Extrusion technology as a promising tool for vegetable oil extraction: Biorefinery of Apiaceae fruits

Evelien Uitterhaegen, Othmane O. Merah, Thierry Talou, Chris V. Stevens, Luc Rigal, Philippe Evon

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

Evelien Uitterhaegen[1,2], O. Merah[1,2], T. Talou[1,2], C.V. Stevens[3], L. Rigal[1,2], P. Evon[1,2]

[1]Université Fédérale de Toulouse Midi-Pyrénées, INP-ENSIACET, LCA (Laboratoire de Chimie Agro-industrielle), F-31030 Toulouse, France
[2]INRA, UMR 1010 CAI, F-31030 Toulouse, France
[3]SynBioC, 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.

LCA LABORATOIRE DE CHIMIE AGRO-INDUSTRIELLE

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

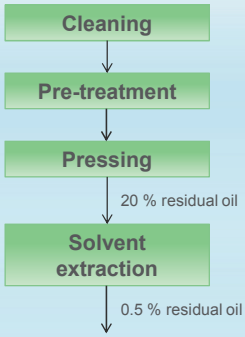
INP ENSIACET INRA agro mat

Overview

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

Introduction

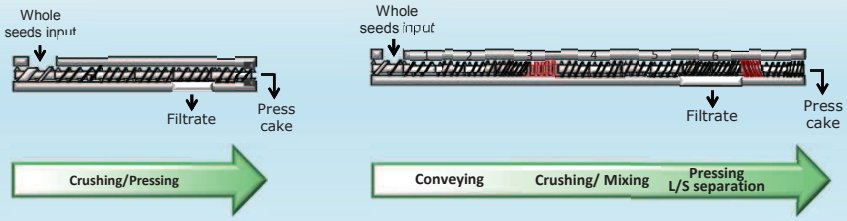
Vegetable oil extraction



- Typical industrial extraction process for high oil content seeds (e.g. rapeseed)
- Solvent extraction → Reduced quality of oil and meal
- Use of hazardous solvents → Health and environmental concerns
- Extrusion technology as a high-pressure operation towards low residual oil contents

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

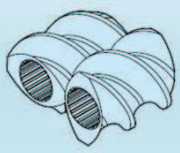
Twin-screw extrusion

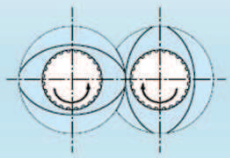
- Co-rotating twin-screw extruder (Clextral BC21)
- Mechanical-thermal-chemical process
- Temperature-regulated modules
- Filter section near the pressing zone
- Screw profile consists of segmental screw elements (25 or 50 cm)
- Different types of screw elements exert different forces on raw material

Vegetable oil extraction

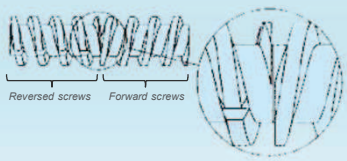
Twin-screw extrusion

- Forward pitch screws → Conveying action





- Reverse pitch screws → Pressing action

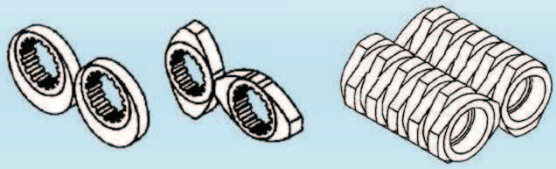


Images from Clextral documentation

Vegetable oil extraction

Twin-screw extrusion

- Monolobe and bilobe paddles → Trituration zone

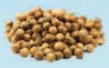


- Versatility through setup of screw profile and pitch of screw elements

Images from Clextral documentation

Coriander as a model herb

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

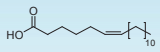


Coriandrum sativum L. fruits

Food and cosmetic industry

20-28% Vegetable oil

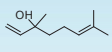
70 % Petroselinic acid



0.3-0.9% Essential oil

Perfume industry

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[1]

[1]Sriti *et al.*, *Ind. Crops Prod.* **2011**, *33*, 659-64.

Results

Twin-screw extrusion

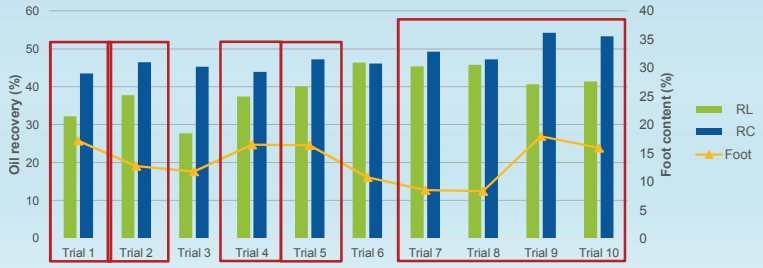
- Screw profile alterations near the pressing module
- Variation of seeds inlet flow rate and screw speed of screw profile 1 (Trials 1-4)
- Variation of seeds inlet flow rate and extrusion temperature on screw profile 2 (Trials 5-10)

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10
Q_S (kg/h)	3.1	4.7	6.2	6.2	3.2	3.9	4.7	4.7	4.7	4.7
S_S (rpm)	100	100	100	133	100	100	100	100	100	100
C_F (g/h rpm)	31	47	62	47	32	39	47	47	47	47
T (℃)	120	120	120	120	120	120	120	100	80	65

Results

Twin-screw extrusion

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10
Q_S (kg/h)	3.1	4.7	6.2	6.2	3.2	3.9	4.7	4.7	4.7	4.7
S_S (rpm)	100	100	100	133	100	100	100	100	100	100
C_F (g/h rpm)	31	47	62	47	32	39	47	47	47	47
T (℃)	120	120	120	120	120	120	120	100	80	65



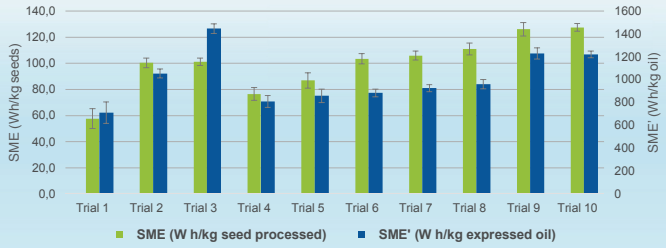
Results

Twin-screw extrusion

- 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[1]
- More economical than single-screw extrusion (80% reduction for jatropha oil)

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

Results

Quality considerations

	Trial 2	Trial 4	Trial 7	Trial 8	Trial 10
PA content (%)	72.8 ± 0.2	72.9 ± 0.2	73.4 ± 0.2	73.3 ± 0.1	73.3 ± 0.2
FFA (%)	1.46 ± 0.04	1.47 ± 0.01	1.41 ± 0.07	1.46 ± 0.01	1.52 ± 0.08
Essential oil content (% db)	0.14 ± 0.01	0.14 ± 0.01	0.14 ± 0.01	0.18 ± 0.01	0.31 ± 0.02

- 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

LCA LABORATOIRE DE CHIMIE AGRO-INDUSTRIELLE

Thank you for your attention!

Evelien.uitterhaegen@ensiacet.fr