Lecture 9. Pre-treatment of feed sources and
Lecture 10. Extrusion and nutritive value

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Pretreatment – where to perform

- The pretreatment agents (enzymes, yeast etc.) might be added before the extrusion line (if not it is not pretreatment)

Bioreactor

Place where pretreatment might be performed.

- Temperature
- Moisture
- Pressure
- pH
- Mixing poss.

Mixer

Incubated material is being mixed with the rest material that is not pretreated

Conditioner

Extruder barrel

www.umb.no
Pretreatment of feed sources I

- **Historical approach**
  - What is the old fashion way of pretreatment?
- **Humans has pretreated their food for ages**
  - Kinema in India (Shrestha and Noomhorm, 2001)
    - Boiled
    - Addition of wooden ash
    - Naturally fermented for 24 – 48 h in bamboo baskets
      - Main bacteria causing fermentation: *Bacillus subtilis*
  - Natto in Japan, first reported in 1087 AD (Tripathi and Misra, 2005)
    - Fermented by *Bacillus natto*
Pretreatment of feed sources II

- **What is pretreatment**
  - Additional treatment to the feed mash, or parts of it, than regular milling and conditioning

- **Why pretreatment**
  - Increase nutritional quality
    - Is being used if extrusion is not increasing nutritional value sufficiently.
    - If high processed ingredients are too expensive. (Might be cheaper to do it inhouse)
      - If water is added; often cheaper to perform it online as to avoid cost of drying process.
Pretreatment – methods I

● Biological
  - Enzymes
    • Singel enzymes
      - Phytases
      - Proteases
      - Carbohydrases
    • Enzyme packages
      - Pancreatin
    - Microbes/yeast – General increasing the nutritional value of the feed
      • End-product is a mix of unknown products
Pretreatment – methods II

- Biological
  - Microbes/yeast/fungi – General increasing the nutritional value of the feed
    - End-product is a mix of unknown components
      - Some desirable
      - Some undesirable
    - Key point:
      » Wise choice of fermenting agent
  - Pretreatment conditions are crucial for obtaining reproducible results
    - Monitor and specify
CASE 1

Fermentation of rape seed meal and effect on fish performance.

Exp. 1

Exp. 2

SGR

SGR

Control diet  RSM diet  FRSM diet

Control diet  RSM diet  FRSM diet
Fermentation of whole meal flour (WMF)

- Digestibility trial with Atlantic salmon
- Fermentation of wheat or barley
- Inclusion level: 24%
- Fermenting agent: *Lactobacillus* strain (AD₂)
- 16 h @ 30°C, 45% moisture
- Chemical composition of diets ~similar
- Extruded diets

Isolated from sourdough

Skrede et al., 2001; 2002
Fermentation of whole meal flour (WMF)

- Fermented meal
- Untreated meal

Skrede et al., 2002
Pretreatment – methods III

- Biological
  - The fermentor itself contributes to the end product
    • Changing the chemical composition of the mash
Pretreatment - methods IV

- Chemical
  - pH
    - Often combined with biological to obtain ideal working conditions for the enzymes/microbes/yeast.
  - Extractions
  - Organic acids
  - Mechanical
    - Grinding - particle size

Not lectured

Described by Ozren Z. in Lecture 4
Pretreatment – physical properties of the feed

- An experiment with on-line pretreatment
- Aim:
  1. Check whether pretreatment itself had any effect on physical properties of the feed
  2. Implement the online pretreatment in a regular extrusion line
## On-line Pretreatment

### Processing parameters

<table>
<thead>
<tr>
<th>Diet</th>
<th>Pretreatment</th>
<th>Conditioned</th>
<th>Incubated</th>
<th>s.e.m.</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Conditioning</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature $^a$ ($^\circ$C)</td>
<td>76</td>
<td>76</td>
<td>0.3</td>
<td>0.7522</td>
<td></td>
</tr>
<tr>
<td><strong>Extrusion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature $^c$ ($^\circ$C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1$^{st}$ section</td>
<td>62</td>
<td>63</td>
<td>1</td>
<td>0.2909</td>
<td></td>
</tr>
<tr>
<td>3$^{rd}$ section</td>
<td>118 $^b$</td>
<td>121 $^a$</td>
<td>0.7</td>
<td>0.0077</td>
<td></td>
</tr>
<tr>
<td>4$^{th}$ section</td>
<td>106 $^b$</td>
<td>110 $^a$</td>
<td>0.9</td>
<td>0.0111</td>
<td></td>
</tr>
<tr>
<td>5$^{th}$ section</td>
<td>117</td>
<td>116</td>
<td>1</td>
<td>0.4546</td>
<td></td>
</tr>
<tr>
<td>Die</td>
<td>106</td>
<td>109</td>
<td>2</td>
<td>0.2009</td>
<td></td>
</tr>
<tr>
<td><strong>Pressure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4$^{th}$ section $^{cc}$ (bar)</td>
<td>0.55 $^b$</td>
<td>0.73 $^a$</td>
<td>0.02</td>
<td>0.0176</td>
<td></td>
</tr>
<tr>
<td>Die (bar)</td>
<td>28</td>
<td>28</td>
<td>1</td>
<td>0.9239</td>
<td></td>
</tr>
<tr>
<td>Screw speed (rpm)</td>
<td>273</td>
<td>273</td>
<td>0.07</td>
<td>0.2328</td>
<td></td>
</tr>
<tr>
<td>Torque $^d$ (Nm)</td>
<td>359 $^a$</td>
<td>338 $^a$</td>
<td>7</td>
<td>0.0433</td>
<td></td>
</tr>
<tr>
<td>SME $^e$ (Wh/kg)</td>
<td>42 $^a$</td>
<td>39 $^b$</td>
<td>0.8</td>
<td>0.0319</td>
<td></td>
</tr>
</tbody>
</table>

*Kraugerud & Svihus; accepted for AFST.*
On-line Pretreatment

- Physical properties

<table>
<thead>
<tr>
<th>Diet</th>
<th>Preament</th>
<th>Conditioned</th>
<th>Incubated</th>
<th>s.e.m.</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness [N]</td>
<td></td>
<td>34 $^a$</td>
<td>24 $^b$</td>
<td>2</td>
<td>0.0026</td>
</tr>
<tr>
<td>Durability [%]</td>
<td></td>
<td>96</td>
<td>93</td>
<td>1</td>
<td>0.0694</td>
</tr>
<tr>
<td>Expansion [%]</td>
<td></td>
<td>26</td>
<td>28</td>
<td>2</td>
<td>0.2195</td>
</tr>
<tr>
<td>Bulk density [g/l]</td>
<td></td>
<td>519 $^a$</td>
<td>498 $^b$</td>
<td>5</td>
<td>0.0092</td>
</tr>
<tr>
<td>Length [mm]</td>
<td></td>
<td>7.7 $^a$</td>
<td>6.5 $^b$</td>
<td>0.1</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>PDI $^b$ [%]</td>
<td></td>
<td>16.3</td>
<td>15.4</td>
<td>0.3</td>
<td>0.1171</td>
</tr>
</tbody>
</table>
Pretreatment – CASE 2

- Find two practical challenges/obstacles with pretreatment
- Groups: two and two
- Two minutes
- Group work
  - Three groups
  - 10 minutes
    - Sketch the system (three groups)
    - Discuss
      - Pros
      - Cons
Pretreatment – literature

Denstadli et al., 2006. Phytate degradation in a mixture of ground wheat and ground defatted soybeans during feed processing: Effects of temperature, moisture level, and retention time in small- and medium-scale incubation systems, Journal of Agricultural and Food Chemistry, 54, 5887-5893


Kraugerud and Svihus, accepted. A comparison of online pretreatment of plant feed ingredients on processing responses and physical properties of extruded fish feed, Animal Feed Science and Technology.


Skrede, G., Storebakken, S., Skrede, Sahlstrøm, Sørensen, Shearer, Slinde, 2002. Lactic acid fermentation of wheat and barley whole meal flours improves digestibility of nutrients and energy in Atlantic salmon (Salmo salar L.) diets, Aquaculture, 210, 305-32.
Lecture 10. Extrusion and nutritive value
EXTRUSION – energy (heat & mechanical)

![Diagram of extruder section with temperature changes and labels for mash and cutting](image)
Starch – effect during extrusion process

Showing disintegrated starch granules

Animation by Kraugerud, 2008;
Drawings by Tester et al., 2004
Shear

- Mechanical tearing that occurs as product is dragged forward or backward by the screws against the barrel wall in the extruder.
- As product is being aggressively pulled in two different directions it is torn apart. This brings about intense friction, high temperatures and pressures.

Pulling

Granules Burst

Dextrinisation
Starch + proteins + extrusion = possible reactions

- Starch $\rightarrow$ dextrines and maltose
  $\Rightarrow$ sugar with reducing ends
- Proteins $\rightarrow$ unfolding
  - $\Rightarrow$ $\varepsilon$-amino group of lysin gets exposed
- Reducing end of sugars react with $\varepsilon$-amino group of lysin
  $\Rightarrow$ reduction of available lysin

Unfolding of proteins.
- $\bullet$: hydrophobic AA residues
- $\circ$: hydrophilic AA residues
- $s-s$: disulphide bonds
Extrusion - effect

- Starch
  - Expansion as effect of temperature

Hashimoto & Grossmann, 2003
Extrusion - effect

- Starch
  - Water stability

![Graph showing protein loss in different ingredients after extrusion.](Cruz-Suarez et al., 2001)
Extrusion – which parameters to consider

- Temperature
  - 110 – 150°C

- Moisture
  - 15 – 60%

- Press
  - 10-50 bar (at the die)

- Mechanical energy (shear)
  - 30 – 150 Wh/kg

- Time
  - 10-60s
Extrusion - effect

Major influencing Process Parameters

- water
- temperature
- shear, i.e. specific mechanical energy dissipation (SME)
- time

\[
SME \ [kWh/t] = \frac{2 \cdot \Pi \cdot \text{screw speed} \ [1/\text{min}] \cdot \text{torque} \ [kNm]}{60 \ [s/\text{min}] \cdot \text{throughput} \ [t/\text{h}]}
\]
SME & moisture → effect on gelatinisation
Condition temperature → effect in extruder

- **CASE**
  - Fish feed
  - 3 T/h
  - 28.5% moisture
  - Retention time 30 s
Starch: Gelatinisation – T & p

- Low DM (not comparable to extrusion)
- Long time (not comparable to extrusion)

**Figure 3.** Pressure–temperature gelatinization diagram of wheat starch. Starch suspensions were 5% DM and treated during 15 min.

Douzals, 2001; J. Agric. Food Chem
Gelatinisation – T, % moisture & shear

Here at same temperatures (as the T, P graph), the starch is NOT gelatinised!
→ Time and water content is also an important factor!

Why the one with higher water content with a lower degree of gelatinisation?
ANSWER: Low moisture → high shear, hence high degree of gelatinisation)

SME when extruding starch: Increase compared with other materials → due to the endothermic nature of gelatinisation.

Cai, 1993; Journal of food science
Simple charts = good charts

Temperature/Time Exposure for Various Products

- Pasta drying
- Bread
- Batch cooked cereals
- Pasta extr.
- Ind. exp. cereals, snacks, extrus.
- Pet food
- Text. proteins
- Dir. exp. cereals, snacks
- Inst. flours

Inactivation of spores
Inactivation of peroxidase 90%
Inactivation of lipoxigenase 90%
Browning reaction

Bühler AG, 2007
### Type of extruder - possibilities

<table>
<thead>
<tr>
<th></th>
<th>Single</th>
<th>Twin co-rotating</th>
<th>Twin Counter-rotating</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product Dependence</strong></td>
<td>high</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td><strong>max. Inlet Moisture</strong></td>
<td>up to 30%</td>
<td>up to 60%</td>
<td>very high</td>
</tr>
<tr>
<td><strong>max. Fat Content</strong></td>
<td>low &lt; 8 – 10 %</td>
<td>high ~ 20%</td>
<td>high</td>
</tr>
<tr>
<td><strong>Throughput range</strong></td>
<td>narrow</td>
<td>wide</td>
<td>very wide</td>
</tr>
<tr>
<td><strong>Mixing effect</strong></td>
<td>poor</td>
<td>good</td>
<td>poor</td>
</tr>
<tr>
<td><strong>Dwell Time Spectrum</strong></td>
<td>wide</td>
<td>narrow</td>
<td>very narrow</td>
</tr>
<tr>
<td><strong>Die Dependence</strong></td>
<td>high</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td><strong>Self cleaning</strong></td>
<td>non</td>
<td>good</td>
<td>good</td>
</tr>
<tr>
<td><strong>Degassing</strong></td>
<td>medium</td>
<td>good</td>
<td>medium</td>
</tr>
<tr>
<td><strong>Product quality</strong></td>
<td>inconstant</td>
<td>constant</td>
<td>constant</td>
</tr>
<tr>
<td><strong>Cleaning</strong></td>
<td>dismantling</td>
<td>rinsing</td>
<td>rinsing</td>
</tr>
</tbody>
</table>
Extrusion – literature

Dust et al., 2004. Extrusion conditions affect chemical composition and in vitro digestion of select food ingredients, J. Agric. Food Chem., 52, 2989-2996

General effect of extrusion

Camire et al., 1990. Chemical and Nutritional Changes in Foods during Extrusion, Critical Reviews in Food Science and Nutrition, 29, 35-57


Extrusion and effect on proteins


General overview of feed extrusion


-Recommended chapters: 8 and 10.