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Application of innovative extraction techniques in sustainable tobacco waste management

Primjena inovativnih tehnika ekstrakcije u održivom gospodarenju duhanskim otpadom

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INTRODUCTION

Industrial waste is a growing problem across the world. Its accumulation has enormous environmental but also economic and social consequences. The tendency to reduce industrial waste has resulted in the development of new technologies that utilize by-products for various purposes. Tobacco waste is a solid waste generated during leaf processing. Tobacco leaves processing generates three fraction of tobacco waste, namely scrap, midrib and dust, with differences in granulation, generation place during processing, and moisture content. The objective of those studies was to investigate the efficacy of different extraction techniques of bioactive compounds from tobacco waste. Influence of extraction parameters on the properties of the obtained extracts has been determined. Using response surface methodology optimal extraction parameters were defined. Green extraction techniques in tobacco waste management have not yet been sufficiently investigated and presented research represents an innovative approach in tobacco waste management.

MATERIALS

TOBACCO WASTE

Tobacco industrial waste (dust, midrib and scrap) was obtained from tobacco processing factory "Fabrika duhana Sarajevo" (Bosnia and Herzegovina).
Tobacco waste was obtained in dry condition, after industry processing. All samples were kept at ambient temperature at dark and dry place before the extraction. Tobacco leaves and waste were pulverized before the extraction (MRC Sample mill C-SM/450-C. Holon, Israel).

Figure 1. Tobacco waste (scrap, dust and midrib)

ANALYSIS

METHODS

- **Gas Chromatography coupled to Mass Spectrometry (GC-MS)**
- **Gas Chromatography with Flame-Ionization Detection (GC-FID)**
- **High Performance Liquid Chromatography (HPLC)**
- **Spectrophotometric analysis**
  - **Total phenols contents (Folin-Ciocalteu assay)**
  - **Antioxidant activity (DPPH method)**
- **Statistical analysis and experimental design using response surface methodology (Design Expert)**

ULTRASOUND-ASSISTED EXTRACTION (UAE)

Tested variables	Time (min)	Temperature (°C)	Solvent/solid ratio (mL/g)	ethanol-water ratio (%)
Experimental range	30-90	30-70	10-30	40-80
Detected compounds	Phenolic compounds, chlorogenic acid, rutin, solanesol, caffeic acid, nicotine, volatile organic compounds, neophytadiene, 4,8,13-duvatriene-1,3-diol			
Activity	Antioxidant activity			
Optimal conditions for polar compounds	Scrap: 46.69 °C, 15.19 min, 10 mL/g, 40% ethanol-water ratio	Dust: 53.59 °C, 38.31 min, 10 mL/g, 55.43% ethanol-water ratio	Midrib: 69.27 °C, 38.31 min, 11 mL/g, 44.83% ethanol-water ratio	
Optimal conditions for non-polar compounds	Scrap: 70 °C, 50 min, 12.74 mL/g	Dust: 70 °C, 45 min, 10 mL/g	Midrib: 70 °C, 20.19 min, 10 mL/g	

SUPERCRITICAL FLUID EXTRACTION (SFE)

Tested variables	Pressure (bar)	Temperature (°C)	Time (min)
Experimental range	100-300	40-80	5-120
Detected compounds	Fatty acids, nicotine, volatile organic compounds		
Optimal conditions	Type: scrap, 120 min, 300 bar and 61.22 °C		

SUBCRITICAL WATER EXTRACTION (SWE)

Tested variables	Time (min)	Temperature (°C)	Solvent/solid ratio (mL/g)
Experimental range	5-25	150-250	10-30
Detected compounds	Phenolic compounds, carbohydrates, chlorogenic acid, rutin, nicotine, 3,4 DHBA, nicotinic acid, nicotinamide, 5-HMF, furfural and 5-MF		
Activity	Antioxidant activity		
Optimal conditions	Scrap: 150 °C, 23 min, 28 mL/g	Dust: 160 °C, 20 min, 10 mL/g	Midrib: 150 °C, 25 min, 30 mL/g

EXTRACTION WITH DEEP EUTECTIC SOLVENTS (DES)

Tested variables	Time (min)	Temperature (°C)	Water content (%)
Experimental range	30-90	30-70	10-30
Detected compounds	Phenolic compounds, chlorogenic acid, rutin		
Activity	Antioxidant activity		
Optimal conditions	Type: scrap, 30 min, 70°C, 29.99 % water Eutectic solvent: Choline chloride: Etan-1,2-diol		

HIGH VOLTAGE ELECTRIC DISCHARGE-ASSISTED EXTRACTION (HVED)

Tested variables	Time (min)	Frequency (Hz)	Solvent/solid ratio (mL/g)
Experimental range	15-45	30-70	300-700
Detected compounds	Phenolic compounds, chlorogenic acid, rutin, nicotine		
Activity	Antioxidant activity		
Optimal conditions	Scrap: 41 Hz, 16.3 min, 692 mL/g	Dust: 73 Hz, 15 min, 700 mL/g	Midrib: 40 Hz, 41 min, 689 mL/g

PULSED ELECTRIC FIELD-ASSISTED EXTRACTION (PEF)

Tested variables	Number of pulses	Field strength (kV/cm)	Solvent/solid ratio (mL/g)	Time (s)
Experimental range	10-50	4-12 kV/cm	10-30	22-66
Detected compounds	Nicotine, phenolic compounds, chlorogenic acid rutin			
Activity	Antioxidant activity			
Optimal conditions	Type: scrap, 46.45 s, 29.76 of pulses, 26.19 mL/g, 7.1 kV/cm			

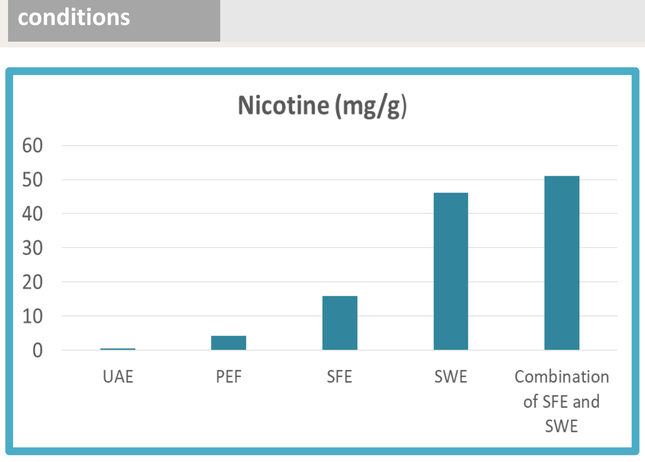

Figure 2. Comparison of different methods in extraction of nicotine from tobacco waste

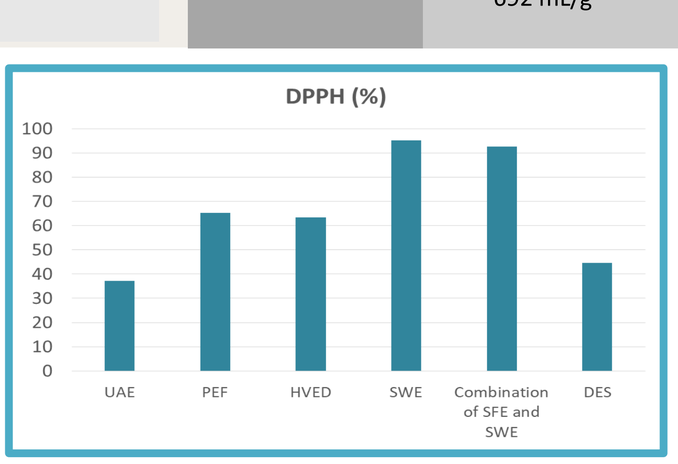

Figure 3. Comparison of influence of different extraction methods on antioxidant activity of tobacco waste

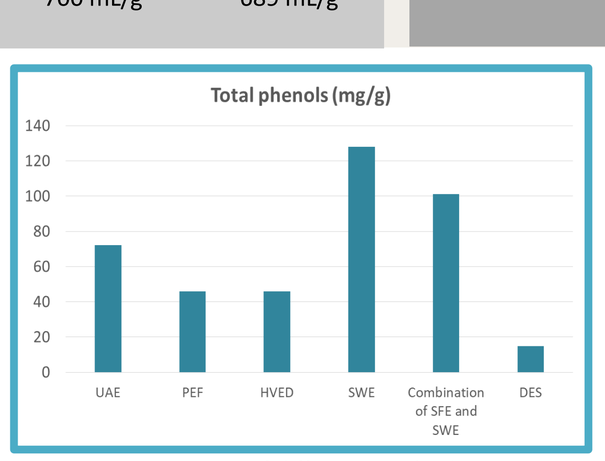

Figure 4. Comparison of different methods in extraction of phenolic compounds from tobacco waste

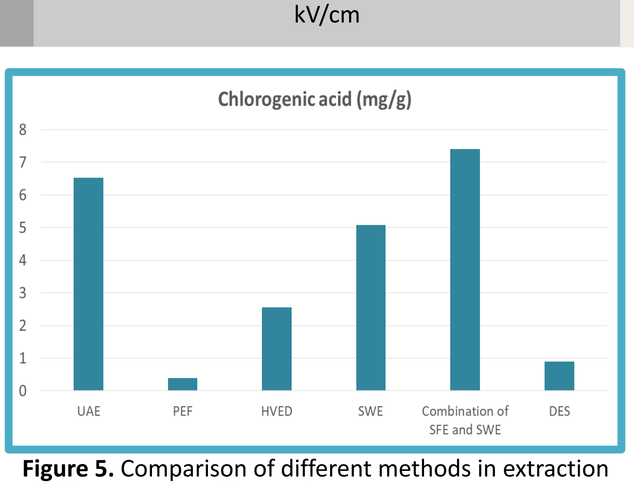

Figure 5. Comparison of different methods in extraction of chlorogenic acid from tobacco waste

CONCLUSIONS

Results showed that SFE has advantages in extracting fatty acids and volatile organic compounds. SWE enabled high extraction yield, but some degradation products (furfurals) occurred on higher temperatures (above 150 °C). UAE and HVED provided satisfying concentration of phenolic compounds (chlorogenic, acid and rutin). Sequence of SFE and SWE showed as most efficient, due to differences in polarity of solvents (supercritical CO_2 and subcritical water).
Treatment of tobacco waste such as recycling and reusing are an imperative today due to rigorous environmental protection legislation. Studied green extraction techniques in this paper provided advantages over conventional extraction methods, such as being "greener", faster and more efficient.

ACKNOWLEDGEMENT

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