Dry fractionation for sustainable production of functional pea ingredients

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Sustainability of protein

Animal protein
4-11 g protein/MJ*

Dry fractionation
28.2 g protein/MJ

Wet fractionation
3.5 g protein/MJ

Wet fractionation of legume protein

Starch-rich legume
- Milling
- Suspension in water
- Hydrocyclone

Starch

Oil-rich legume
- Milling
- Extraction
- Suspension in water

Oil

Solubilise protein

Insoluble carbohydrates

Precipitate protein

Soluble carbohydrates

Neutralise

Dry

Protein isolate

Mechanism dry fractionation legumes

- 23% protein bodies (3µm)
- 56% starch granules (22µm)
- 13% fibres
Milling and air classification

Pea -> Mill -> Flour -> Air classifier

Protein bodies -> Coarse material
Multi-processing system (Hosokawa-Alpine, Augsburg, Germany)
Dry fractionation versus wet fractionation

- Dry fractionation consists of combined milling and dry separation. Key advantages:
  - Less water, less energy
  - Retains native protein functionality
    - E.g. protein concentrates with high solubility
    - Retained potential for structuring
  - Protein purity 55% (pea) – 59% (lupine)
    - Focus on functionality rather than purity
- Dry enriched legume proteins: are low in fat rich in protein, dietary fibre and a variety of micronutrients and phytochemicals
Aim

- Explore more sustainable processing routes.
- Increase our understanding of:
  - material properties of the legume seeds.
  - process conditions relevant to the combined milling and dry separation of legumes.

**Milling of starch- and oil-rich legumes**

**Dry separation challenges**

- Obtain functional ingredient protein fractions rather than molecular pure proteins.

**Functionality of pea and lupine fractions**
Milling of starch-rich legumes

- Milling speed influences disclosure

- Insufficient: no complete disentanglement
- Optimal: loose protein bodies and starch granules
- Too fine: damage to starch granules
## Composition of pea fractions

<table>
<thead>
<tr>
<th>Sample</th>
<th>Starch content (g/100 g dry matter)</th>
<th>Protein content (g/100 g dry matter)</th>
<th>Fibre* (g/100 g dry matter)</th>
<th>NSI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starch isolate</td>
<td>84.3 ± 0.7</td>
<td>ND</td>
<td>15.7 ± 0.7</td>
<td>ND</td>
</tr>
<tr>
<td>Coarse</td>
<td>67.2 ± 1.6</td>
<td>9.5 ± 0.0</td>
<td>23.3 ± 1.6</td>
<td>89.4 ± 1.7</td>
</tr>
<tr>
<td>Flour</td>
<td>47.6 ± 1.0</td>
<td>22.4 ± 0.8</td>
<td>30.0 ± 1.3</td>
<td>85.8 ± 3.3</td>
</tr>
<tr>
<td>Fine</td>
<td>1.7 ± 0.0</td>
<td>49.7 ± 0.2</td>
<td>48.6 ± 0.2</td>
<td>85.0 ± 1.9</td>
</tr>
<tr>
<td>Protein isolate</td>
<td>ND</td>
<td>83.5 ± 0.2</td>
<td>16.5 ± 0.2</td>
<td>24.8 ± 2.2</td>
</tr>
</tbody>
</table>

ND: not detected, *included minor additional components, i.e. 2 g/100 g dry matter fat and 3 g/100 g dry matter ash.
Milling of oil-rich legumes (lupine)

- **Problem:**
  - Lupine contains fat
    - powder without fat
    - powder with fat
    - non sticky
    - sticky
  - Milling reduces the size of fibre to that of protein bodies

- **Solution:** mill coarse
Air classification challenges

- Problem: low dispersibility (yield)
Air classification challenges

- **Problem:** low dispersibility (yield)

- **Solution:** add dispersant for higher yield

<table>
<thead>
<tr>
<th>Sample</th>
<th>Protein content fine fraction (w/dw)</th>
<th>Protein separation efficiency (%)</th>
<th>Yield fine fraction % (w/w)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lupine</td>
<td>58.9 ± 0.1</td>
<td>10.0 ± 0.3</td>
<td>6.1 ± 0.1</td>
</tr>
<tr>
<td>Lupine + aerosil</td>
<td>49.7 ± 0.5</td>
<td>21.3 ± 5.8</td>
<td>13.9 ± 3.9</td>
</tr>
</tbody>
</table>

Protein content versus yield

- Starch-rich legumes
- Oil-rich legume
Dry fractionation - Different driving forces
Laboratory-scale E-Separator

- **Experimental set-up:**
  - 1: \( \text{N}_2 \) Flow meter
  - 2: Power supply
  - 3: Feeder funnel & charging tube
  - 4: Separation chamber
Lab-scale E-separation results

- **Protein content (g protein / 100g dry matter)**
  - Pea flour
  - Pea fine
  - Pea coarse
  - Lupine flour
  - Lupine fine
  - Lupine coarse

- **Start material**
- **Grounded electrode**
- **Positive electrode**
Functionality of pea

Hypothesis: starch/protein ratio influences WHC

Native pea flour

- Native: protein contents > 30% → concentrated liquid, due to high solubility
- Denatured: high WHC, due to gelatinized starch

Pea: Heat-induced gel formation

- Gel strength increases with increasing starch content
- Protein and fibres form domains that weaken the gel

Green: aqueous phase, red: protein, light blue: cell wall (cellulose)
Enzymatically-induced pea protein gels are stronger than heat-induced protein gels.

Starch and fibre in the fine fraction absorb water, which increases the protein content and the gel strength.

Suspensions of fractions

- Suspension phase separate
- Mild separation method: 77.4 g protein/100 g dry matter, yield 63 g/100 g
- Conventional wet fractionation: 80-85 g protein/100 g, yield of 55-65 g/100 g

<table>
<thead>
<tr>
<th>Sample</th>
<th>Protein content layer 1 (g/100 g dry matter)</th>
<th>Protein content layer 2 (g/100 g dry matter)</th>
<th>Protein content layer 3 (g/100 g dry matter)</th>
<th>Protein content layer 4 (g/100 g dry matter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse</td>
<td>42.5 ± 0.8</td>
<td>61.1 ± 0.6</td>
<td>14.0 ± 0.2</td>
<td>1.4 ± 0.1</td>
</tr>
<tr>
<td>Flour</td>
<td>55.3 ± 0.4</td>
<td>65.9 ± 0.3</td>
<td>18.7 ± 0.3</td>
<td>2.2 ± 0.3</td>
</tr>
<tr>
<td>Fine</td>
<td><strong>68.6 ± 0.6</strong></td>
<td><strong>67.4 ± 2.7</strong></td>
<td>27.0 ± 0.2</td>
<td>8.9 ± 2.6</td>
</tr>
</tbody>
</table>

*Boyé, et al., 2010; Fredrikson, et al., 2001; Makri, et al.; 2005; Mondor, et al., 2012*
Lupine: Functionality

- Hypothesis: heating (less mild fractionation) changes functional properties

- Viscosity is lower for native proteins
- After digestion more small proteins are available in native proteins

Potential for high protein beverages
Conclusions

- **Dry fractionation:**
  - Separation is based on legume morphology
  - Is a sustainable way to refine protein
  - Delivers functional and healthy protein fractions
Outlook

- Further development of dry fractionation:
  - Optimise milling behaviour behaviour
  - Use combination of driving forces for separation
  - Select legume varieties ‘designed’ for dry fractionation

- Develop new product concepts that use functionality of dry-enriched fractions.
  - Suitable for high protein beverages and gels
  - Potential application in structured products (meat replacers)
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