The twin-screw extruder, a continuous liquid/solid extractor and separator during sunflower (*Helianthus annuus* L.) biorefinery

<u>P. Evon</u> [a,b,*], **L. Labonne** [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, 31030 Toulouse Cedex 4, France
[b] INRA, Laboratoire de Chimie Agro-industrielle, 31030 Toulouse Cedex 4, France
* E-mail address (presenting author): Philippe.Evon@ensiacet.fr (P. Evon)

Biorefinery of sunflower whole plant can be conducted with water using a nine modules Clextral Evolum HT 53 twin-screw extruder (TSE). Aqueous extraction of oil is an environmentally cleaner alternative technology to solvent extraction. TSE carries out three unit operations: conditioning and grinding, liquid/solid (L/S) extraction and L/S separation.

The compressing action by the reverse screws (CF2C) is essential for L/S separation. Positioned in module 9, CF2C screws push part of the mixture upstream against the general movement in TSE, and this counter pressure ensures the L/S separation efficiency above the metal filter, located in eighth position.

Oil is extracted in the form of two emulsions, stabilized by phospholipids and proteins, and usable as co-emulsifiers in cosmetic industry. An aqueous extract containing water-soluble components from whole plant is also generated; it could be recycled. As a mixture of fibers and proteins, the cake can be moulded by thermo-pressing into boards, usable in the furniture and building industries.

In this study, fractionation was conducted from next inlet flow rates: 54 kg/h solid and 183 kg/h water (3.4 L/S ratio). The screw speed varied from 249 to 124 rpm, corresponding to a filling coefficient (ratio of the solid inlet flow rate to the screw speed) from 217 to 436 g/h rpm.

The filling coefficient directly affects the L/S separation efficiency. The latter can be estimated from next experimental data: the outlet flow rates of both cake and filtrate, the cake moisture content, the residual contents of oil and water-soluble components in the cake, and the extraction yields in dry matter, lipids and water-soluble components.

For low filling coefficients (i.e. high screw speed), the L/S mixture compression in CF2C screws is insufficient, not allowing a satisfactory L/S separation. Conversely, for high filling

coefficients (i.e. low screw speed), solid particles accumulate more upstream from the pressing zone, obstructing part of the filtering screens and thus reducing the filtration surface. A less efficient L/S separation is then observed.

From the experimental data evolution, optimal screw speed was estimated at 182 rpm using a second order polynomial regression, corresponding to a filling coefficient of 297 g/h rpm. Extraction yields in dry matter, lipids and water-soluble components were 22%, 49% and 40%, respectively. Such filling would lead to a specific mechanical energy of 103 W/h kg whole plant processed.

Key words: sunflower whole plant, biorefinery, twin-screw extruder, aqueous extraction process, oil and extraction, proteins and extraction

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[a] Université de Toulouse, INP, Laboratoire de Chimie Agro-industrielle, ENSIACET, 31030 Toulouse, France

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

* Corresponding author. Tel.: + 33 5 62 44 60 80; fax: + 33 5 62 44 60 82

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

Introduction

- Biorefinery of sunflower whole plant can be conducted with water using a nine modules Clextral (France) Evolum HT 53 twin-screw extruder (TSE) [1].
- Aqueous extraction of oil is an environmentally cleaner alternative technology to solvent extraction.
- TSE carries out three unit operations: (i) **conditioning and grinding**, (ii) **liquid/solid (L/S) extraction** and (iii) **L/S separation**.
- The compressing action by the reverse screws (CF2C) is essential for L/S separation. Positioned in module 9, CF2C screws push part of the mixture upstream against the general movement in TSE, and this counter pressure ensures the L/S separation efficiency above the metal filter, located in eighth position.
- Oil is extracted in the form of two emulsions, stabilized by phospholipids and proteins, and usable as co-emulsifiers in **cosmetic industry** [1, 2].
- An aqueous extract containing water-soluble components from whole plant is also generated; it could be recycled [1, 2].
- As a mixture of fibers and proteins, the cake can be moulded by thermo-pressing into boards, usable in the **furniture and building industries** [1-3].
- Because the filling coefficient of TSE directly affects the L/S separation efficiency, this study aimed to evaluate its optimal value.

Keywords: *Sunflower whole plant, biorefinery, twin-screw extruder, aqueous extraction process, oil and extraction, proteins and extraction.*

Results and discussion

- In this study, fractionation was conducted from next inlet flow rates: 54 kg/h solid and 183 kg/h water (i.e. 3.4 L/S ratio). The screw speed (S_S) varied from 249 to 124 rpm, corresponding to a filling coefficient (ratio of the solid inlet flow rate to the screw speed) (C_F) from 217 to 436 g/h rpm.
- The filling coefficient directly affects the L/S separation efficiency. The latter can be estimated from next experimental data: the outlet flow rates of both cake (Q_C) and filtrate (Q_F) (Fig. 1), the cake moisture content (H_C) (Fig. 2a), the residual contents of lipids (L_C) and water-soluble components (WS_C) in the cake (Fig. 2b), and the extraction yields in dry matter (R_{DM}), lipids (R_L) and water-soluble components (R_{WS}) (Fig. 2c).

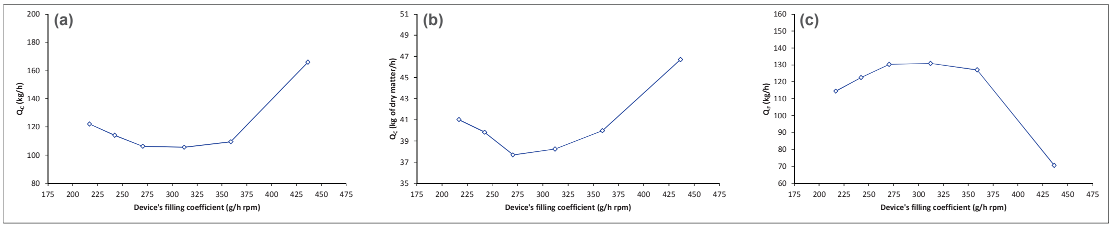

Fig. 1. Outlet flow rates of the cake (a and b) and the filtrate (c) as a function of the device's filling coefficient.

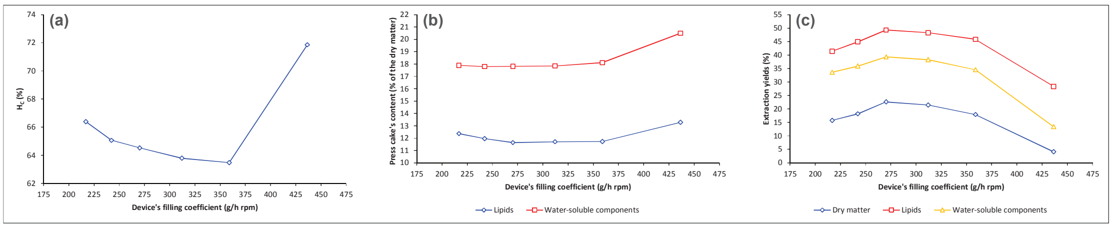

Fig. 2. Moisture content (a) and residual contents in lipids (b) and water-soluble components (b) of the cake, and extraction yields in dry matter (c), lipids (c) and water-soluble components (c) as a function of the device's filling coefficient.

- For low filling coefficients (i.e. high screw speed), the L/S mixture compression in CF2C screws is insufficient, not allowing a satisfactory L/S separation.
- Conversely, for high filling coefficients (i.e. low screw speed), solid particles accumulate more upstream from the pressing zone, obstructing part of the filtering screens and thus reducing the filtration surface. A less efficient L/S separation is then observed.

Table 1. Optimal device's filling coefficient and optimal screw speed estimated using a second order polynomial regression from each experimental data, and corresponding mean value and standard deviation.

Experimental data	Q_C (kg/h)	Q_C (kg of DM/h)	Q_F (kg/h)	H_C (%)	R_{DM} (%)	L_C (% of DM)	R_L (%)	WS_C (% of DM)	R_{WS} (%)	*Mean value*
Optimal C_F value (g/h rpm)	299	295	299	306	297	307	300	276	291	***297±9***
Optimal S_S value (rpm)	181	183	181	176	182	176	180	196	186	***182±6***

DM, dry matter.

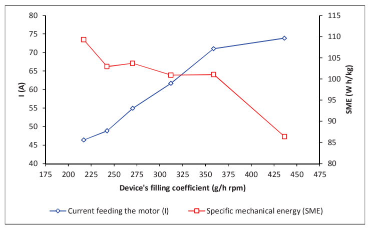

Fig. 3. Current feeding the motor and specific mechanical energy as a function of the device's filling coefficient.

Conclusion

- From the experimental data evolution, optimal filling coefficient was estimated at 297 g/h rpm using a second order polynomial regression, corresponding to a screw speed of 182 rpm (Table 1).
- Extraction yields in dry matter, lipids and water-soluble components were then estimated at 22%, 49% and 40%, respectively (Fig. 2c).
- Such filling would lead to a specific mechanical energy of 103 W/h kg whole plant processed (Fig. 3).

REFERENCES

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