Feed for recirculating aquaculture systems

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• Strong growth in the recirculation segment in Denmark
• Large and growing production of salmon smolt in recirculated facilities
• Production of other species from larvae to grower in recirculation (European seabass, Gilthead sea bream and others)
• Generally, recirculation technology makes it possible to produce species far away from their natural habitat due to full control of water chemical and physical parameters
Development of recirculation diets
- what have we done so far...

-many trials run since 2004...

- ReFeed I and II: Biofilter response of diets, pH regulation and total biofilter load
- ReFeed III: Focus on water quality and modelling of recirculation systems
  - 2 lab-scale trials in Hirtshals
  - Several commercial trials
- Faecal design I+II
- Various raw material trials with focus on faeces ’quality’
- Protein:energy manipulated diets
- Amino acid optimization
- Phosphorus reduction
Main concepts of the recirculation diet

- Amino acid optimization
- Stabilize faecal structure – for easy removal of fecal matter by the means of fecal traps and/or mechanical filters (drum filters)
- Strict raw material demands – no negative effects on fecal structure and high digestibility
Possible add-on concepts…

• Low phosphorus diets
  - use of RM’s with low P content
  - Use of phytase
• Floating feed (indicator effect; minimize feed waste)
• Use of attractants – assure high feed intake
• A sustainable version of the diet (Concept 121; one-to-one), which guarantees the use of maximum one kg industrial fish to produce one kg farmed trout
Main concept 1: Dietary DP:DE ratio

- The optimal dietary DP:DE ratio assures the most efficient utilisation of feed proteins (reduction of nitrogen (NH$_4^+$) discharge)
Main concept 2: Amino acid optimization
- assuring the correct proportion of protein “building blocks”

- Proteins are built from amino acids
- 10 of those are essential, i.e. they cannot be produced by the fish itself and have to be supplied in the feed
- If just one of them becomes deficient, it will decrease the performance of the feed
- This amino acid is called the first limiting amino acid
- It is the level of the first limiting amino acid that determines the performance of the feed, not the total protein level.
Main concept 3: Feces structure

- Faecal structure may be improved by choice of raw materials
- Binders in feed may have positive effects on faeces structure

Faeces obtained from feeding 6 different commercially available diets (100 grams of feed)
Main concept 4: Choice of raw materials

- The choice of raw materials will affect digestibility, fecal stability and general performance of the diet.
- Raw materials used for recirculation feeds should be highly digestible and have no negative effects on fecal structure.
- Especially protein digestibility and amino acid profile of the raw materials are of utmost importance, since these two parameters will determine how much protein is lost during fish production.
- Wasted protein is released from the fish in the form of $\text{NH}_4^+$ which, by the biofilters, needs to be converted into $\text{NO}_3^-$ (or N2). This is a typical bottleneck in recirculated systems.
Calculated example of nitrogenous waste load

1 ton of feed
48% protein
77 kg N

Undigested
8 kg N

Digested
90%
69 kg N

Digitabolised
37 kg N

Growth
32 kg N

Traditional high performance feed
From theory to real life:

RD08040:
“Commercial recirculation and sustainable feeds”
Materials and methods

• 1 trial diet and 2 commercial diets tested in triplicate tanks (9 tanks)
• Each tank was stocked with approximately 2 kg of trout with an individual weight of approximately 63 grams
• Water temperature during trial was 9.7±0.4°C
• Oxygen content during trial was 7.2±2.0 mg/l
• The fish had an acclimation period of 6 days, after which a growth trial of 25 days was conducted. After this a digestibility trial was conducted using a modified Guelph settling column setup.
• At the end of the digestibility trial water samples as well as whole fish were taken for N and P analyses, in order to make a total phosphorus and nitrogen budget
### Feed analyses

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Orbit</th>
<th>Control I</th>
<th>Control II</th>
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<tbody>
<tr>
<td>Protein (%)</td>
<td>42,1</td>
<td>43,7</td>
<td>46,9</td>
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<tr>
<td>Lipid (%)</td>
<td>31,3</td>
<td>28,6</td>
<td>31,1</td>
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<tr>
<td>Ash (%)</td>
<td>5,7</td>
<td>7,0</td>
<td>8,6</td>
</tr>
<tr>
<td>Water (%)</td>
<td>8,4</td>
<td>7,8</td>
<td>5,5</td>
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<tr>
<td>Phosphorus (%)</td>
<td>0,94</td>
<td>1,10</td>
<td>1,21</td>
</tr>
<tr>
<td>DE (MJ/kg)</td>
<td>21,7</td>
<td>20,9</td>
<td>22,0</td>
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Feed conversion ratios

![Feed conversion ratios chart]

Control I has the highest feed conversion ratio, followed by Control II and Orbit.
Specific growth rates (%/day)

- Orbit
- Control I
- Control II
Daily feed intakes (%/day)

Orbit  Control I  Control II

1.25  1.30  1.35

1.40  1.45  1.50

1.55  1.60  1.65
Protein digestibility (%)
Phosphorus digestibility (%)
Fate of nitrogen per tonne of fish produced

N excreted via gills reduced between 17.0 – 20.9%

N excreted via feces reduced between 36.7 – 40.7%
Fate of phosphorus per tonne of fish produced

P excreted *via* feces reduced between 43.8 – 50.9%

P excreted *via* urine was not significantly reduced

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<tr>
<td><strong>P retained (kg)</strong></td>
<td><img src="image" alt="Graph" /></td>
<td><img src="image" alt="Graph" /></td>
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<tr>
<td><strong>P excreted via urine (kg)</strong></td>
<td><img src="image" alt="Graph" /></td>
<td><img src="image" alt="Graph" /></td>
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</tr>
<tr>
<td><strong>P excreted in feces (kg)</strong></td>
<td><img src="image" alt="Graph" /></td>
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Achieved

- A diet performing similarly or better than commercial products concerning growth and feed conversion
- Improved feces structure allowing efficient removal of fecal matter from system water
- Up to 3% improvement of protein digestibility
- Up to 20% improvement of phosphorus digestibility
- Up to 21% lower ammonium (NH$_4^+$) excretion per tonne of fish produced
- Up to 41% lower nitrogen excretion via feces per tonne of fish produced
- Up to 51% lower phosphorus excretion via feces per tonne of fish produced
- No significant reduction of phosphorus released via urine
- Confirmation of feed performance results in 7 commercial trials
Thank you for your attention!