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EXTRUSION TECHNOLOGY AS A PROMISING TOOL FOR VEGETABLE OIL EXTRACTION: BIOREFINERY OF APIACEAE FRUITS

Evelien Uitterhaegen¹,², O. Merah¹,², T. Talou¹,², C.V. Stevens³, L. Rigal¹,², P. Evon¹,²

¹Université Fédérale de Toulouse Midi-Pyrénées, INP-ENSIACET, LCA (Laboratoire de Chimie Agro-industrielle), F-31030 Toulouse, France
²INRA, UMR 1010 CAI, F-31030 Toulouse, France
³SynBioC, Department of Sustainable Organic Chemistry and Technology, Ghent University, Ghent, Belgium
evelien.uitterhaegen@ensiacet.fr

As fossil resources are steadily depleting and environmental concerns have developed into one of the main discussion points in public and political agendas, sustainability and an ecological viewpoint have become indispensable terms in modern society. This critical pressure towards ‘greener’ alternatives has led to a progressive application of renewable resources by the chemical industry. Vegetable oils present an interesting class of bioresources, with a market comprising both food and non-food applications. Their extraction is a key process as it will exert a strong impact on the resulting oil characteristics and quality. It is most frequently executed through solvent extraction, although mechanical pressing may present an interesting alternative as it represents a generally safer and more sustainable process. Furthermore, oils obtained through pressing are considered to be of superior quality and do not contain any solvent traces. The main drawback to this process involves the extraction yield, which is typically lower than for solvent extraction. Therefore, research has recently focused on continuous oil extraction through extrusion technology and its process optimization in order to increase extraction yields. Single-screw, as well as twin-screw extrusion was employed to efficiently extract vegetable oil from Apiaceae fruits, with Coriandrum sativum L. as a model herb. Coriander vegetable oil is particularly interesting as it has recently been approved as Novel Food Ingredient and is rich in petroselinic acid, allowing applications in oleochemistry. Simultaneously, this allowed coriander fruit biorefinery, as the press cakes may be transformed into agromaterials through thermopressing or be incorporated into a thermoplastic matrix such as PLA for injection molding. This represents a key advancement in the overall process economics and an important waste reduction. The oil extraction efficiency was significantly enhanced through the application of pre-treatments of the fruits prior to the extrusion process. Specifically, the fruit moisture content was shown to exhibit a key impact on their crushing behavior and oil extraction yields. As an example, when mechanical pressing is conducted in a Clextral BC 21 twin-screw extruder, an extraction yield of 68% is reached, representing a 44% increase, when the fruit moisture content is reduced from 9.8 to 0.3%, further leading to a significant decrease in the residual oil content of the obtained press cake.
Extrusion technology as a promising tool for vegetable oil extraction:

Biorefinery of Apiaceae fruits

Evelien Uitterhaegen, O. Merah, T. Talou, C.V. Stevens, L. Rigal, P. Evon

Biorefinery for Food, Fuels and Materials 2015 symposium

Overview

- Introduction
  - Vegetable oil extraction
  - Twin-screw extrusion
  - Coriander as a model herb
- Results
- Conclusion
Vegetable oil extraction

Single-screw vs twin-screw extrusion

- Traditional oil pressing technique
- Low capital cost
- High energy consumption
- Low flexibility

- Innovative technique for oil extraction
- High capital cost
- Reduced energy consumption
- High flexibility & versatility
Vegetable oil extraction
Twin-screw extrusion

- Co-rotating twin-screw extruder (Clextral BC21)
- Mechanical-thermal-chemical process
- Temperature-regulated modules
- Filter section near the pressing zone
- Screw profile consists of segmental screw elements (25 or 50 cm)
- Different types of screw elements exert different forces on raw material

Vegetable oil extraction
Twin-screw extrusion

- Forward pitch screws → Conveying action
- Reverse pitch screws → Pressing action

Images from Clextral documentation
Vegetable oil extraction

Twin-screw extrusion

- Monolobe and bilobe paddles → Trituration zone

- Versatility through setup of screw profile and pitch of screw elements

Coriander as a model herb

- *Coriandrum sativum* L. (Apiaceae)
- Well known spice and medicinal herb
- Wide range of biological activities

- Food and cosmetic industry
  - 20-28% Vegetable oil
  - 0.3-0.9% Essential oil
- Perfume industry
  - 70% Petroselinic acid
  - 70% Linalool

Source of novel oleochemicals
Results

Seeds characterization
- Coriander fruits cultivated in southwest of France
- Vegetable oil content 28% of dry matter
- Essential oil content 0.70% of dry matter

Vegetable oil extraction
- Extraction yield of 81 ± 3% through n-hexane Soxhlet extraction
- Extraction yield of 39 ± 2% through SS extrusion with preoptimized parameters

Sriviti et al., Ind. Crops Prod. 2011, 33, 659-64.

Results

Twin-screw extrusion
- Screw profile alterations near the pressing module
- Variation of seeds inlet flow rate and screw speed of screw profile 1 (Trials 1-4)
- Variation of seeds inlet flow rate and extrusion temperature on screw profile 2 (Trials 5-10)

<table>
<thead>
<tr>
<th>Trial</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Trial 4</th>
<th>Trial 5</th>
<th>Trial 6</th>
<th>Trial 7</th>
<th>Trial 8</th>
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<tr>
<td>Q_s (kg/h)</td>
<td>3.1</td>
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<td>6.2</td>
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<tr>
<td>S_s (rpm)</td>
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<td>100</td>
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<tr>
<td>C_F (g/h rpm)</td>
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<td>62</td>
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<td>39</td>
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<td>T (°C)</td>
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Results

Twin-screw extrusion

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<td>S_p (rpm)</td>
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Screw profile, extruder filling and temperature important extrusion parameters

Optimization of pressing zone through reversed screw pitch and distance between filter and pressing zone

Intermediate filling of the extruder to enhance pressing and avoid excessive foot contents

Reduction in extrusion T increases extraction efficiency and foot content

Solutions for excessive foot include adjustments of filter section and screw profile
Results

Economical considerations

- Enhanced pressure buildup (higher $C_F$ or lower $T$)
- Increase in energy consumption
- Coriander oil more expensive to produce than jatropha oil
- More economical than single-screw extrusion (80% reduction for jatropha oil)

1Evon et al., Ind. Crops Prod. 2013, 47, 33-42.

Biorefinery for Food, Fuels and Materials 2015

Results

Quality considerations

<table>
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<tr>
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<th>Trial 2</th>
<th>Trial 4</th>
<th>Trial 7</th>
<th>Trial 8</th>
<th>Trial 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA content (%)</td>
<td>72.8 ± 0.2</td>
<td>72.9 ± 0.2</td>
<td>73.4 ± 0.2</td>
<td>73.3 ± 0.1</td>
<td>73.3 ± 0.2</td>
</tr>
<tr>
<td>FFA (%)</td>
<td>1.46 ± 0.04</td>
<td>1.47 ± 0.01</td>
<td>1.41 ± 0.07</td>
<td>1.46 ± 0.01</td>
<td>1.52 ± 0.08</td>
</tr>
<tr>
<td>Essential oil</td>
<td>0.14 ± 0.01</td>
<td>0.14 ± 0.01</td>
<td>0.14 ± 0.01</td>
<td>0.18 ± 0.01</td>
<td>0.31 ± 0.02</td>
</tr>
</tbody>
</table>

- Good quality oil rich in petroselinic acid for all trials
- Significant increase in essential oil content of press cake with decreasing extrusion $T$
- Co-extraction of vegetable and essential oil during extrusion
Conclusion

- Coriander oil shows high potential for food, cosmetic and chemical industry
- Extrusion technology as an efficient and environmentally friendly method for coriander oil extraction
- Screw profile, extruder filling and temperature most important parameters
- Oil recoveries of about 50% may be improved through seed pre-treatments prior to extrusion
- Co-extraction of vegetable and essential oil renders flavoured vegetable oil with added value

Thank you for your attention!

Evelien.uitterhaegen@ensiacet.fr