Alternatives to water-plasticization in the extrusion process – reduced drying costs and improved physical pellet quality

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Outline

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  - Fish feed manufacturing process and challenges
  - Relationship between physical properties and final product quality
- Background and objectives
- Results and discussion
- Conclusive remarks
Introduction

Atlantic Salmon feed composition in Norway

- **marine proteins**
- **marine oil**
- **plant proteins**
- **plant oil**
- **starches**
- **microingredients**

Ytrebstøyl et al., 2015. Aquacult. 448, 365-375.
Processing technique

Texturized expanded product should meet:
- Expansion (porosity)
- Durability and hardness
- Density specifications
- Sinking velocity
- Water stability

Bin Feeder

Preconditioner
Moisture: 18 - 30%
Temp: 77 - 95 °C
1.5 - 4 min.

Extruder
Moisture: 18 - 30%
Temp: 120 - 145 °C
< 1 min.

with permission from Wenger
### General experience

<table>
<thead>
<tr>
<th>Feed Ingredient</th>
<th>Melt temperature</th>
<th>Torque</th>
<th>SME</th>
<th>Paste viscosity</th>
<th>Pellet quality at low moisture</th>
<th>Pellet quality at high moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fishmeal</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>Soy protein concentrate</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Poor</td>
<td>Good</td>
</tr>
</tbody>
</table>

- Inconsistent quality
- High moisture and thermomechanical energy required for plasticization
- High drying cost
Relationship between ingredient rheological properties and pellet quality

- Transformation from solid to less viscous flow-able state
  - Glass and flow transitions (T_g & T_f)
  - Reduction in viscosity
  - Viscoelastic properties
- Proteins with high T_f need more moisture and thermomechanical energy
Determination of physical properties – Phase Transition Analyzer (PTA)

Apparent viscosity at $T_f = 10^5$ Pa s

Plasticizing effect of solubles in fishmeal

1) Peptide size distribution of water soluble protein
2) Degree of protein hydrolysis
3) Water insoluble protein (thermal properties)
4) Particle size
5) Salt contents
6) pH

Plasticizing effect of solubles in fishmeal

Physical pellet quality

Objectives

1) Assess the plasticizing effect of free amino acid, pH and minerals salts in a SPC model system

2) Quantify the effect of the tested variables compared to moisture
Experimental design

- A screening design extended to a full face-centered central composite design were used to assess the significance of the studied variables:

  • Variables: moisture, amino acid, mono/divalent mineral salts, and pH
  
  • Responses: $T_g$ and $T_f$
## Results and discussion

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Glass transition temperature ($T_g$)</th>
<th>Flow-starting temperature ($T_f$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Amino acid</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Monovalent salt</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Divalent salt</td>
<td>↓</td>
<td>NS</td>
</tr>
<tr>
<td>pH</td>
<td>NS</td>
<td>↑</td>
</tr>
</tbody>
</table>

$T_g$ - 2.2 g amino acid gives equal effect as 1 g water

$T_f$ - 1.3 g amino acid gives equal effect as 1 g water
Reduced drying cost

<table>
<thead>
<tr>
<th>Inlet moisture (%)</th>
<th>Outlet moisture (%)</th>
<th>Water removal per ton of product produced (kg)</th>
<th>Increase in water removal (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>10</td>
<td>184</td>
<td>-</td>
</tr>
<tr>
<td>27</td>
<td>10</td>
<td>233</td>
<td>27</td>
</tr>
<tr>
<td>30</td>
<td>10</td>
<td>286</td>
<td>55</td>
</tr>
</tbody>
</table>

Feed produce in 2013 in Norway = 1.5 million metric tons

- Av. energy required for water evaporation = 3250 kJ
- Energy price in Norway = 4166 kJ / NOK
- Cost for 27% inlet moisture = 273 million NOK
- Cost for 30% inlet moisture = 335 million NOK
- Reduced cost replacing 3% moisture = 62 million NOK

Conclusive remarks

- For aquaculture sustainability, fishmeal has to be replaced with alternative plant proteins
- SPC based diet needs high moisture and thermomechanical energy
- Use of high moisture will increase drying cost; can be reduced by addition of alternative plasticizers
- Mineral salts have no plasticizing effect at high moisture content
- Amino acids will be effective plasticizers
- Exchange of water with an amino acid will reduce the energy consumption during drying of the pellet
Acknowledgement

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