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

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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

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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 (hydophilic 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 dephted 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): 8.5% of moisture content; – 6.5% of mineral content; 28.8% of oil content; 10.2% 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 [3-8].
- Denser fiberboards have promising mechanical properties in bending (until 11.5 MPa for flexural strength at 2.2 GPa for elastic modulus, and 1040 kg/m² for the corresponding density). 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 (until 88.5 mW/m K for thermal conductivity at 25 °C, 0.228 m² kW for thermal resistance, and 500 kg/m³ for the corresponding density).

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.

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