OPPORTUNITIES FOR RENDERED PRODUCTS IN AQUACULTURE
Advancing science & industry through partnership

Jesse T. Trushenski

CENTER FOR FISHERIES, AQUACULTURE, & AQUATIC SCIENCES
THE WORLD IS HUNGRY

We will need 60% more food by 2050

Population growth, urbanization, and changing diets driving shifts in per capita consumption and eating habits

WHO 2002, CGIAR CCAFS 2013
WHERE IS OUR SEAFOOD COMING FROM?

We are unlikely to get more food from our oceans

80% of fish stocks are fully exploited or in decline FAO 2012

Aquaculture puts food on tables. Half of all seafood is farm-raised.
AQUACULTURE PRODUCES PROTEIN EFFICIENTLY

Swine: 3 to 1
Beef Cattle: 8 to 1
Poultry: 2 to 1
Fish: 1-1.5 to 1

Fish beat terrestrial livestock in both feed conversion efficiency and dress-out.

50-60% of a salmon carcass is edible compared to 40% for beef.
GLOBAL AQUACULTURE IS DIVERSE

More than 500 species are raised worldwide

Including more than 400 finfishes and crustaceans

Annual Production (MMT)
FAO 2014

- Freshwater Fish
- Mollusks
- Crustaceans
- Marine Fish
- Other
Aquafeed manufacturing is outpacing aquaculture

*Year by year, the aquaculture becomes larger and more intensive*
THE CHALLENGES OF FEEDING FISH

Nutritional Demands

Omnivores  Carnivores

Tilapia
- Protein
- Lipid
- Other

Poultry
- Protein
- Lipid
- Other

Swine
- Protein
- Lipid
- Other
FISH HAVE HIGH PROTEIN DEMANDS

*But require amino acids, not protein*

<table>
<thead>
<tr>
<th>Species</th>
<th>Dietary Protein (%)</th>
<th>Species</th>
<th>Dietary Protein (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asian sea bass</td>
<td>45</td>
<td>Freshwater basses</td>
<td>35-47</td>
</tr>
<tr>
<td>Atlantic halibut</td>
<td>51</td>
<td>Trouts</td>
<td>40-53</td>
</tr>
<tr>
<td>Atlantic salmon</td>
<td>55</td>
<td>Flatfishes</td>
<td>50-51</td>
</tr>
<tr>
<td>Tilapias</td>
<td>30-40</td>
<td>Catfish</td>
<td>32-36</td>
</tr>
<tr>
<td>Pacific salmonids</td>
<td>40-45</td>
<td>Beef cattle</td>
<td>7-18</td>
</tr>
<tr>
<td>Carps</td>
<td>31-43</td>
<td>Dairy cattle</td>
<td>12-18</td>
</tr>
<tr>
<td>Eels</td>
<td>40-45</td>
<td>Sheep</td>
<td>9-15</td>
</tr>
<tr>
<td>Sea basses</td>
<td>45-50</td>
<td>Swine</td>
<td>12-13</td>
</tr>
<tr>
<td>Sea breams</td>
<td>50-55</td>
<td>Poultry</td>
<td>14-28</td>
</tr>
</tbody>
</table>

Halver and Hardy 2002
## ESSENTIAL AMINO ACID REQUIREMENTS

<table>
<thead>
<tr>
<th>Essential Amino Acids</th>
<th>Estimated Requirement (Rainbow Trout)</th>
<th>Fish Meal Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arginine</td>
<td>3.3-5.9</td>
<td>6.2</td>
</tr>
<tr>
<td>Histidine</td>
<td>1.6</td>
<td>2.8</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>2.4</td>
<td>4.2</td>
</tr>
<tr>
<td>Leucine</td>
<td>4.4</td>
<td>7.2</td>
</tr>
<tr>
<td>Lysine</td>
<td>3.7-6.1</td>
<td>7.8</td>
</tr>
<tr>
<td>Methionine</td>
<td>1.8-3.0</td>
<td>3.4</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>4.3-5.2</td>
<td>3.9</td>
</tr>
<tr>
<td>Threonine</td>
<td>3.2-3.7</td>
<td>4.2</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>0.5-1.4</td>
<td>0.8</td>
</tr>
<tr>
<td>Valine</td>
<td>3.1</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Data expressed as % crude protein  

*Halver and Hardy 2002; Omega Protein, Inc. 2006*
FISH ALSO HAVE HIGH LIPID DEMANDS

*But require fatty acids, not lipid*

<table>
<thead>
<tr>
<th>Species</th>
<th>Dietary Lipid (%)</th>
<th>Species</th>
<th>Dietary Lipid (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trout</td>
<td>18-20</td>
<td>Milk Fish</td>
<td>7-10</td>
</tr>
<tr>
<td>Other salmonids</td>
<td>20-30</td>
<td>Catfish</td>
<td>5-6</td>
</tr>
<tr>
<td>Tilapia</td>
<td>&lt;10</td>
<td>Turbot</td>
<td>&lt;15</td>
</tr>
<tr>
<td>Sea breams</td>
<td>10-15</td>
<td>Sole</td>
<td>5</td>
</tr>
<tr>
<td>Carp</td>
<td>&lt;18</td>
<td>Beef Cattle</td>
<td>1-2</td>
</tr>
<tr>
<td>Sea basses</td>
<td>12-18</td>
<td>Dairy Cattle</td>
<td>1-2.5</td>
</tr>
<tr>
<td>Yellow tail</td>
<td>11</td>
<td>Sheep</td>
<td>2.5-3</td>
</tr>
<tr>
<td>Red drum</td>
<td>7-11</td>
<td>Swine</td>
<td>2-6</td>
</tr>
<tr>
<td>Grouper</td>
<td>13-14</td>
<td>Poultry</td>
<td>~3</td>
</tr>
</tbody>
</table>

Guillaumé et al. 2001
Limited physiological functions

Distinct physiological functions
FEEDING HABITS DRIVE REQUIREMENTS

Saltwater

Euryhaline

Freshwater

Trophic Level

1 2 3 4 5
FEEDING HABITS DRIVE REQUIREMENTS

Saltwater

Euryhaline

Freshwater

Trophic Level

1 2 3 4 5
GROWTH HAPPENS WHEN LIMITING RESOURCES BECOME AVAILABLE AND IS AS FAST AS THE SLOWEST PROCESS

All the building blocks must be available before new molecules or tissues can be synthesized.
Macro- & Micronutrients

- Membrane Competence
- Metamorphosis
- Reproduction
- Behavior
- Stress Response
- Biosynthetic Rates
- Cell Signaling
- Appetite Regulation
- Growth & Development
- Osmoregulation
- Immunity & Survival
- Energy Substrates
- Pigmentation
- Metabolic Regulation
- Endocrine Status
- Seafood Quality
- Antioxidative Defense

Tocher 2003, Li et al. 2008
WHAT DO WE FEED FISH?

<table>
<thead>
<tr>
<th>Typical Ingredients</th>
<th>High Energy (Carnivorous)</th>
<th>Medium Energy (Carnivorous)</th>
<th>Low Energy (Omnivorous)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish meal</td>
<td>25-50</td>
<td>20-40</td>
<td>0-20</td>
</tr>
<tr>
<td>Soy products</td>
<td>0-15</td>
<td>25-35</td>
<td>30-50</td>
</tr>
<tr>
<td>Gluten &amp; animal products</td>
<td>5-20</td>
<td>15-20</td>
<td>15-20</td>
</tr>
<tr>
<td>Cereal grains</td>
<td>10-18</td>
<td>20-25</td>
<td>30-45</td>
</tr>
<tr>
<td>Fats/oils</td>
<td>20-30</td>
<td>5-10</td>
<td>2-5</td>
</tr>
<tr>
<td>Other</td>
<td>3-5</td>
<td>3-5</td>
<td>3-5</td>
</tr>
</tbody>
</table>
THE RISING COST OF FISH MEAL

Price in $US/MT


“...much research has focused on finding replacements for fish meal...Partial replacements have been achieved. However, no dramatic breakthroughs have been reported, and the share of fish meal and fish oil used in aquaculture is increasing...” FAO 2008
“...given the difficulty in replacing fish oils...it is clear that competition for fish oil is likely to be a more serious obstacle for some sections of the aquaculture industry.” *FAO 2008*
FEEDSTUFF ATTRIBUTES TO CONSIDER

Compositional profile and practical feeding value
  Protein content and quality
  Carbohydrate levels
  Presence of antinutritional factors

Economic and environmental costs of raw materials
  Availability
  Cost-effectiveness relative to marine ingredients AND other feedstuffs
  Sustainability

Influence on product quality
  Nutritional value
  Safety
FEEDSTUFF ATTRIBUTES TO CONSIDER

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CARBOHYDRATES IN AQUAFEEDS

Digestion is limited by enzyme production
Utilization is limited by ability to metabolize effectively

Laporte et al., unpublished data
ANTINUTRITIONAL FACTORS IN AQUAFEEDS

Protease inhibitors—reduce protein digestibility
Lectins—irritate the intestinal epithelium
Phytic acid—reduces protein and phosphorus digestibility
Saponins—toxic, reduce feed intake
Antigenic compounds—cause allergic responses

Burrells et al. 1999, Francis et al. 2001
Customers and retailers are increasingly focused on sustainability criteria.

Fish meal/fish oil usage negatively affects rankings.
SAFETY OF FARmed FISH

Although there is variability in levels, marine ingredients are potential sources of organic and inorganic contaminants.

Risks of contaminants in farmed fish are largely overblown.

Risk outweighed by benefits of seafood consumption.

**National Academies Institute of Medicine**
*Food and Agriculture Organization*
*World Health Organization*

**BUT**, perception is reality and feeding rendered fats can reduce contaminant burdens.

[Graph showing WHO-TEQ levels in fish oils and animal fats]
Fish oil sparing affects fillet composition and associated nutritional value

Trushenski et al. 2011
MINIMIZING LOSS OF NUTRITIONAL VALUE

No growth effects
Substantial LC-PUFA loss
Trushenski and Boesenberg 2009

No growth effects
Limited LC-PUFA loss
Trushenski et al. 2008

No growth effects
Limited LC-PUFA loss
Trushenski 2009
RENDERED FATS HELP MAINTAIN NUTRITIONAL VALUE

Gause and Trushenski 2013
RENDERED FATS HELP MAINTAIN NUTRITIONAL VALUE

Gause and Trushenski 2013
RENDERED FATS MAY ALSO MAKE FATTY ACID REQUIREMENTS EASIER TO ATTAIN

Break Point = 29.3 g LC-PUFA/kg diet

Growth was suppressed among fish fed high levels of C\textsubscript{18}-rich soybean oil, but not SFA-rich soybean oil

Trushenski et al. 2013
RENDERED FATS MAY ALSO MAKE FATTY ACID REQUIREMENTS EASIER TO ATTAIN

Sparing fish oil with beef tallow does not impair performance in the way that sparing with other lipids does.
THE CHALLENGES...

Fish meal and oil are finite resources which aquaculture increasingly monopolizes.

Sources of amino acids abound, but may be improperly balanced, unpalatable.

*Alternative proteins impact production performance, livestock resilience, etc.*

Sources of essential fatty acids can be limiting.

*Alternative lipids affect fillet nutritional value, product safety, reproductive performance, etc.*
THE OPPORTUNITIES...

Strategic use of resources including rendered animal products solves problems.

Aquaculture puts food on tables. Half of all seafood is farm-raised.

Farms now raise more seafood than beef.

Strategic use of resources including rendered animal products solves problems.
ACKNOWLEDGMENTS

Authors of the various works cited herein

Fats and Proteins Research Foundation

Center for Fisheries, Aquaculture and Aquatic Sciences