Tailor made emerging extraction processes for the recovery of targeted antioxidant compounds

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Introduction

✓ **Plant food materials wastes & by products as well as algae matters** are a good source of high-added value compounds such as vitamin C, carotenoids, polyphenols, etc., thus having antioxidant activities.

✓ **High-added value compounds** can be used for different purposes (i.e. natural food additives &/or nutraceuticals)

✓ The **recovery of antioxidant compounds** from wastes & by-products kills two bird with one stone & addresses both the use of waste & by-products & societal health

Antioxidant compounds in algae and vegetable matters

**Polyphenols**

✓ *Secondary metabolites of plants*

✓ Commonly found in plant food materials like fruits, vegetables, cereals, legumes, and nuts

✓ Pigmentation of vegetable foodstuffs

✓ Associated with the astringency of many edible fruits before they ripen

✓ Related to the sensory quality of both fresh & processed foods of plant origin

✓ Related to reduction in risk of coronary heart diseases and degenerative human diseases because of their antioxidant and free radical scavenging properties

Antioxidant compounds in algae and vegetable matters

**Carotenoids**

- Natural pigmentation
- Provitamin A activity
- Antioxidant capacity
- Healthy compounds
- Related to reduction in risk of coronary heart diseases and degenerative human diseases because of their antioxidant and free radical scavenging properties

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**References**

Antioxidant compounds in algae and vegetable matters

**Chlorophylls**

- **Green pigments with role in photosynthesis**
- Sources: plant food materials, algae, etc.
- Positive effects on inflammation, wound healing, can form complexes with some carcinogens
- Use for preparing food products

Introduction

✓ As industrialisation continues, *greater quantities* of waste at a given location

✓ While this can create *greater environmental problems*, the concentrated waste can often be *more easily re-assimilated* into the food cycle & can be a useful tool to obtain highly nutritional products

✓ Conventional extraction: *time consuming, toxic solvents, high temperature*

✓ There is a need to develop new methods in full correspondence with *green extraction concept*
Extraction

✓ “Green” solvents, particularly water at room temperature, are often inadequate for an efficient extraction from food plants

✓ Cellular tissue must be initially denatured to become permeable for the intracellular compounds targeted by the extraction

✓ In industry, such tissue denaturation is most often achieved through a thermal process (e.g., using steam or hot water) & consumes high amounts of energy.

✓ Thermo-sensitive compounds of plant tissue degrade under the influence of heat, affecting products quality (loss of vitamins, colors, flavours, etc.)
New trends

USN

HP

Electrotech

Green solvents
Electrotechnologies: Pulsed Electric Fields (PEF) and High Voltage Electrical Discharges (HVED)

Fundamental principles and applications
Electrotechnologies

- Pulsed Electric Fields (PEF) and High Voltage Electrical Discharges (HVED) consist on applying an electrical treatment of short time (from several nanoseconds to several milliseconds) between 2 electrodes (normally plate electrodes).

Material recommended for the electrodes:

- stainless steel, graphite or titanium
PEF-assisted extraction

✓ Consists of applying electric fields from 0.1-20 kV/cm, although normally lower than 10 kV/cm.

理论：在低电场效果下，PEF，生物膜被电穿孔并暂时或永久丧失半透性。这些变化允许对高附加值化合物的选择性回收来自不同基质的化合物。
HVED-assisted extraction

✓ Subjecting food wastes and by-products to electric pulses of high voltage (40 kV) and high current (approximately 10 kA) of short duration (μs–ms) between two electrodes (usually needle electrode and a grounded one (normally flat geometry)).

✓ Theory: The application of high voltage electrical discharges (HVED) is based on the physico-chemical process of dielectric breakdown or arcing that occurs when the electrical discharges keep attached to water.

✓ Fragmentation of cell tissues due to the electrical damage produced during this process and extraction of compounds.
The factors that may influence the efficiency of PEF extraction are:

- Electric field/Electrical pulse
- Treatment time
- Temperature
- pH
- Conductivity
- Liquid/solid ratio
- Type of solvent
- Solvent concentration
PEF applications

✓ Extraction of *valuable compounds* from different matrices in full correspondence with *green extraction concept*:

- Temperature
- Time
- Solvent

✓ PEF can be combined with supplementary extraction with other technologies

✓ PEF treatment preserves *heat-labile food bio-compounds*
Recovery of polyphenols: Exotic fruits and by-products
Recovery of polyphenols: Exotic fruits and by-products

Papaya peels
Recovery of anthocyanin: Berries and by-products

Table 1  Anthocyanins extracted expressed in mg (equivalent malvidin-3-O-glucoside/L) during ultrasound (US), pulsed electric field (PEF), and high-voltage electrical discharge (HVED) treatments, at equivalent cell disruption index Z.

<table>
<thead>
<tr>
<th></th>
<th>Total anthocyanins (mg/L)</th>
<th>Mal-3-glu (mg/L)</th>
<th>Pea-3-glu (mg/L)</th>
<th>Poly-3-glu (mg/L)</th>
<th>Delph-3-glu (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US 0.2</td>
<td>14.73 ±1.49ab</td>
<td>8.75 ±1.59ab</td>
<td>4.19 ±0.09ab</td>
<td>1.59 ±0.09ab</td>
<td>0.20 ±0.03ab</td>
</tr>
<tr>
<td>0.4</td>
<td>71.70 ±0.64ab</td>
<td>11.18 ±0.20ab</td>
<td>7.08 ±0.73ab</td>
<td>3.59 ±0.11ab</td>
<td>0.76 ±0.02ab</td>
</tr>
<tr>
<td>0.6</td>
<td>31.23 ±0.80ab</td>
<td>16.54 ±0.35d</td>
<td>10.27 ±0.20ab</td>
<td>3.80 ±0.16cd</td>
<td>0.58 ±0.03cd</td>
</tr>
<tr>
<td>PEF 0.8</td>
<td>51.21 ±0.41f</td>
<td>26.85 ±0.25e</td>
<td>16.67 ±0.32e</td>
<td>7.06 ±0.40e</td>
<td>1.13 ±0.07e</td>
</tr>
<tr>
<td>0.2</td>
<td>11.80 ±0.93c</td>
<td>6.65 ±0.62ab</td>
<td>4.53 ±0.31c</td>
<td>0.86 ±0.03c</td>
<td>0.14 ±0.06c</td>
</tr>
<tr>
<td>0.4</td>
<td>11.61 ±1.80f</td>
<td>5.74 ±0.99d</td>
<td>4.85 ±0.99e</td>
<td>1.17 ±0.76d</td>
<td>0.71 ±0.02ab</td>
</tr>
<tr>
<td>0.6</td>
<td>46.29 ±3.43e</td>
<td>26.24 ±2.92f</td>
<td>14.43 ±1.35e</td>
<td>4.82 ±0.56e</td>
<td>0.77 ±0.09cde</td>
</tr>
<tr>
<td>0.8</td>
<td>63.47 ±3.17e</td>
<td>36.48 ±2.90f</td>
<td>20.64 ±2.18d</td>
<td>4.88 ±1.75e</td>
<td>1.35 ±0.23f</td>
</tr>
<tr>
<td>HVED 0.2</td>
<td>10.45 ±1.12a</td>
<td>5.73 ±0.02e</td>
<td>3.75 ±0.02e</td>
<td>0.66 ±0.15e</td>
<td>0.26 ±0.02b</td>
</tr>
<tr>
<td>0.4</td>
<td>9.14 ±0.77d</td>
<td>9.63 ±0.49e</td>
<td>8.25 ±0.75e</td>
<td>7.62 ±0.61cd</td>
<td>0.47 ±0.03cd</td>
</tr>
<tr>
<td>0.6</td>
<td>32.53 ±1.35g</td>
<td>13.14 ±1.16cd</td>
<td>14.53 ±1.52c</td>
<td>4.06 ±0.093d</td>
<td>0.79 ±0.28c</td>
</tr>
<tr>
<td>0.8</td>
<td>40.64 ±1.28h</td>
<td>16.84 ±1.06d</td>
<td>17.62 ±1.76d</td>
<td>5.27 ±0.85c</td>
<td>1.18 ±0.04c</td>
</tr>
</tbody>
</table>

For each column, means that are followed by the same letter are not significantly different (P<0.05).

Table 2  Energy consumption required to extract compounds during ultrasound (US), pulsed electric field (PEF), and high-voltage electrical discharge (HVED) treatments, at equivalent cell disruption index Z.

<table>
<thead>
<tr>
<th></th>
<th>Treatment</th>
<th>Energy consumption (kWh/mg TPC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>US</td>
<td>1.29 ±0.01</td>
</tr>
<tr>
<td></td>
<td>PEF</td>
<td>0.95 ±0.00</td>
</tr>
<tr>
<td>0.4</td>
<td>US</td>
<td>1.41 ±0.01</td>
</tr>
<tr>
<td></td>
<td>PEF</td>
<td>0.95 ±0.00</td>
</tr>
<tr>
<td>0.6</td>
<td>US</td>
<td>0.88 ±0.02</td>
</tr>
<tr>
<td></td>
<td>PEF</td>
<td>0.73 ±0.02</td>
</tr>
<tr>
<td>0.8</td>
<td>US</td>
<td>1.15 ±0.02</td>
</tr>
<tr>
<td></td>
<td>PEF</td>
<td>0.91 ±0.04</td>
</tr>
<tr>
<td></td>
<td>HVED</td>
<td>0.16 ±0.04</td>
</tr>
</tbody>
</table>

Recovery of anthocyanin: Berries and by-products

Blackberries

HVED (Z = 1; 100 kJ/kg)

PEF (Z=1; 864 kJ/kg)
Recovery of polyphenols chlorophylls and carotenoids: Microalgae

*Eb: Extraction at basic pH (pH = 11). **(PEF) (20 kV/cm, 1-6 ms). The treatments at normal (pH = 8.5) and basic (pH = 11) conditions are referred further on as PEFn, and PEFb, respectively.

Parniakov, O.; Barba, F. J.; Griml, N.; Marchal, L.; Jubeau, S.; Lebovka, N. & Vorobiev, E. (2014), 'Pulsed electric field assisted extraction of nutritionally valuable compounds from microalgae using the binary mixture of organic solvents and water', Innovative Food Science and Emerging Technologies 27, 79-85.

General Remarks

✓ **PEF can be used to effectively disrupt plant cell & thereby increase extraction efficiency & yields of polyphenolic compounds & carotenoids from different plant sources (e.g., citrus fruits, berries, tomatoes, & tea leaves)**

✓ However, the recovery effectiveness & commercial viability often depends on the applied **PEF conditions, the type of solvent, the target compound, & the structure & composition of the biomaterial matrix**

✓ PEF-assisted extraction can potentially enable the cost effective production of a **new generation of functional extracts**, which can be used as ingredients in novel healthy food products, nutraceuticals & pharmaceuticals
Current applications and new opportunities for the use of pulsed electric fields in food science and industry

Francisco J. Barba, Oleksii Parhiak, Sofia A. Pereira, Artur Wiktor, Nabil Grimi, Nadia Boussetta, Jorge A. Saraiva, Javier Raso, Olga Martín-Bellosa, Dorota Witrowa-Rajchert, Nikolai Lebovka, Eugène Vorobiev

An overview of the impact of electrotechnologies for the recovery of oil and high-value compounds from vegetable oil industry: Energy and economic cost implications

Eduardo Puértolas, Mohamed Koubaa, Francisco J. Barba
Ultrasound assisted extraction:

Fundamental principles and applications
Ultrasound processing

- Can be defined as inaudible sound waves at a frequency above 20 kHz
USN-assisted extraction

FACTORS

- USN frequency
- Time
- Temperature
- pH
- Liquid/solid ratio
- Type of solvent
- Solvent concentration
## Recovery of polyphenols: Plant food materials and by-products

<table>
<thead>
<tr>
<th>Plant material</th>
<th>Treatment conditions</th>
<th>Ethanol/Water</th>
<th>Polyphenols yield increase</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>25 kHz 150 W 10-40 °C 5-55</td>
<td>50:50</td>
<td>20%</td>
<td>(Virot, Tomao, Le Bourvellec, Renard, &amp; Chemat, 2010)</td>
</tr>
<tr>
<td>Black chokolate</td>
<td>25.5 kHz 100 W 20-80 °C 0-250</td>
<td>50:50</td>
<td>85%</td>
<td>(Galvan D’Alessandro, Dimitrov, Vaucl, &amp; Nikov, 2013)</td>
</tr>
<tr>
<td>Grape</td>
<td>20 kHz 50-150 W 30 30</td>
<td>100%</td>
<td>15%</td>
<td>(Da Porto, Porretto, &amp; Decorti, 2013)</td>
</tr>
<tr>
<td>Onion</td>
<td>469 kHz 40-60 °C 15-35</td>
<td>40:80:60-20</td>
<td>50%</td>
<td>(Jang et al., 2013)</td>
</tr>
<tr>
<td>Orange peel</td>
<td>25 kHz 150 W 30 15</td>
<td>50:50</td>
<td>50%</td>
<td>(Ma, Chen, Liu, &amp; Ye, 2009)</td>
</tr>
<tr>
<td>Origanum majorana</td>
<td>20 kHz 1500 W 15-35</td>
<td>80:20</td>
<td></td>
<td>(Hossain et al., 2012)</td>
</tr>
<tr>
<td>Rice</td>
<td>2.4 kHz 25</td>
<td>2-90</td>
<td>0:100</td>
<td>22-24% per antioxidant yield</td>
</tr>
<tr>
<td>Wheat</td>
<td>3.5 kHz 400 W 40-60 °C 3.3</td>
<td>85:15</td>
<td></td>
<td>(Chen et al., 2007)</td>
</tr>
<tr>
<td>Wheat grain</td>
<td>3.5 kHz 140 W 40-60</td>
<td>50:90:50:10</td>
<td>60%</td>
<td>(Tabaraki &amp; Nateghi, 2011)</td>
</tr>
<tr>
<td>Wheat distiller’s grain</td>
<td>4.1 kHz 250 W 33-67</td>
<td>43-77:57:23</td>
<td>60%</td>
<td>(Tabaraki &amp; Nateghi, 2011)</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>4.1 kHz 140 W 0.5-20</td>
<td>0:100</td>
<td>14.29%</td>
<td>(Izadifar, 2013)</td>
</tr>
</tbody>
</table>

1 Methanol was used instead of ethanol. 2 Hydrochloric acid was used instead of water. 3 Acetone was used instead of ethanol. 4 n-hexane was used as solvent.
## Recovery of carotenoids: Plant food materials and by-products

<table>
<thead>
<tr>
<th>Material</th>
<th>Treatment conditions</th>
<th>Solvent</th>
<th>Carotenoids yield (%)</th>
<th>Increase</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Foods</td>
<td></td>
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<tr>
<td>Auyama/Cabbage/Lettuce waste</td>
<td>kHz: 75, W: 300, °C: 40, min: 60</td>
<td>-</td>
<td>-</td>
<td>Total yield (24%)</td>
<td>(Alzate, Gonzalez, &amp; Londono-Londono, 2013)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Hexane (100:0)</td>
<td>b-carotene (4%)</td>
<td>(Li, Fabiano-Tixier, Tomao, Cravotto, &amp; Chemat, 2013)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Methanol (100:0)</td>
<td>b-carotene (11%), lutein (10%) and zeaxanthin (10%)</td>
<td>(Almahy, Ali, &amp; Band-Ali, 2013)</td>
</tr>
<tr>
<td>Red grapefruit</td>
<td>kHz: 170, W: 200, °C: 30-70, min: 10-50</td>
<td>Ethanol (100:0)</td>
<td>b-carotene (81%)</td>
<td>(Xu &amp; Pan, 2013)</td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>kHz: 2, W: 700-900, °C: 38-40, min: 1-3</td>
<td>Ethanol (100:0)</td>
<td>Carotenoids (360%)</td>
<td>(Ye, Feng, Xiong, &amp; Xiong, 2011)</td>
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<td></td>
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<td></td>
<td>Lycopene (26%)</td>
<td>(Kumcuoglu, Yilmaz, &amp; Tavman, 2013)</td>
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<td></td>
<td></td>
<td></td>
<td>Ethyl acetate (100:0)</td>
<td>Lycopene (26%)</td>
<td>(Fanfu &amp; Zelong, 2008)</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hexane, acetone, ethanol (50:25:25)</td>
<td>Lycopene (26%)</td>
<td>(Eh &amp; Teoh, 2012)</td>
</tr>
<tr>
<td>Algae</td>
<td>kHz: 37, W: 140, °C: 31.6-48.4, min: 23.2-56.8</td>
<td>Ethanol (100:0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlorella vulgaris</td>
<td>kHz: 40, W: 200, °C: 41.1, min: 16</td>
<td>Ethanol, ethyl acetate</td>
<td>Lutein 29%, β-carotene 25%</td>
<td>(Kwang et al., 2010)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Ethanol, ethyl acetate</td>
<td>Astaxanthin 55%</td>
<td>(Zou, Jia, Li, Wang, &amp; Wu, 2013)</td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Acetone</td>
<td>Astaxanthin 66%</td>
<td>(Ruen-ngam, Shotipruk, &amp; Pavasant, 2011)</td>
</tr>
</tbody>
</table>

1 Compared to supercritical fluid extraction. 2 With 2% dichloromethane (w/v) and 0.05% (w/v) butylated hydroxytoluene (BHT).
## Recovery of polyphenols, chlorophylls and carotenoids: Microalgae

<table>
<thead>
<tr>
<th>Algae</th>
<th>Treatment conditions</th>
<th>Solvent</th>
<th>Carotenoids yield increase</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kHz</td>
<td>W</td>
<td>°C</td>
<td>min</td>
</tr>
<tr>
<td>Chlorella vulgaris</td>
<td>–</td>
<td>–</td>
<td>50-160</td>
<td>120</td>
</tr>
<tr>
<td>Haematococcus pluvialis</td>
<td>40</td>
<td>200</td>
<td>41.1</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>18.4</td>
<td>45</td>
<td>60</td>
<td></td>
</tr>
</tbody>
</table>
Clean recovery of antioxidant compounds from plant foods, by-products and algae assisted by ultrasounds processing. Modeling approaches to optimize processing conditions

Elena Roselló-Soto, Charis M. Galanakis, Mladen Brnčić, Vibeke Orliend, Francisco J. Trujillo, Raymond Mawson, Kai Knoerzer, Brijesh K. Tiwari and Francisco J. Barba

Introduction
Over the last decades, the food, pharmaceutical and nutraceutical processing industry have increased their interest in novel non-thermal processing technologies to improve and replace largely heat-based conventional processes. Recovery of valuable compounds from food processing streams, including by-products, is generally achieved by free flow extraction techniques such as solvent extraction, spray drying, and supercritical fluid technology. However, very often, these procedures are not suitable for the recovery of high-value compounds. To overcome this challenge, high-intensity processing methods, such as ultrasonics, are currently receiving considerable attention. Ultrasound sound treatment is an alternative, affordable, effective and reproducible method for the improved recovery of bioactive compounds from different processing streams. The objective of this review is to discuss the impact of ultrasound-assisted extraction on the recovery of phenolic compounds and chlorophylls from natural and algae material. Optimisation strategies will be reviewed, and the appropriate equipment design and configuration of ultrasonic treatments, and the critical parameters, including ultrasound power, temperature and extraction time, which enhance the yield and biological activity of the extract. Modelling strategies to characterise and optimise ultrasound processes are also be highlighted in this manuscript.
High Pressure Processing:
Fundamental principles and applications
High Pressure Assisted Extraction

✔ Subjecting foods to pressures normally from 100 to 600 MPa, (equivalent to about 1000-6000 times atmospheric pressure) with temperatures from 20 °C to 60 °C & at treatment times from seconds to up to 60 min

✔ Theory: HP treatment enhances mass transfer processes within plant or animal cellular tissues, as the permeability of cytoplasmatic membranes can be affected.

✔ The use of HP can enhance mass transfer rates by increasing cell permeability as well as secondary metabolite diffusion.
High Pressure Assisted Extraction

✓ **HP treatment** produces the *physical disruption of plant* tissue, thus inducing changes in the permeability of cell membranes.

✓ *Modifications in the molecular organization of the lipid-peptide complex* & *disruptions in the phosphatidic acid bilayer membrane structure*

✓ These changes promote raw material fragmentation & *extraction of intracellular compounds*, including bioactives
High Pressure Assisted Extraction

✓ The factors that may influence the efficiency of HP extraction are:

- Pressure level
- Holding time
- Liquid/solid ratio
- Type of solvent
- Solvent concentration
High Pressure Assisted Extraction

**Practice:**

- The versatility of HP allows this technology to be used as a *macroscopic pre-treatment to permeabilize cell membrane*

- facilitating the *extraction* of bioactive components *before conventional solvent* extraction

- or can be used combined with water or other solvent to extract directly the antioxidant compounds

- An *HP treatment* can be performed at *ambient temperature* & the overall timescale required for an HP treatment is in the *range of minutes*, thus HP treatment preserves *heat-labile food bio-compounds*
**Examples of Applications**

<table>
<thead>
<tr>
<th>Product</th>
<th>Application</th>
<th>Conditions</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GRAPES</strong></td>
<td>Yield of anthocyanins &amp; total phenolics</td>
<td>600 MPa/70 °C/1 h</td>
<td>Corrales et al. (2008), Corrales et al. (2009)</td>
</tr>
<tr>
<td></td>
<td>Increase in some extractable carotenoids (b-cryptoxanthin, -cryptoxanthin-5,8-epoxide, b-carotene, lutein, zeaxanthin, lycopene, neolycopene)</td>
<td>400 MPa/25 °C/1 min</td>
<td>De Ancos et al. (2007)</td>
</tr>
<tr>
<td><strong>PAPAYA SLICES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Examples of Applications

LONGAN FRUIT PERICARP

HP at 500 MPa obtained the higher phenolic acid contents & antioxidant activities compared to other high pressure processing & conventional extractions (CE).
200-500 MPa/30 ºC/2.5-30 min

Prasad et al. (2009a, 2010)

LITCHI FRUIT PERICARP

Increase in catechin, epicatechin & procyanidin B in comparison to ultrasounds & conventional treatment
400 MPa

Prasad et al. (2009b)

Examples of Applications

**PROPOLIS**

**TOMATO PUREE**

- **Increased flavonoids**
  - 500 MPa/room temperature/1 min
  - **Shouqin et al. (2004)**

- **Significant increase in β-carotene (36%) after HPP**
  - Increase (21-60%) in lycopene after HPP
  - 400-500 MPa/20-25 ºC/2-15 min
  - **Sánchez-Moreno et al. (2006), Krebbers et al. (2003), Patras et al. (2008)**

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Examples of Applications

**TEA LEAVES**

**RHODIOLA SACHALINENSIS**

**Similar extraction yields after 400 MPa/15 min than organic solvent extraction for 2 h.**

**TPC at 450 MPa were higher than those of conventional extraction.**

**Jun et al. (2010)**

**Compared with traditional extraction methods (ultrasonic extraction, leaching extraction, soxhlet extraction & reflux extraction), HP extraction provided much more flavones & an increase of at least 10% of the extraction yield of crude extract.**

**Zhang et al. (2007)**

General Remarks about HPP

✓ **HP can be used to effectively disrupt plant cell & thereby increase extraction efficiency & yields of polyphenolic compounds & carotenoids from different plant sources (e.g., citrus fruits, berries, tomatoes, & tea leaves)**

✓ However, the recovery effectiveness & commercial viability often depends on the applied HP conditions, the type of solvent, the target compound, & the structure & composition of the biomaterial matrix

✓ HP-assisted extraction can potentially enable the cost effective production of a new generation of functional extracts, which can be used as ingredients in novel healthy food products, nutraceuticals & pharmaceuticals
Challenges and opportunities for the extraction of valuable compounds from winery by-products and microalgae
## Winery by-products

### Matrix, compound and processing conditions

<table>
<thead>
<tr>
<th>Matrix</th>
<th>Extracted compounds</th>
<th>Treatment conditions</th>
<th>Extraction improvement</th>
<th>Reference</th>
</tr>
</thead>
</table>
| **PEF** | **Wine grape** | Polyphenols | 1) 0.5 kV/cm, 50 pulses, 0.1 kJ/kg  
2) 2.4 kV/cm, 50 pulses 2.3 kJ/kg | 1) 13%  
2) 28% | (Balasa et al., 2006) |
| | Anthocyanins and tannins | 0.8-5 kV/cm, 1-100 ms, 42-53 kJ/kg | >50% | (El Darra et al., 2013a) |
| | Anthocyanins | 13.3 kV/cm, 0-564 kJ/kg | >50% | (Barba et al., 2015a) |
| | Polyphenols | 13.3 kV/cm, 0-1500 pulses, 50 °C, 50-762 kJ/kg | Up to 2-fold increase | (Rajha et al., 2014a) |
| **HVED** | **Vine shoots** | Polyphenols | 40 kV | ≈7-fold | (Boussetta et al., 2012) |
| | Grape seeds | Polyphenols and anthocyanins | 40 kV | HVED more energy efficient to recover polyphenols compared to PEF and USN | (Barba et al., 2015a) |
| | Vine shoots | Polyphenols | 40 kV/50 °C/10-240 kJ/kg/3 h diffusion | Up to 3-fold increase. More energy efficient extraction compared to USN and PEF. | (Rajha et al., 2014a) |
| **USN** | **Grapes** | Resveratrol | 47 kHz, 60 °C, 30 min | 24-28% | (Cho et al., 2006) |
| | Polyphenols | 35 kHz, 70 °C/1 min | ≈50% | (Corrales et al., 2008) |
| | Polyphenols | 24 kHz, 20-75 W/ml | ≈11% | (Vilkhu et al., 2008) |
| | Polyphenols and proteins | 20 kHz, 50-150 W, 30 °C, 30 min | ≈0% | (Da Porto et al., 2013)  
(Rajha et al., 2014a) |
Review

Green alternative methods for the extraction of antioxidant bioactive compounds from winery wastes and by-products: A review

Francisco J. Barba a, *, Zhenzhou Zhu b, Mohamed Koubaa c, Anderson S. Sant’Ana d, Vibeke Orlien a
The effect of PEF treatment (+=5.2 %) on extraction of proteins was rather significant as compared with supplementary contributions of HVED (+=1.15%) or USN (+=1.8%).

Electrically-assisted techniques (PEF and HVED) allowed selective extraction of water soluble ionic components, small molecular weight organic compounds (amino-acids) and proteins. However, PEF and HVED are inefficient for extraction of pigments.
References PEF

- Roselló-Soto, E., Barba, F. J., Parniakov, O., Galanakis, C. M., Lebovka, N., Grimi, N., & Vorobiev, E. (2014). High voltage electrical discharges, pulsed electric field, and ultrasound assisted extraction of protein and phenolic compounds from olive kernel. Food and Bioprocess Technology, 8, 885–894.
References USN

References HPP


Thank you for your attention!

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