The thermo-mechano-chemical fractionation of sunflower whole plant in twin-screw extruder, an opportunity for its biorefinery

Abstract:

Biorefinery of sunflower whole plant is conducted according to an aqueous process using a twin-screw extruder. Aqueous extraction of oil is looked upon as an environmentally cleaner alternative technology to solvent extraction. Twin-screw extruder carries out three unit operations continuously: conditioning and grinding of whole plant, liquid/solid extraction and liquid/solid separation. Extraction efficiency depends on screw speed, and input flow rates of whole plant and water. In best conditions, oil yield is 57%, and residual oil content in cake meal is 14%. These conditions lead to the co-extraction of proteins, pectins and hemicelluloses. Oil is extracted in the form of two oil-in-water emulsions stabilized by phospholipids and proteins at interface. They could be used as co-emulsifiers for creams production in cosmetic industry. An aqueous extract containing part of the water-soluble constituents from whole plant, mainly proteins and pectins, is also generated. It can be recycled to the process. As a mixture of fibers and proteins, the cake meal can be moulded by thermo-pressing. Denser fiberboards have promising mechanical properties in bending. They could be used in furniture industry. Fiberboards with the lowest densities are more fragile but they could be used for their heat insulation properties in building industry.

Key words: sunflower whole plant, twin-screw extruder, aqueous extraction process, oil and extraction, proteins and extraction, thermo-pressing, biodegradable agromaterials

The thermo-mechano-chemical fractionation of sunflower whole plant in twin-screw extruder, an opportunity for its biorefinery

Ph. Evon [a,b,*], V. Vandenbossche [a,b], P.Y. Pontalier [a,b], L. Rigal [a,b]

[a] Université de Toulouse, INP, Laboratoire de Chimie Agro-industrielle, ENSIACET, 4 Allée Emile Monso, BP 44362, 31030 Toulouse Cedex 4, France

[b] INRA, Laboratoire de Chimie Agro-industrielle, 31030 Toulouse Cedex 4, France

* Corresponding author. *E-mail address:* Philippe.Evon@ensiacet.fr (Ph. Evon)

Introduction

- The aqueous extraction process is an environmentally cleaner alternative technology to the solvent oil extraction process from oilseeds [1-2]. It enables the simultaneous production of an oil-in-water emulsion (hydrophobic phase) and a protein isolate (hydrophilic phase) in the same process.
- The use of a co-rotating twin-screw extruder allows the aqueous extraction of sunflower oil from seeds or press cakes [1-2]. However, no filtrate is obtained without the addition of fibers (wheat straw or sunflower depithed stalk) upstream from the filtration module.
- The aqueous extraction of sunflower oil is still effective starting from the whole plant [3-4]. Wringing out the mixing is even easier because of the natural abundance of fibers in the sunflower stalk (until 80%).
- Direct application of the fractions obtained after aqueous extraction in the twin-screw extruder as bases for industrial products is investigated in this study.

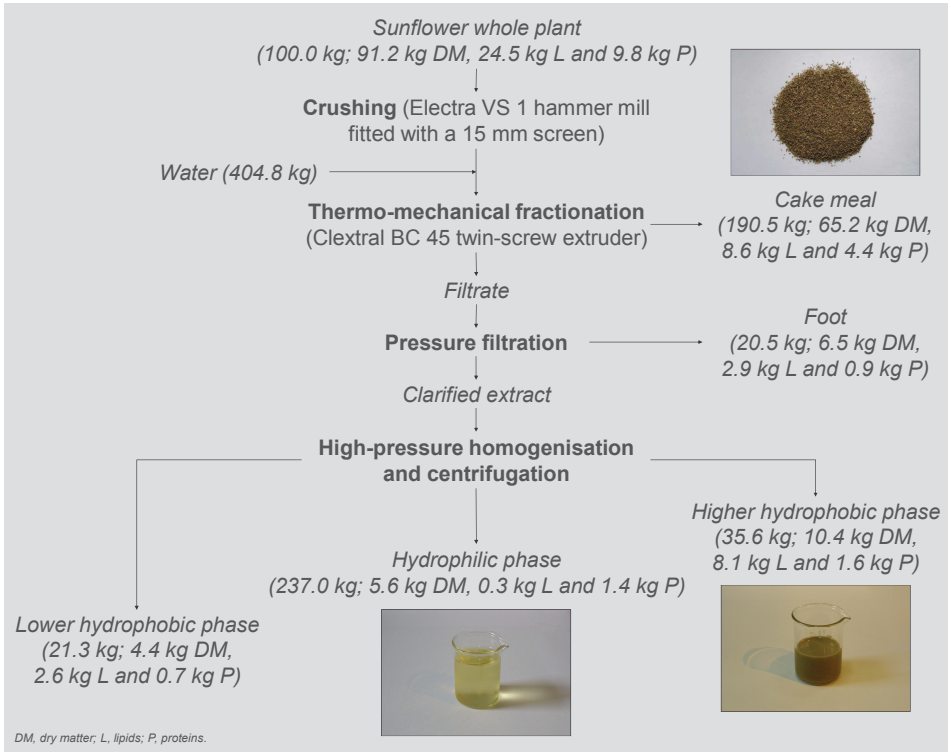
Key words: *sunflower whole plant, twin-screw extruder (TSE), aqueous extraction process, oil and extraction, proteins and extraction, thermo-pressing, biodegradable agromaterials.*

Experimental

- **Oleic sunflower whole plant** (15 mm homogenate) (La Toulousaine de Céréales, France): 8.8% of moisture content. – 6.5% of mineral content; 26.8% of oil content; 10.7% of protein content; 40.9% of fibers content (cellulose, hemicelluloses and lignins).
- Clextral BC 45 (France) **co-rotating and co-penetrating twin-screw extruder** (optimized screw profile, 80° C for thermal induction).

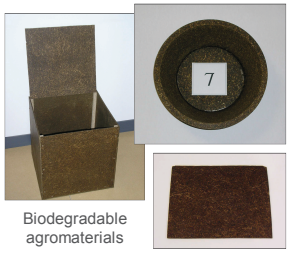
Results and discussion

- Biorefinery of sunflower whole plant is conducted according to an aqueous process using a TSE. Aqueous extraction of oil is looked upon as an environmentally cleaner alternative technology to solvent extraction.
- Twin-screw extruder carries out three unit operations continuously: conditioning and grinding of whole plant, liquid/solid extraction and liquid/solid separation.
- Extraction efficiency depends on screw speed, and input flow rates of whole plant and water. In best conditions, oil yield is 57%, and residual oil content in cake meal is 14%. These conditions lead to the co-extraction of proteins, pectins and hemicelluloses.
- Oil is extracted in the form of two *oil-in-water emulsions* stabilized by phospholipids and proteins at interface. They could be used as co-emulsifiers for creams production in **cosmetic industry**.
- An *aqueous extract* containing part of the water-soluble constituents from whole plant, mainly proteins and pectins, is also generated. It can be recycled to process.
- As a mixture of fibers and proteins, the *cake meal* can be moulded into agromaterials by thermo-pressing [3-6].
- Denser fiberboards have promising mechanical properties in bending (until 11.5 MPa for flexural strength at break, 2.2 GPa for elastic modulus, and 1040 kg/m^3 for the corresponding density). They could be used in **furniture industry**.



Matter assessment for the thermo-mechanical fractionation of sunflower whole plant conducted with the Clextral BC 45 twin-screw extruder (60 rpm for the screw rotation speed; 5.0 kg/h for the inlet flow rate of sunflower whole plant; 20.3 kg/h for the inlet flow rate of water)

- Fiberboards with the lowest densities are more fragile but they could be used for their heat insulation properties in **building industry** (until 88.5 mW/m K for thermal conductivity at 25° C, 0.228 m^2 K/W for thermal resistance, and 500 kg/m^3 for the corresponding density).



Biodegradable agromaterials

Conclusion

- The feasibility of an aqueous extraction process for the biorefinery of sunflower whole plant using a co-rotating twin-screw extruder is confirmed.
- Aqueous extraction of sunflower oil is chosen as an environment-friendly alternative to the solvent extraction.
- The co-rotating twin-screw extruder behaves like a thermo-mechanical reactor. It is equipped with a filtration module to obtain separately an extract and a raffinate. This only apparatus is used to carry out continuously three essential unit operations: (i) conditioning and grinding of sunflower whole plant, (ii) liquid/solid extraction, and (iii) liquid/solid separation.
- The process can be considered as an original and powerful solution for fractionation and value-adding to sunflower since the obtained fractions may have applications as bases for industrial products.

REFERENCES

[1] Evon, Ph., Vandenbossche, V., Pontalier, P.Y., Rigal, L., Direct extraction of oil from sunflower seeds by twin-screw extruder according to an aqueous extraction process: feasibility study and influence of operating conditions. *Industrial Crops and Products*, **26 (3)**, 351-359 (2007).

[2] Evon, Ph., Vandenbossche, V., Pontalier, P.Y., Rigal, L., Aqueous extraction of residual oil from sunflower press cake using a twin-screw extruder: feasibility study. *Industrial Crops and Products*, **29 (2-3)**, 455-465 (2009).

[3] Evon, Ph., Vandenbossche, V., Pontalier, P.Y., Rigal, L., La technologie d'extrusion bi-vis, une solution originale et performante pour le bioraffinage du tournesol plante entière. *Oléagineux, Corps gras & Lipides*, **17 (6)**, 404-417 (2010).

[4] Evon, Ph., Vandenbossche, V., Pontalier, P.Y., Rigal, L., Method for manufacturing a solid material from an oleaginous plant, and resulting solid material. Patents *FR 2 967 689* and *WO/2012/069738* (2012).

[5] Evon, Ph., Vandenbossche, V., Pontalier, P.Y., Rigal, L., Thermo-mechanical behaviour of the raffinate resulting from the aqueous extraction of sunflower whole plant in twin-screw extruder: manufacturing of biodegradable agromaterials by thermopressing. *Advanced Materials Research*, **112**, 63-72 (2010).

[6] Evon, Ph., Vandenbossche, V., Rigal, L., Manufacturing of renewable and biodegradable fiberboards from cake generated during biorefinery of sunflower whole plant in twin-screw extruder: influence of thermo-pressing conditions. *Polymer Degradation and Stability*, **97 (10)**, 1940-1947 (2012).

INP ENSIACET · INRA · Université de Toulouse

Montréal 2013 — 104th AOCS Annual Meeting & Expo — April 28–May 1, 2013 | Palais des congrès de Montréal | Montréal, Québec, Canada