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New process for the biorefinery of sunflower whole plant by thermo-mechanical fractionation and aqueous extraction in a twin-screw extruder

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Fractionation of sunflower whole plant is carried out with water in a twin-screw extruder. An extract and a raffinate are produced in a single step. Oil extraction yield is 55%. Lipids are extracted in the form of two oil-in-water emulsions: the higher hydrophobic phase and the lower one.
Stability of both hydrophobic phases is ensured by the presence at interface of surface-active agents co-extracted: phospholipids and proteins. Pectins and non pectic sugars complete the dry matter of the lower hydrophobic phase. Hydrophobic phases may have applications for non food uses: biolubricants market, transport of active principles (odours, colours, bactericides, antifungals), and treatment of hydrophilic surfaces. They can be also used for oil production because their demulsification with ethanol is efficient. Oil recovery produces also a precipitate containing proteins with tensioactive properties.
The extract contains also a hydrophilic phase (aqueous phase). This largest phase is an extract of the soluble constituents from whole plant: proteins from kernel, pectins from pith and head, and hemicelluloses from stalk. Valorization of hydrophilic phase is difficult because it is much diluted. Nevertheless, it would be potentially recyclable for aqueous extraction. It would be also possible to use it for the production of proteins with surface-active properties and pectins.
The raffinate (cake meal) is rich in fibres and proteins with thermoplastic properties. It would be suitable for use in animal feeds and for energy production. It is also a natural composite, and it can be manufactured into biodegradable agromaterials by compression moulding. Panels can be used as inter-layer sheets for pallets or for the manufacturing of containers.

New process for the biorefinery of sunflower whole plant by thermo-mechanical fractionation and aqueous extraction in a twin-screw extruder

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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 implementation of a co-rotating twin-screw extruder allows the aqueous extraction of sunflower oil [3-4]. However, no filtrate is obtained without the addition of fibers upstream from the filtration module. Two lignocellulosic residues were tested successfully: the wheat straw and the sunflower depithed stalk.

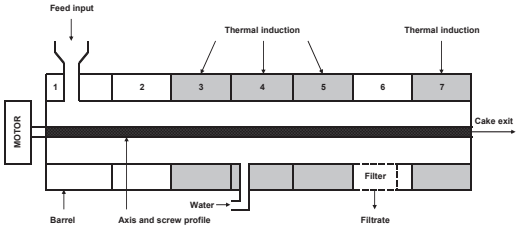
► The aqueous extraction of sunflower oil is still effective starting from the whole plant [5]. Wringing out the mixing is even easier because of the natural abundance of fibers in the sunflower stalk (until 80%).

► Direct application of the fractions obtained after aqueous extraction in the twin-screw extruder as bases for industrial products is investigated in this study.

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).

► **Twin-screw extruder:**



1	2	3	4	5	6	7
T2F 66 / C2F 50	C2F 33	DM 10×10 (45°) / C2F 25	BB 5×5 (90°) / C2F 33	C1F 33 / C1F 25	BB 5×5 (90°) / C1F 33 / C1F 33	C1F 25 / C1F 15 / CF1C 15 / C1F 25

T2F = trapezoidal double-thread screw. C2F = conveying double-thread screw. C1F = conveying simple screw. BB = bilobe paddle-screw. DM = monolobe paddle-screw. CF1C = reversed simple screw. – The numbers following the type of the screw indicate the pitch of T2F, C2F, C1F and CF1C screws and the length of the BB and DM screws.

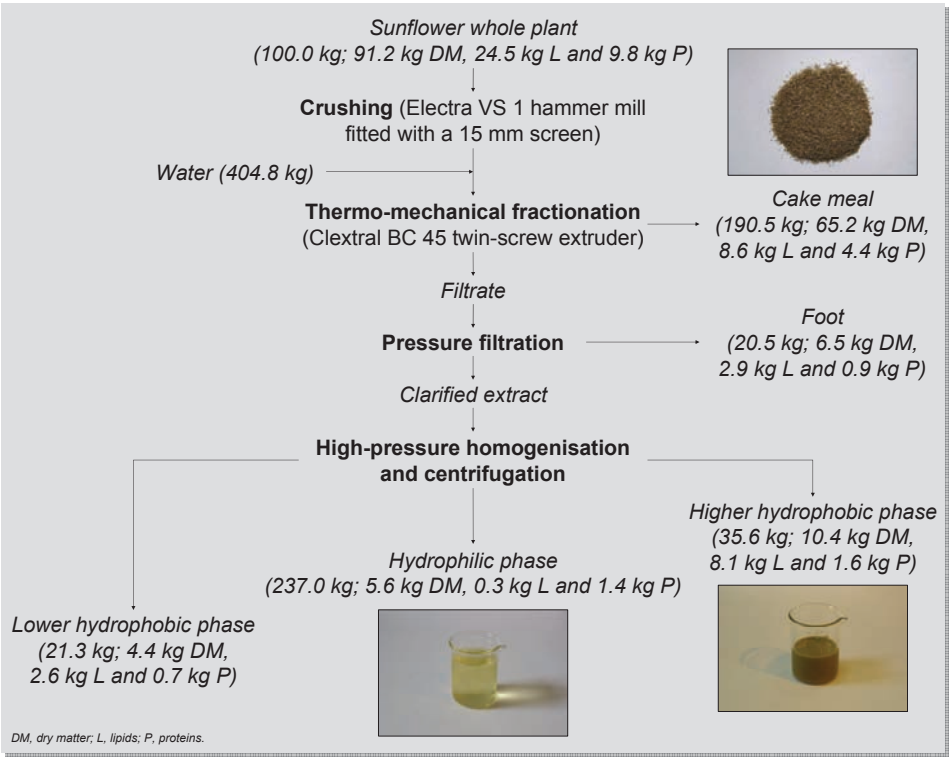
Schematic modular barrel and screw configuration of the Clextral BC 45 (France) twin-screw extruder (θ = 80℃ for thermal induction).

Results and discussion

► Fractionation of sunflower whole plant is carried out with water in a twin-screw extruder.

► An extract and a raffinate are produced in a single step.

► Oil extraction yield is 53%, and protein extraction yield is 46%.



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).

► Lipids are extracted in the form of two different **oil-in-water emulsions**: (i) the **higher hydrophobic phase**, and (ii) the **lower hydrophobic phase**.

► Stability of both hydrophobic phases is ensured by the presence at interface of surface-active agents co-extracted during the aqueous process: (i) phospholipids, and (ii) proteins. Pectins and non pectic sugars complete the dry matter of the lower hydrophobic phase.

► Hydrophobic phases may have applications for non food uses: (i) the biolubricants market, (ii) the transport of active principles (odours, colours, bactericides, antifungals), and (iii) the treatment of hydrophilic surfaces.

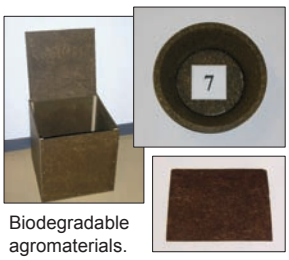
► They can be also used for oil production because their demulsification with ethanol or with ethanol/ether mixture (3/1) is efficient. Oil recovery produces also a precipitate containing proteins with tensioactive properties.

► The extract contains also a **hydrophilic phase** (**aqueous phase**). This largest fraction is an aqueous extract of the soluble constituents from whole plant: (i) proteins from kernel, (ii) pectins from pith and head, and (iii) hemicelluloses from stalk.

► Valorization of hydrophilic phase is difficult because it is much diluted. Nevertheless, it would be potentially recyclable for aqueous extraction. It would be also possible to use it for the production of proteins with surface-active properties and pectins.

► The **raffinate** (**cake meal**) is rich in fibers and proteins with thermoplastic properties. It would be suitable for use in animal feeds and for energy production. It is also a natural composite, and it can be manufactured into biodegradable agromaterials by compression moulding (until 11.5 MPa for the stress at break, and 1.04 for the corresponding mean apparent density).

► Panels can be used as inter-layer sheets for pallets or for the manufacturing of containers by assembly of panels.



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 three essential unit operations in a single step and in a continuous mode: (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.

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