Development of a new tool for the prediction of fruit juices microfiltration performance

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Outlines

Context and aim of the work

Scientific strategy

Results and discussion

1. Juices physicochemical characterization
2. Juices filterability tests
3. Statistical analysis
4. Prediction of fruit juices filterability

Conclusion
Context of the Work

Consumption of fruit juices and drinks containing fruit juices

Cross-flow microfiltration

• Safe product
• Fresh-like quality

Predicting and controlling juice filterability

Membrane fouling

Membrane permeability diminution

Aim of the Work

Most of publications

- Optimization approaches and strategies
- Pre-treatment and/or conditioning of juices to be filtered

Lack of knowledge

- Study the possibility of predicting fruit juices filterability according to some of their intrinsic characteristics

Lab-scale study

Develop a simple and fast juice filterability prediction tool

Potentiel industrial application
Scientific strategy

**Filterability response**

- Highlight most important juice characteristics for predicting fruit juices filterability.

**Physicochemical characterization**

- Conventional parameters: pH, conductivity, Dry matter.
- Physical Analysis: Particles size distribution, rheological behavior...
- Elemental analysis: Nitrogen, mineral...

**Variables / intrinsic characteristics of studied juices**

- **Response / filterability**

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**Juices physicochemical characterization**

**Juices selection**

Nine different commercial brands of orange juices

Stored at -20°C and defrosted before use at 4°C/one night

**Studied parameters**

<table>
<thead>
<tr>
<th>conventional</th>
<th>Total soluble solids (TSS), suspended insoluble solids (SIS), dry matter (DM), total acidity (TA), pH, conductivity, turbidity</th>
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<tr>
<td>Physical measurements</td>
<td>Particle size distribution, rheological behavior, capillary suction time</td>
</tr>
<tr>
<td>Elemental analysis</td>
<td>Nitrogen (N), Phosphorus (P), K+, Cl~, Na~, Ca^{2+}, Mg^{2+}</td>
</tr>
</tbody>
</table>
Values of these attributes were in the range of those previously reported for commercial orange juices.

Conventional parameters
Elemental analysis

![Graph showing elemental analysis of CJ 1 to CJ 9.](image)

**ICOM 2014** 9 24th of July 2014

![Another graph showing elemental analysis with N and P.](image)

**ICOM 2014** 10 24th of July 2014
Particle size measurement

**Equipement**
Laser diffraction, Malvern Mastersizer 3000
Refractive Indices 1,33 (water) 1,73 (cloud particles)
Absorption index 0,1 (cloud particles)

**Measurement method**
42% Obscuration
1500 rpm

\[D[3.2] = \frac{\sum n d_i^3}{\sum n d_i^2}\]

\(n\): number of particles
\(d\): diameter of particles

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Rheological behavior

\[\eta = K\dot{\gamma}^{n-1}\]

\(K\): consistency coefficient
\(n\): flow behavior index

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<table>
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<tr>
<th>Juices</th>
<th>CJ 1</th>
<th>CJ 2</th>
<th>CJ 3</th>
<th>CJ 4</th>
<th>CJ 5</th>
<th>CJ 6</th>
<th>CJ 7</th>
<th>CJ 8</th>
<th>CJ 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>(D[3.2])</td>
<td>27,3</td>
<td>21</td>
<td>100</td>
<td>138</td>
<td>52</td>
<td>30,7</td>
<td>100</td>
<td>81</td>
<td>51</td>
</tr>
</tbody>
</table>

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<th>CJ 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>(K)</td>
<td>12,6</td>
<td>12,2</td>
<td>197,9</td>
<td>440,3</td>
<td>96,6</td>
<td>13,4</td>
<td>8,9</td>
<td>9,7</td>
<td>11,5</td>
</tr>
<tr>
<td>(n)</td>
<td>0,6</td>
<td>0,6</td>
<td>0,4</td>
<td>0,3</td>
<td>0,4</td>
<td>0,6</td>
<td>0,3</td>
<td>0,3</td>
<td>0,3</td>
</tr>
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</table>
Capillary suction time

CST-meter, measure of capillary suction time

\[ \text{CST}= T_2 - T_1 \]

- Originally developed for assessing sludge filterability and industrial suspensions (Gale and Baskerville, 1967, (Ruiz et al., 2010)
- Not yet tested for fruit juices

Juices filterability tests

Filtration cell

- 25 mL
- 300 rpm
- Glass fiber membrane 1.2 μm

Evaluate the filterability of the studied juices

\[ \int (kg.h^{-1}.m^{-2}) = \frac{dm}{dt}, m \]

Robust Loess smoothing
Juices filterability tests

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<th>CJ 8</th>
<th>CJ 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Fluxes (Kg.h(^{-1}).m(^{-2}))</td>
<td>8.6</td>
<td>12.3</td>
<td>6.8</td>
<td>9.5</td>
<td>16.3</td>
<td>11.4</td>
<td>10.6</td>
<td>13.2</td>
<td>14.2</td>
</tr>
<tr>
<td>Initial Fluxes (Kg.h(^{-1}).m(^{-2}))</td>
<td>12.1</td>
<td>15.6</td>
<td>9.5</td>
<td>12.2</td>
<td>22.8</td>
<td>15.1</td>
<td>12.6</td>
<td>16.5</td>
<td>18.9</td>
</tr>
</tbody>
</table>

\[ y = 1.3157x \]
\[ R^2 = 0.9537 \]

Initial fluxes were used as the only filterability response variable in the statistical analysis.

Statistical analysis

Predictor variables > sample number

Variables correlated

- model-wise method (Afanador et al., 2013)
- PLS-VIP method (Afanador et al., 2013)

\[ R^2 = 0.957 \]
Statistical analysis and Prediction of fruit juices filterability

Predictor variables > number of samples

Variables correlated

PLS (Partial Least Squares regression)

Lease-one-out cross-validation test (LOOCV) (Cawley and Talbot, 2004)

<table>
<thead>
<tr>
<th>Number of samples</th>
<th>Number of variables</th>
<th>Mean of the measured initial fluxes</th>
<th>RMSEC et RMSECV &lt; 20% of the mean (Bikindou et al., 2012)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>17</td>
<td>15.0</td>
<td>0.79, 2.10, 0.957</td>
</tr>
<tr>
<td>9</td>
<td>5</td>
<td>15.0</td>
<td>1.06, 2.09, 0.923</td>
</tr>
</tbody>
</table>

Conclusion

It is possible to predict juices filterability according to their intrinsic characteristics

Filterability can be satisfactorily predicted according to Only five simple predictor variables

Possibility of extrapolating this strategy to industrial scale since the selected variables are simple and fast to measure
Thank you for your attention