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The twin-screw extruder, a continuous liquid/solid extractor and separator during sunflower biorefinery

*Helianthus annuus* L.) biorefinery

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

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Introduction

- Biorefinery of sunflower whole plant can be conducted with water using a nine modules Clextral (France) Evolvm 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 compressed action by the reverse screws (CF2C) is essential for L/S separation. Positioned in module 9, CF2C screw push part of the mixture up-stream 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) varied from 249 to 124 rpm, corresponding to a filling coefficient (ratio of the solid inlet flow rate to the screw speed) (C) 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) and filtrate (Q) (Fig. 1), the cake moisture content (H) (Fig. 2a), the residual contents of lipids (L) and water-soluble components (WS) in the cake (Fig. 2b), and the extraction yields in dry matter (R), lipids (R) and water-soluble components (R) (Fig. 2c).

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.

<table>
<thead>
<tr>
<th>Experimental data</th>
<th>Optimal C value (g/h rpm)</th>
<th>Optimal S value (rpm)</th>
<th>Mean value</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qc (kg/h)</td>
<td>217</td>
<td>181</td>
<td>297</td>
<td>297 ± 21</td>
</tr>
<tr>
<td>Qr (kg of DM)</td>
<td>436</td>
<td>183</td>
<td>300</td>
<td>300 ± 27</td>
</tr>
<tr>
<td>Hc (%)</td>
<td>307</td>
<td>176</td>
<td>276</td>
<td>276 ± 19</td>
</tr>
<tr>
<td>Lc (%)</td>
<td>300</td>
<td>182</td>
<td>196</td>
<td>196 ± 14</td>
</tr>
<tr>
<td>Rs (%)</td>
<td>249</td>
<td>168</td>
<td>188</td>
<td>188 ± 12</td>
</tr>
<tr>
<td>WSc (%)</td>
<td>297</td>
<td>183</td>
<td>291</td>
<td>291 ± 21</td>
</tr>
<tr>
<td>Rs (%)</td>
<td>124</td>
<td>176</td>
<td>300</td>
<td>300 ± 27</td>
</tr>
<tr>
<td>DM, dry matter</td>
<td></td>
<td></td>
<td>297 ± 21</td>
<td></td>
</tr>
</tbody>
</table>

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


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 (c) 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.

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