To investigate low cost and low complexity oil extraction techniques realistically adoptable by industry, and to evaluate them in terms of oil yield and quality.
- To assess SCG oil extraction process feasibility at the industrial scale.

EXPERIMENTAL PLAN

SCG collection from coffee bars

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Drying 75 °C for 24 h

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Extraction with isooctane

- MHE: 20°C, 0.1 MPa, 5-15 min, high-speed stirring
- ASE: 105°C, 10.3 MPa, 6-12 min
- Soxhlet-hexane based as a reference

Determinations: Oil yield (gravimetric), fatty acids and sterols (GC-MS, GC-FID-MS), diterpenes contents (HPLC), antioxidant activity (DPPH), and oxidative status (peroxide value), thermal behavior (DSC).

Cost estimation: For small-and large-scale SCG oil production, based on initial investment, annual and daily fixed costs, hourly operating costs.

RESULTS

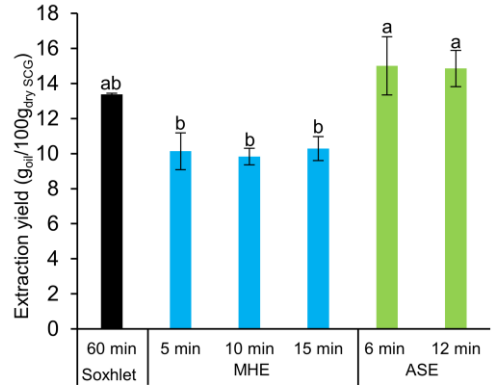

Figure 1: SCG oil yield

- Soxhlet and ASE exhibited the highest oil yield, indicating superior efficiency compared to MHE.

Table 1: Chemical composition and melting temperature of SCG oil

Extraction method and time (min)		Fatty acids: Saturated (g/kg oil)	Fatty acids: Unsaturated (g/kg oil)	Sterols (g/kg oil)	Diterpenes (g/kg oil)	Melting peak (°C)
Soxhlet	60	350.6 ± 0.2^{ab}	400.6 ± 5.2^{ab}	8.2 ± 0.1^{a}	23.2 ± 0.9^{c}	3.2 ± 0.04^{a}
MHE	5	392.9 ± 49.8^{a}	432.5 ± 54.0^{a}	8.7 ± 0.1^{a}	21.08 ± 2^{c}	3.2 ± 0.3^{a}
	10	416.9 ± 15.9^{a}	459.1 ± 16.3^{a}	8.5 ± 0.2^{a}	22.8 ± 1.8^{c}	2.9 ± 0.1^{a}
	15	394.4 ± 73.8^{a}	439.1 ± 82.7^{a}	8.4 ± 0.2^{a}	28.8 ± 0.9^{b}	3.1 ± 0.2^{a}
ASE	6	398.9 ± 5.8^{a}	440.0 ± 7.1^{a}	8.2 ± 0.2^{a}	33.9 ± 1.6^{a}	3.1 ± 0.1^{a}
	12	419.7 ± 19.7^{a}	462.1 ± 20.4^{a}	8.1 ± 0.1^{a}	34.6 ± 3.9^{a}	2.9 ± 0.1^{a}

- No significant differences were observed in different extraction methods and time on fatty acids, sterols and melting temperature.
- ASE showed higher diterpenes content compared to MHE and Soxhlet extraction.

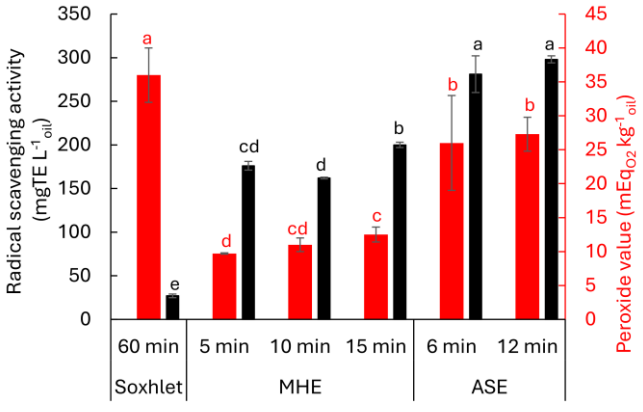

Figure 2: Radical scavenging activity and peroxide value

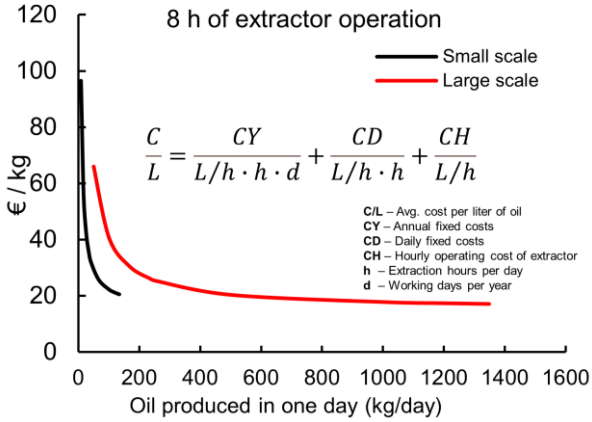

Figure 3: SCG oil cost estimation

- ASE and MHE showed the highest radical scavenging activity compared to Soxhlet extraction.
- ASE and Soxhlet exhibited significantly higher peroxide values compared to MHE.
- Small-scale system unit production cost is initially high at low output but decreases rapidly as daily oil production increases.
- Large-scale system exhibit consistently lower costs across all production levels, reflecting superior cost efficiency.

Conclusion

- Bioactive-rich oil can be extracted from spent coffee grounds using moderate processing techniques suitable for industry.
- Economic analysis shows that large-scale systems are consistently more cost-efficient, while small-scale systems benefit greatly from increased output.

References:
1. Forcina et al. 2023. J. Clean Prod. 385, 135727.
2. Basso et al. 2025. J. Agri. Food Res. 24, 102417.
3. de Melo et al. 2014. J. Sup. Fluids. 24, 150-159.

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