"Advanced Pulsed Electric Fields in Agro-Industrial By-Product Valorization: Unlocking the Phenolic's Recovery from Pomegranate Seeds"

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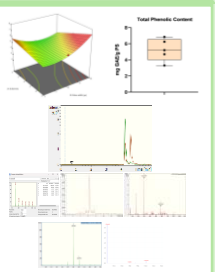
INTRODUCTION

Pulsed Electric Fields (PEF) is a **non-thermal** and **eco-friendly** food processing technology that can be used for enhancing the **extractability of compounds** from various food matrices. This is achieved by **increasing mass transfer** of bioactive compounds (BCs) from the plant cells through electroporation.

OBJECTIVES

- Optimization of **polyphenol extraction** from dried pomegranate seeds (PSs) utilizing PEF
- Systematic assessment of **Electric Field Strength** (**E**, kV/cm), **Pulse Width** (**PW**, μs), and **Pulse Number** (**PN**, N) impact on the **Total Phenolic Content** (**TPC**, mg GAE/g PS) and **Total Specific Energy** (W_T, kJ/kg) (extraction responses)
- Evaluation of the **phytochemical composition** and **antioxidant activity** of the obtained extracts
- Identification and profiling of **(poly)phenolic** compounds using **UHPLC-QTOF-MS**
- Development of an **eco-friendly alternative** to conventional extraction methods

EXPERIMENTAL WORKFLOW

① Preparation of Samples	② PEF – Assisted Extraction	③ Chemical Analysis	④ Interpretation of Data
Industrial Pomegranate Seed Waste (PS) received **freeze dried** from the juice industry ASPIS (Corinth, Greece) Submersion of dried PS waste in H_2O for **5 min** to increase its relative humidity	 Batch Treatment Chamber Optimization through **RSM** based on **Box-Behnken Design** **E (kV/cm)** : 2-4.5 – 7 **Pulse Width (μs)** :2-11-22 **Pulses (N)** : 20-50-80	Of extracts obtained through **optimal PEF - conditions** **Phytochemical Characterization** Total Phenolic Content (TPC) Total Flavonoid Content (TFC) **Antioxidant Activity** DPPH Radical Scavenging Activity **(Poly)phenols Identification** UPLC - QTOF - MS	

OPTIMIZATION OF PEF – ASSISTED EXTRACTION

Regression Analysis

TPC is **negatively affected by E and PW individually**, but **their combined effect (E*PW) is positively affected**

This suggests a **synergistic effect** at moderate-to-high combinations of both factors

ANOVA
- **E** ($p < 0.0216$)
- **PW** ($p < 0.0116$)
- **PN** ($p < 0.0005$)

Model Fitting
- **R^2 :** 0.94
- **Adjusted R^2 :** 0.90
- **Predicted R^2 :** 0.83

RSM

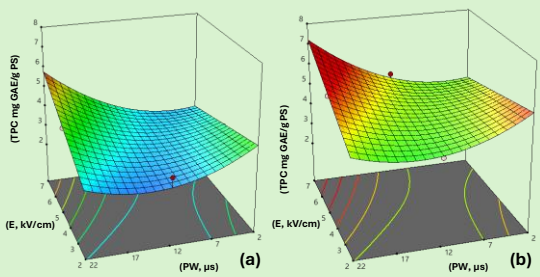


Figure 1 : 3D Plots illustrating the effect of electric field strength (E, kV/cm) and pulse width (PW, μs) on TPC (mg GAE/g PS) during PEF pretreatment, whereas (a) : PN = 20, (b) : PN = 80

Optimization

Goal : ↑ TPC (mg GAE/g PS) ↓ W_T (kJ/kg)

Processing Variables as estimated by the model

(E, kV/cm): **5.394**
(PW, μs) : **2**
(PW, μs) : **80**
→ Optimum Parameters

Responses	Values	
	Predicted	**Actual**
TPC (mg GAE/g PS)	**4.92 ± 0.34**	**5.01 ± 1.57**
W_T (kJ/kg)	**3.54 ± 0.41**	**2.66 ± 0.21**

CHEMICAL ANALYSIS

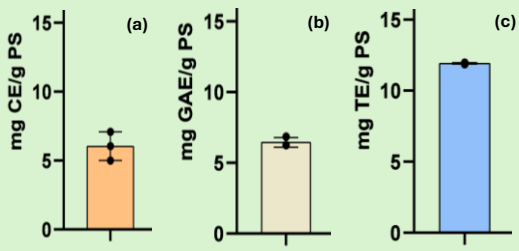


Figure 2 : Phytochemical content [(a):**TPC**, (b): **TFC**] and (c) : **antioxidant capacity** of PS extract obtained by optimal PEF conditions [(E, kV/cm): **5.394,** (PW, μs) : **2,** (PW, μs): **80**]

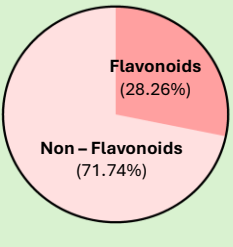


Figure 3. Distribution of polyphenolic compounds identified in pomegranate seed extracts by UHPLC-QTOF-MS, classified into flavonoid (28.26%) and non-flavonoid (71.74%) groups

Identification of **15 (poly)phenolic** compounds across various chemical classes through UHPLC-QTOF-MS

- Phenolic acids
- Stilbenes
- Tyrosols
- Flavan-3-ols
- Flavonols
- Flavanons
- Dihydrochalcone

CONCLUSIONS

- The process provides an **eco-friendly** and energy-efficient alternative to conventional solvent-based extraction methods, supporting **sustainable valorization** of agro-industrial side streams.
- UHPLC-QTOF-MS analysis confirmed the **compositional richness** and **bioactive potential** of the obtained extracts.
- PEF **optimized** and resulted in the highest extraction efficiency, **maximizing TPC** while **minimizing W_T** from PSs.

REFERENCES

1. Lampakis D, Skenderidis P, Leontopoulos S. Processes. 2021 27;9(2):236.
2. Fomo G, Madzimbamuto TN, Ojumu TV. Sustainability. 2020 28;12(13):5244.

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