Fish Waste Management:
Turning fish waste into healthy feed

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Fish Silage and AMR

• Use of fish silage in treating dead fish to prevent spreading of disease

• Fish silage as antimicrobial product to reduce use of antibiotic and to promote healthy immune system of fish
FISH PROCESSING

- 55% is processed
- Most common in industrial fisheries and with larger species
- Less processing in small scale fisheries or with smaller species 20 – 80% waste generated

World Fish Utilization 2014

- Direct Human Consumption: 30%
- Dried, salted, smoked or cured forms: 12%
- Prepared and preserved form: 13%
- Frozen form: 45%
Fish Processing Byproducts

17% - Head-on gutted Salmon

45% - Salmon fillets

70% - canned tuna

57.3% flesh – Milkfish
8.6% backbone in Atlantic salmon (Chile)
3.1% backbone in Trout
Fish Processing Byproducts

14% in Atlantic salmon
10% in coho
8% in trout
3 to 5% in carp
9.5% milkfish

10.1% in milkfish
2.0% in Atlantic salmon
1.2% in trout
Fish Processing Byproducts

- Contains:
  - Proteins
  - Ether extract or fat
  - Minerals
  - Palmitic acid, stearic acid, oleic acid and DHA
Fish Waste Byproducts Utilization

2025, fish meal produced from fish waste will represent 38% of world fish meal production, compared with 29% for the 2013 to 2015 average level.

Fish Oil: 0.856 million tonnes produced on 2015

Raw materials used for production of fishmeal and fish oil in 2015
- Whole fish 13.9Mt
- By-product from wild capture 3.75Mt
- By-product from aquaculture 1.94Mt

Source: Institute of Aquaculture, University of Sterling and IFFO, July 2016.
Fish Waste Byproducts Utilization

- Fish Protein Hydrolysate
- Fish Collagen/Gelatin
- Fish Sauce
- Fish Leather
Fish Silage

What is fish silage?
- minced fish or parts of fish, added a preservative stabilizing the mixture
- a liquid solution where proteins are pre-digested, but with a nutrient composition similar to fishmeal

Why make fish silage?
- simple
- does not require huge investments
- product can be preserved for longer periods, even years
- waste problem can be converted into profit
Production of Silage

Raw Material
What can be used for fish silage production
• whole fish
• parts of fish
• important to include viscera

Condition of raw material
• Fresh
• Raw

Use of acid
• organic or inorganic
• organic: formic acid, ensure a stable and storable product
• inorganic: lower cost, but will require a lower pH
• lactic acid bacteria fermentation: complicated and requires a closer follow up

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Principles

Enzymatic degradation
• digestive system
• breaks down the proteins to peptides and amino acids
• pH of 3.5 to 4.0
• temperature 5 to 40°C

Particle size
• small enough (max 1mm) to ensure the acid can penetrate all cells

Quality Control
• raw material
• pH
• effect of fish bones
• storage

Potential Problems
• variations in the raw material
• high levels of bones
• undissolved bones
Safety

- handling of any acid
- protective glasses/safety face shield
- acid resistant gloves
- rubber boots
- protective clothing
Equipment

Grinder
• small enough to enable the preservative (acid) to enter into the heart of the particle

Pump
• move silage
• for circulating the product
✓ to ensure all fish particles are exposed to acid and enzymes which transforms the fish into silage

Mixing Tank
• made of an acid resistant material: plastic, fiberglass or stainless steel

Storage Tank
• stable the pH of the product
• resistant to corrosion
• galvanized materials should not be used: lead to the development of some toxic components.
Storage of Silage

Shelf life
• can be stored for years

Quality Assurance
• regular control, maintenance and cleaning of the equipment
• regular stirring of silage
• pH control

Separation of oil
• warmer climates, the fat/oil will float on top of the silage
• decantation
• antioxidant

Separation of bones
• high levels of bones = higher consumption of acid
• removed from the tank on a regular basis
Silage Production Process

- Processing
- Waste segregation
- Grinding
- Stir
- Addition of acid
- Storage
Utilization of Silage

**Directly as feed**
- relatively low acidity
- pigs: resulting in higher growth rates, improved health and reduced mortality

**Mixed with other feed ingredients**
- will not require any further processing
- retain all the nutritional and health benefits
Utilization of Silage

Use in pellet production and extruded feeds

• partially replaces fish meal in feeds (typically 5-15%)
• high level of free amino acids and peptides: improve the growth performance
• stronger and more resistant

Fertilizer

• if it does not meet the quality requirements for feed purposes
• good source of Nitrogen (from the protein)
• source of Phosphorus, Potassium, Calcium, Magnesium (particularly from the bone structure)
• most trace element needed for plants
• part of the irrigation process (adding 5-10 % liquid silage)
Antimicrobial Product

- During storage, endogenous, proteolytic enzymes break down the tissue protein to low molecular weight peptides and amino acids.

- Peptides have antimicrobial properties.
Table 2: Overview of antimicrobial peptides from fish known to date

<table>
<thead>
<tr>
<th>Fish</th>
<th>Name</th>
<th>Length</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Anguilla japonica</em></td>
<td>Ajl-2</td>
<td>142</td>
<td>Antibacterial</td>
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<tr>
<td><em>Chenoplectes chinensis</em></td>
<td>LEAP</td>
<td>78</td>
<td>Antimicrobial</td>
</tr>
<tr>
<td><em>Dato rario</em></td>
<td>hepaticin 1</td>
<td>20</td>
<td>Antimicrobial</td>
</tr>
<tr>
<td><em>Dicentrarchus labrax</em></td>
<td>Dicentracin</td>
<td>22</td>
<td>Antimicrobial</td>
</tr>
<tr>
<td><em>Epinephelus coioides</em></td>
<td>Epinecindin</td>
<td>25</td>
<td>Antimicrobial</td>
</tr>
<tr>
<td><em>Gyropterus cygnoglossus</em></td>
<td>Pleurocidin-like peptides</td>
<td>26</td>
<td>Antimicrobial</td>
</tr>
<tr>
<td><em>Grammistis sexlineatus</em></td>
<td>Grammistsins</td>
<td>26</td>
<td>Antibacterial</td>
</tr>
<tr>
<td><em>Hippoglossoides platessoides</em></td>
<td>Pleurocidin-like peptides</td>
<td>26</td>
<td>Antimicrobial</td>
</tr>
<tr>
<td><em>Ictalurus punctatus</em></td>
<td>Hipposin</td>
<td>51</td>
<td>Antibacterial</td>
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<tr>
<td><em>Lateolabrax japonicus</em></td>
<td>Hepaticin-like peptide</td>
<td>21</td>
<td>Antimicrobial</td>
</tr>
<tr>
<td><em>Limanda ferruginea</em></td>
<td>Pleurocidin-like peptides</td>
<td>25</td>
<td>Antimicrobial</td>
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<tr>
<td><em>Mugilus anguillarcaudatus</em></td>
<td>Misgarin</td>
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<tr>
<td><em>Morone chrysa</em></td>
<td>Moronecindin</td>
<td>23</td>
<td>Antimicrobial</td>
</tr>
<tr>
<td><em>Morone chrysaops</em></td>
<td>Moronecindin</td>
<td>21</td>
<td>Antibacterial</td>
</tr>
<tr>
<td><em>Morone saxatilis</em></td>
<td>Moronecindin</td>
<td>22</td>
<td>Antibacterial</td>
</tr>
<tr>
<td><em>Myxine glutinosa</em></td>
<td>HAP</td>
<td>38</td>
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<tr>
<td><em>Onchorhyncus mykiss</em></td>
<td>Salmocidins</td>
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<tr>
<td><em>Pagrus major</em></td>
<td>Oncorhyncins</td>
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<tr>
<td><em>Pardachirus marmoratus</em></td>
<td>Histone H2A</td>
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<td><em>Pelleobagrus fulvidraco</em></td>
<td>β-defensin 1</td>
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<td><em>Petromyzon marinus</em></td>
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</tr>
<tr>
<td><em>Pleuronectes platessa</em></td>
<td>LEAP2B</td>
<td>77</td>
<td>Antimicrobial</td>
</tr>
<tr>
<td><em>Salmo salar</em></td>
<td>Claryophisins</td>
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<td>Antimicrobial</td>
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<tr>
<td><em>Silenus asatus</em></td>
<td>hepaticin</td>
<td>33</td>
<td>Antimicrobial</td>
</tr>
<tr>
<td><em>Siniperca chuatsi</em></td>
<td>DEAP</td>
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<td>Antibacterial</td>
</tr>
<tr>
<td><em>Sparus auratus</em></td>
<td>SAMPHI</td>
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<td>Antibacterial</td>
</tr>
<tr>
<td><em>Sparus indicus</em></td>
<td>Parasin I</td>
<td>19</td>
<td>Antibacterial</td>
</tr>
<tr>
<td><em>Siniperca chuatsi</em></td>
<td>Moronecindin</td>
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Abbreviations: LEAP: liver-expressed antimicrobial peptide, HAP: hematopoietic antimicrobial peptide, CRP: Corticostatin-related peptide. Antimicrobial differs from Antibacterial by fungal activity.
Organic acid

- Use in animal nutrition due to their strong antimicrobial effect
- Antibacterial effects = pathogenic Gram-negative bacteria

Minimum inhibitory concentration (MIC values) of selected organic acids for various microorganisms


(Coelho, 1980)
Fish Silage Processing Method (FSPM)

Ensilation:
- pH ≤ 4.0
- Formic acid
- Incubation: ≥ 24 hours
- ≤ 10mm

Heat treatment:
- ≥ 85°C
- ≥ 25 minutes

• Processed into fish oil, protein water and protein concentrate
• Agricultural fertilizers
• Biofuels
• Feed for fur, zoo, pet, circus animals
Fish Silage Processing Method (FSPM)
Prevent spreading of disease

Effective against:
• Non-spore forming bacteria
• Clostridium perfringens
• Moulds
• Saprolegnia (cotton moulds)
• Parasites
• Viruses
Non-spore forming bacteria

Salmonella
- 85°C for 1 minute
- Formic acid, pH 4.0-4.1, 24 hours = 4 log reduction

Enterobacteriaceae
- 80-85°C for 30 minutes

• Listeria monocytogenes
• Mycobacterium
• Vibrio
• Lactococcus garvieae
• Aeromonas
• Francisella
Spore forming bacteria

- *Clostridium botulinum*
  - Inactivation of toxin:
    - heat treatment at 79°C for 20 minutes
    - 85°C at 5 minutes

- *Clostridium perfringens*
  - 85°C, pH ≤ 4.0, 25 minutes

Viruses

- Infectious pancreatic necrosis – a viral disease usually associated with salmonids
- IPNV - among the most resistance virus
  - 99.999% inactivation after 30 minutes at 60°C, pH 3.0
Moulds

- Saprophyte or pathogen
- Fish fungal pathogens:
  - *Aphanomyces invadans*
  - *Aphanomyces astaci*
  - *Icthyophonus hoferi*

soft abdominal cuticle caused by *Aphanomyces astaci* infection

*Aphanomyces invadans*  
*Icthyophonus hoferi* “spores” in hearts
Moulds

- Fungi affecting fish are strictly aquatic
- Cannot survive outside an aqueous environment
- Negligible levels at > 40°C

FSPM method will inactivate fungi and Saprolegna
Parasites

- 85°C will kill any parasites possibly found in farmed or wild living fish
- 60 to 77°C – sufficient to destroy any known parasites

FSPM method will inactivate all known types of parasites
Mycotoxins

- Heat stable
- Knowledge on toxicokinetics of mycotoxins in fish is scarce
- No knowledge of potential effect of mycotoxins from fish on animal or human health
- No evidence that mycotoxins are more associated with waste of fish origin than healthy fish slaughtered for human consumption

FSPM method will not inactivate mycotoxins, however it has not been shown that mycotoxins from fish may pose a hazard to animal or human health
Prions

- Transmissible Spongiform encephalopathy (TSE)
- Proteinous particles able to give infection in mammals, including human.
- Maintain infectivity after heat treatment, irradiation and exposure towards disincentive agents

**FSPM method will not inactivate potential prions in by products from fish, however it is not likely that prions from fish may pose a hazard to animal or human health**
Antibiotic Resistance Genes

- DNA fragments degradation in acidified and heat treated foods
- Experiment (Bauer et al., 2003) pH 4.3, 65°C = 99% degradation observed within 90 minutes
  - Main factor = low pH

Free DNA will most probably not retain its functionality after FSPM method, such DNA would not be able to transfer antibiotic resistance
AMR and Fish Silage Management

- Workshop and Training on Fish Silage Production (July 2017 in Manila Philippines)
- On-going feasibility study on the potential production and utilization of fish silage
- Fish Silage Manual (for publication)

Prospect and Future Actions

- Creation of web-based platform for exchange of ideas and information on fish waste utilization
- More capacity building and training on fish silage technology
- Scaling up and commercialization/potential markets
FAO Project “Strengthening capacities, policies and national action plans on prudent and responsible use of antimicrobials in fisheries”
03-07 July 2017 Manila, Philippines
Thank you