Valorization of peach (*Prunus persica* L.) by-products using green methods

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Food Technology Trends 2023

1) Alternative Proteins
2) Nutraceuticals
3) E-commerce
4) Food Safety & Transparency
5) Personalized Nutrition
6) Restaurant Digitization
7) Digital Food Management
8) Food Waste Reduction
9) Robotics
10) 3D Food Printers
Peach

(Prunus persica L.) - Rosaceae family
(similar to apricot, cherry and plum)

- Large global agricultural production (1.5 million hectares)
- China: 61% of global production (2020)
- Greece: 3rd in peach production after Spain and Italy (Europe)

Nutritional value per 100 g (3.5 oz)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>165 kJ (39 kcal)</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>9.54 g</td>
</tr>
<tr>
<td>of which sugars</td>
<td>8.39 g</td>
</tr>
<tr>
<td>Dietary fiber</td>
<td>1.5 g</td>
</tr>
<tr>
<td>Fat</td>
<td>0.25 g</td>
</tr>
<tr>
<td>Protein</td>
<td>0.91 g</td>
</tr>
</tbody>
</table>

(USDA, 2019)
Large annual production of peaches & seasonality

Most fresh peaches are being processed

Significant amounts of by-products (e.g., peels)

Can be used as animal feed

Mainly discarded, increasing the volume of food waste

Resource of bioactive compounds with low processing costs

Industrialization into products with high added value containing natural compounds

(Munekata et al., 2022)
Peach peels

Higher concentrations of bioactive components compared to mesocarp (flesh)

2-2.5 times higher concentrations of phenolic compounds & carotenoids (outer skin layer)

Main phenolic acids: chlorogenic, neo-chlorogenic acid

Main flavonoids: catechin, epicatechin, quercetin glucosides

Phenolic compounds contribute to the protection from environmental stresses & microbial threats

(Campbell & Padilla-Zakour, 2013; Liu et al., 2015; Munekata et al., 2022; Kurtulbaş & Şahin, 2022)
Peach kernels

Pit or endocarp: 3 - 8% of the total fresh fruit mass

Mainly composed of unsaturated fatty acids (40-50%), proteins (15-45%), and fibers (4-8%)

Oil & lipophilic compounds content (almond) | Reference
--- | ---
Total oil content: 42.2 – 54.5 g/100 g | Chamli et al., 2017
UFA: 92.0 – 92.5 g/100 g oil
Oleic acid content: 69.3 – 73.6 g/ 100 g oil
Linoleic acid content: 16.0 – 20.5 g/100 g oil |
Total oil content: 48 g/100 g | Maikhuri et al., 2021
UFA: 92 g/100 g oil
MUFA: 59.6 g/100 g oil
PUFA: 32.4 g/100 g oil
Oleic acid content: 58.0 g/100 g oil
Linoleic acid content: 30.8 g/100 g oil
Ultrasound-assisted extraction (UAE)

Mechanism/principle: acoustic cavitation

**Advantages**
- Reduced extraction time compared to conventional techniques
- Lower energy consumption
- Simplicity of use
- Small volumes of solvent required

**Disadvantages**
- High temperatures may degrade the bioactive compounds

«Green» extraction technique

(Gil-Martin et al., 2022)
Aim of the study

Valorization of by-products from the peach industries of Northern Greece (e.g., peels, kernels)
Recovery of bioactive compounds (e.g., phenolics)

Goals to be achieved
✓ sustainability – circular economy – agricultural/food waste reduction
✓ exploitation of natural compounds as additives – nutraceuticals
✓ food safety
Methodology

Clingstone peach variety: Catherina

Response surface methodology – model development (31 experiments)

Lyophilization & milling
(d: 0.10 – 0.17 mm)

Peach peels

Ultrasound-assisted extraction
(50% amplitude, < 35°C)

Extraction duration: 1 – 31 min
Ethanol concentration in solvent: 0 – 80% v/v
Solvent: solid ratio: 10:1 – 70:1 v/w
Pulse duration on – off: 0.1 – 0.9 (per 1 cycle)

Total phenolic content (Folin-Ciocalteu assay)

Total flavonoid content (aluminum chloride assay)

DPPH radical scavenging activity

ABTS radical scavenging activity

Chlorogenic acid concentration (HPLC-DAD)

Extracts analysis
Peach peels (phenolics extraction)

Response surface methodology – model development

Enzyme pre-treatment optimization (50°C)
- Duration: 60-240 min
- Enzyme type (cellulase: pectinase): 0-100%
- Enzyme concentration: 2-4% w/w
- Solvent/solid waste ratio: 2:1 to 6:1 v/w

Lyophilization & milling
(d: 0.10 – 0.17 mm)

Total phenolic content (Folin-Ciocalteu assay)
Total flavonoid content (aluminum chloride assay)
DPPH radical scavenging activity
ABTS radical scavenging activity
Chlorogenic acid concentration (HPLC-DAD)

Extraction duration: 1 – 31 min
- Ethanol concentration: 0 – 80% v/v in water
- Solvent: solid ratio: 10 – 70 v/w
- Pulse duration on – off: 0.1 – 0.9
Peach kernels (oil extraction)

Peach kernels

Drying (40°C, 24 h) & milling

Response surface methodology – model development

Optimization of ultrasound-assisted extraction

Dependent factor: oil yield (g oil/g kernel powder)

Clingstone peach variety: Catherina

Extraction temperature: 20–65 ºC
Amplitude level: 30–60%
Solvent/solid waste ratio: 8:1 to 24:1 v/w
Extraction time: 35 min
Solvent: hexane
Results
Total phenolic content (TPC)

- TPC values ranged from 1.75 – 7.58 mg gallic acid equivalents (GAE)/ g dry weight of peach peels (DW)
- 40% - 60% v/v of EtOH – highest TPC
- 70:1 v/w solvent: solid ratio – highest TPC
- Duration and pulse on-off: non-significant factors for TPC

| Ethanol concentration (X2) | 0.000 |
| Solvent: solid ratio (X3) | 0.000 |
| On-off (X4) | 0.539 |

Surface Plot of TPC vs EtOH concentration (% v/v), Solvent:Solid ratio (v/w)

- TPC: 60% v/v EtOH & 0.7: 0.3 on-off per 1 cycle

Surface Plot of TPC vs EtOH concentration (% v/v), On-Off

- TPC: 70:1 v/w solvent: solid ratio & 0.5: 0.5 on-off per 1 cycle

Surface Plot of TPC vs Solvent:Solid ratio (v/w), On-Off

- TPC: 40% v/v EtOH & 70:1 v/w solvent: solid ratio

p-value = 0.000

p-value = 0.000

p-value = 0.000
Total flavonoid content (TFC)

- TFC values ranged from 2.02 – 5.02 mg catechin equivalents (CAT)/ g dry weight of peach peels (DW)
- 60% v/v of EtOH – highest TFC
- 70:1 v/w solvent: solid ratio – highest TFC
- 0.9: 0.1 pulse on-off (per 1 cycle) – highest TFC
- Duration: non-significant factor for TFC

\[
\begin{align*}
R^2 (\%) & \quad 95.31 \\
R^2_{adj} (\%) & \quad 90.93 \\
p-values & \quad 0.000 \\
Regression & \quad 0.000 \\
Lack of fit & \quad 0.973 \\
Duration (X_1) & \quad 0.707 \\
\end{align*}
\]

- Ethanol concentration (X_2) 0.000
- Solvent: solid ratio (X_3) 0.000
- On-off (X_4) 0.002

Interactions among factors were non-significant for this response
✓ DPPH radical scavenging activity values ranged from 4.48 – 28.86 μmol Trolox equivalents (TRE)/ g dry weight of peach peels (DW)
✓ 60% v/v of EtOH
✓ 70:1 v/w solvent: solid ratio
✓ 0.9: 0.1 pulse on-off (per 1 cycle)
✓ Duration: non-significant factor

**ABTS: Lack-of-fit < 0.05**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R^2$ (%)</td>
<td>96.62</td>
</tr>
<tr>
<td>$R^2_{adj}$ (%)</td>
<td>93.47</td>
</tr>
<tr>
<td>$p$-values</td>
<td></td>
</tr>
<tr>
<td>Regression</td>
<td>0.000</td>
</tr>
<tr>
<td>Lack of fit</td>
<td>0.927</td>
</tr>
<tr>
<td>Duration ($X_1$)</td>
<td>0.201</td>
</tr>
<tr>
<td>Ethanol concentration ($X_2$)</td>
<td>0.000</td>
</tr>
<tr>
<td>Solvent: solid ratio ($X_3$)</td>
<td>0.000</td>
</tr>
<tr>
<td>On-off ($X_4$)</td>
<td>0.019</td>
</tr>
</tbody>
</table>

p-value = 0.011

↑Antioxidant activity: 60% v/v EtOH & 0.7: 0.3 on-off per 1 cycle
Chlorogenic acid (CGA)

- CGA concentration ranged from 3.74 – 53.81 mg/ 100 g dry weight of peach peels (DW)
- Responses followed the same trend as TPC
- 40% v/v of EtOH – highest chlorogenic acid content
- 70:1 v/w solvent: solid ratio – highest chlorogenic acid content
- Duration and pulse on-off: non-significant factors for CGA

\[
\begin{align*}
R^2 (\%) & = 85.94 \\
R^2_{\text{adj}} (\%) & = 72.81 \\
P-values \\
\text{Regression} & = 0.000 \\
\text{Lack of fit} & = 0.061 \\
\text{Duration} (X_1) & = 0.954 \\
\text{Ethanol concentration} (X_2) & = 0.000 \\
\text{Solvent: solid ratio} (X_3) & = 0.008 \\
\text{On-off} (X_4) & = 0.157
\end{align*}
\]

Quantification based on a chlorogenic acid standard curve (10 – 200 ppm) – HPLC-DAD

Surface Plot of Chlorogenic acid (CGA) vs EtOH concentration (% v/v), Solvent:Solid ratio (v/w)

p-value = 0.025
↑CGA concentration: 40% v/v EtOH & 70:1 v/w solvent: solid ratio
Optimum extraction conditions (peach peels & kernels)

**OPTIMUM CONDITIONS**
Extraction duration: 17 min
EtOH concentration: 53% v/v
Solvent: solid ratio: 70:1 v/w
Pulse on – off: 0.9: 0.1 (per 1 cycle)

**OPTIMUM CONDITIONS**
(enzyme pre-treatment)
50% pectinase
3% w/w enzyme concentration

**OPTIMUM CONDITIONS**
(peach kernel oil)
Extraction temperature: 42.5 °C
Amplitude level: 45%
Solvent/solid waste ratio: 16:1 v/w

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**Graphs**

- TPC (mg GAE/ g DW)
- TFC (mg CAT/ g DW)
- DPPH (μmol TRE/ g DW)
- CGA (mg/ 100 g DW)

**Measured values**  **Predicted values**
Conclusions

✓ **Effective optimization** of phenolics compounds extraction from peach peels with UAE

✓ Enzyme pre-treatment with **cellulase/pectinase** may enhance the total yield of phenolic compounds from peach peels

✓ UAE seems a promising method for peach kernel oil extraction

✓ Potential of peach by-products **valorization**

✓ Possible future applications as **natural additives** (e.g., antioxidants)

✓ Production of **functional** food products
Thank you for your attention!

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