Valorization of fish processing waste through enzymatic extraction: a short review

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Food

«We are what we eat...»
Food wastes

«We are what we eat...»
Food wastes
100 millions
Food wastes

Food wastes

Food wastes

- 3.3% Fish
- 24.2% Eggplant
- 21.7% Fruits
- 12.1% Wheat
- 11% Meat
- 9.8% Milk
- 7.3% Vegetables
- 3.9% Fats
- 5.3% Cheese
- 1.4% Other
Canned tuna processing wastes

Tuna represents 20% of the value of all marine capture fisheries and over 8% of all globally traded seafood.

Catches of tuna and tuna-like species continued their year-on-year increase, reaching their highest levels in 2018 at over 7.9 million tonnes.

Thailand, Ecuador, China, Indonesia, and were the largest exporters of canned and processed tuna (Italy 8th)

Overview, G., 2010. 4 4.1 Canned Tuna Processors 85–95.
Canned tuna processing wastes

Main products

- **Fish protein hydrolysates (FPH)**
  - Antioxidant activity with a high amount of antihypertensive, anticancer, anti-anemia peptides

- **Tuna oil**
  - Source of polyunsaturated fatty acids (PUFAs), especially omega-3 EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid)

By-products

50-70%

Still contain a high portion of valuable protein, lipid and nutritional components

Canned tuna processing wastes

- **Enzymatic extraction**

Enzymatic hydrolysis is an ideal method to recover **protein and lipids** from fish by-products/wastes

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Enzymatic hydrolysis is the process of breaking down proteins into smaller components, such as peptides, using enzymes. This method is particularly useful for recovering valuable nutrients from fish by-products and wastes.
Canned tuna processing wastes

- **Enzymatic extraction**

Enzymatic hydrolysis is an ideal method to recover **protein and lipids** from fish by-products/wastes.

One of the most used enzymes in the production of bioactive peptides and oil is **Alcalase**.

- Alkaline proteases
- Obtained from *Bacillus subtilis*
- Optimum temperature 55°C

Mensiena B. G. Kiewiet et al. (2018) Nutrients, 10, 904
Valorization of tuna viscera

- **Enzymatic extraction**

<table>
<thead>
<tr>
<th>Component</th>
<th>%</th>
<th>±</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proteins</td>
<td>17,70</td>
<td>± 0,20</td>
</tr>
<tr>
<td>Lipids</td>
<td>2,58</td>
<td>± 0,08</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>NR</td>
<td></td>
</tr>
<tr>
<td>Humidity</td>
<td>77,5</td>
<td>± 0,1</td>
</tr>
<tr>
<td>Hush</td>
<td>2,22</td>
<td>± 0,1</td>
</tr>
</tbody>
</table>

Valorization of tuna viscera

- Enzymatic extraction

**DoE** (MODDE 7 and CAT)
Central Composite Face Centered

Factors:  
- E/S (%), t (min), pH

Levels:  
- E/S (0,1-0,55-1 %)
- t (30-75-120 min)
- pH (6,5-7,5-8,5)

Valorization of tuna viscera

- **Enzymatic extraction**

  Heating at 90° for 10 min
  
  Cooling at room temperature
  
  Adding buffer (pH 6.5, 7.5, 8.5) in a ratio 1:1
  
  Thermostating at 55°C for 30 min
  
  Adding Alcalase to the mixture (0.1, 0.55, 1 E/S%)
  
  Extraction time of 30, 75 and 120 min
  
  Heating at 90° for 10 min
  
  Cooling at room temperature
  
  Centrifugation for 20 min 5000 rpm

- OIL → GC-MS
  - Light lipid-protein → Discarded
  - FPH → DH%
    - Solid residue → Discarded

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Valorization of tuna viscera

- **Enzymatic extraction**

Response surface methodology (RSM)

Valorization of tuna viscera

- Enzymatic extraction

Evaluation of the Progress of Protein Hydrolysis (pHstat method)

\[ \text{DH}\% = \frac{a \cdot bt}{1 + ct} \]

Valorization of tuna viscera

• **Enzymatic extraction**

<table>
<thead>
<tr>
<th></th>
<th>EPA</th>
<th>DHA</th>
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</thead>
<tbody>
<tr>
<td>mg/g of oil</td>
<td>24.86 ± 3.16</td>
<td>108.27 ±11.35</td>
</tr>
<tr>
<td>%</td>
<td>2.49 ± 0.32</td>
<td>10.83 ±1.13</td>
</tr>
</tbody>
</table>

EPA and DHA contribute to preventing some cardiovascular and various inflammatory diseases such as hyperlipidemia, atherosclerosis and cancer, and present some beneficial effects on the nervous system.


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Valorization of tuna viscera

**Enzymatic extraction**

**LCA comparison (DoE experiments)**

- **Software**: SimaPro 9.0.48
- **Database**: Ecoinvent 3.0.
- **Goal**: Choose the best extraction condition in term of environmental sustainability
- **Functional unit (FU)**: 1 g of fish oil produced
- **Method**: ReCIPE Midpoint (H)

**Impact category:**
- Climate change (kg CO$_2$ eq)
- Ozone depletion (kg CFC-11 eq)
- Freshwater eutrophication (kg P eq)
- Marine eutrophication (kg N eq)
- Terrestrial acidification (kg SO$_2$ eq)

Valorization of tuna viscera

- Enzymatic extraction

PCA (LCA-DoE experiments)
Valorization of tuna viscera

- **Enzymatic extraction**

Sankey Diagrams

Climate change, Ozone depletion, Terrestrial acidification, Freshwater eutrophication

Marine eutrophication

Enzyme

- (1) Electricity 2.09%
- (2) Enzyme 2.39%
- (3) Electricity 6.43%
- (4) Electricity 100%

Sankey Diagrams

Enzyme

- (1) Electricity 1.33%
- (2) Electricity 49.1%
- (3) Electricity 50.1%
- (4) Electricity 100%

Valorization of tuna viscera

• **Conclusions**

- Enzymatic extraction with alcalase is suitable for extracting oil and FPH from tuna viscera.

- The higher oil yield is obtained at pH 8.5 and E/S=1.

- The reaction kinetics showed that hydrolysis reaches a steady state after one hour.

- LCA confirms the results obtained by the DoE.

- To increase the sustainability of the process it is necessary to reduce the reaction times or to use renewable energy.

Thanks for your attention!

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