New value added products from rest raw material.
Protein hydrolysates and Lipids
~43,000 t lipids

~6,500 t w:3 lipids

~58,000 t proteins

~26 million people per year

~2.5 million people per year
Marine lipids

- Marine lipids are rich in long chain ω-3 polyunsaturated fatty acids (LC-PUFA), esp. eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA)
  - “essential”, RDI (EPA + DHA) ~ 250 mg/day
  - beneficial effect on human health

- In most of Western-Europe there is a low intake of fatty fish and fish products - intake of EPA and DHA is far below nutritional recommendations.

- A way to increase the populations intake of w-3 FA is to add fish oil to different food products – "functional foods"
Omega 3: beneficial health effects

- Omega 3 fatty acids (EPA and DHA) have positive effect on human health and development
- Brain and nerves contained high amounts and DHA (40-60% LCPUFA of total lipids)
  - Brain, eyesight development, mental condition
- Prostaglandins control inflammation processes. EPA influences formation of prostaglandins and relieve illness progress
  - Arthritis, arteriosclerosis
- EPA and DHA can be defined as “essential” nutritional components
Marine oils from *fresh raw materials*

- Fresh Norwegian rest raw materials for high quality omega-3 oil production
  - Rest raw materials from salmon and trout aquaculture
  - Rest raw materials from pelagic filleting industry
  - Liver from cod or other white fish species (both wild and farmed)
  - Oil from other marine sources (calanus, krill etc.)
<table>
<thead>
<tr>
<th>Fatty acid</th>
<th>Farmed Atlantic Salmon</th>
<th>Tuna</th>
<th>Jack mackerel</th>
<th>Herring</th>
<th>Atlantic cod liver</th>
<th>Atlantic menhaden</th>
<th>South American anchovy</th>
<th>Capelin</th>
<th>Sardine</th>
<th>Seal</th>
<th>Krill</th>
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<td>4.2</td>
<td>3.9</td>
<td>7.3</td>
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<td>7.5</td>
<td>7</td>
<td>8</td>
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<tr>
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<td>15.7</td>
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<td>15.7</td>
<td>16</td>
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<td>18</td>
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<td>20.8</td>
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<tr>
<td>C16:1n-7</td>
<td>5.1</td>
<td>5.4</td>
<td>5.1</td>
<td>6</td>
<td>9.6</td>
<td>9.1</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>14.3</td>
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<tr>
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<td>0.9</td>
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<tr>
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<td>12.4</td>
<td>9.9</td>
<td>13</td>
<td>23.4</td>
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<tr>
<td>C18:1n-7</td>
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<td></td>
<td>4.9</td>
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<tr>
<td>C20:1n-9</td>
<td>3.3</td>
<td>1.3</td>
<td>8.3</td>
<td>12</td>
<td>7.8</td>
<td>2</td>
<td>1.6</td>
<td>17</td>
<td>4</td>
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<td>&lt;1</td>
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<td>C22:1 n11</td>
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<td>20</td>
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<tr>
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<tr>
<td>C18:4 n-3</td>
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<td>12.4</td>
<td>10.9</td>
<td>5</td>
<td>11.5</td>
<td>11</td>
<td>17</td>
<td>8</td>
<td>18</td>
<td>6.6</td>
<td>18.2</td>
</tr>
<tr>
<td>C20:5 n-3 (EPA)*</td>
<td>15.7</td>
<td>27.8</td>
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<td>6</td>
<td>12.6</td>
<td>12.6</td>
<td>8.8</td>
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<td>9</td>
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<td>Total n-3</td>
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<td>41.9</td>
<td>24.4</td>
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<td>25.7</td>
<td>22</td>
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<td>19.7</td>
<td>27.3</td>
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</tbody>
</table>

Structure of SINTEF's rest raw material platform

Marine rest raw materials

Ingredients

Lipid platform

Hydrolysate platform

Consumables, pharmaceuticals

Aim: To produce oil and protein hydrolysate of premium quality
SINTEFs lipid platform

**Extraction**
Production of raw oil

**Purification**
Production of highly purified oil

**Transformation**
Production of new lipids

**Stabilisation**
Prevent oxidation in oil and food

Extraction equipment in lab and pilot scale. From 50 ml batch to 1000 kg/h continuous (Mobile SeaLab)

Reactors (100L) for:
- Degumming, bleaching
- Deodorization (1000L)
- Short path distillation (lab and pilot 10l/h)

Infrastructure (0,5 mill €)

Reactors:
- 6 reactors of 250 ml
- 32 reactors of 3 L
- Several reactors from 8 L to 1500L

Equipment for measuring oxidation kinetics (OSI, and oxygen consumption). Effect of pro oxidants and anti oxidants

Analytical capabilities:
Characterisation: Fatty acid composition, lipid classes, phospholipid classes, positioning of fatty acids
- Wet chemical: PV, Ansidin value, TBARS,
- Instrumentation: GC, Iatroscan, HPLC-Corna, NMR (Low-high field), GC-MS-MS, LC-TOF-MC
Enzyme reactors for lipid extraction and transformation
Mobile SeaLab for Bioingrediens
Mobile Sea Lab

Continuous oil production with decanter
Oil and proteins from rest raw material (1 and 2)
Oil and proteins from rest raw material (3)

1. Mincer
2. Heat exchanger
3. Mincer
4. Hydrolysis tank
5. Polishing centrifuge
6. Dry material
7. Crude oil
8. Stick water
9. Oil after stick water hydrolysis
10. Dry material
11. Stick water hydrolysate
## Ultra fresh herring oil quality

<table>
<thead>
<tr>
<th></th>
<th>Fresh raw material</th>
<th>Conventional fish oil</th>
<th>Oil from silage</th>
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<tr>
<td></td>
<td>Prosess1</td>
<td>Prosess 2</td>
<td>Prosess 3</td>
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<tr>
<td>Oil 1</td>
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<tr>
<td>Oil 2</td>
<td></td>
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</tr>
<tr>
<td>Oil 1’</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Oil 3</td>
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</tr>
<tr>
<td>FFA (%)</td>
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<td>0,30</td>
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<td>AV</td>
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<tr>
<td>Totox</td>
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<td>11,5</td>
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</table>
Mobile Sea Lab
Batch hydrolysis- and oil production with decanter
SINTEFs Hydrolysis platform

Biochemistry of hydrolysis

Process optimization

Process verification

Process design

Choice of enzyme(s)
Characterisation of raw material and product
Reactors, 6 of 250 ml, 32 of 3L

Selection of conditions for best profit
Yield, quality
Temperature, water content
pH, time…
32 reactors of 3L

The best hydrolysis conditions are tested on site with Mobile SeaLab.
1 reactor of 800L
Capacity 500kg/h

Scale up data.
Dewatering and drying in cooperation with SINTEF Energy and Engineering companies

Analytical capabilities:
Characterisation: Protein, lipid, ash and water content, Amino acid composition, free and bound, Molecular weight distribution, Water holding capacity, Foaming and emulsifying capability, Fat absorption, Antioxidative properties.
Instrumentation: GC, FPLC, NMR (Low-high field), GC-MS-MS, LC-TOF-MC, electrophoresis
# Fish protein hydrolysates (FPH)

**Bioactive properties**
- Antioxidative properties
- Antihypertensive
- Antithrombic
- Immunomodulatory activities
- Anticoagulant and antiplatelet properties
- Accelerate calcium absorption
- Possess hormone-like peptides and growth factors
- Obesity modulation

**Bulk properties**
- Tolerate heat without precipitating
- Soluble over a wide range of pH
- Water holding capacity
- Foaming and emulsifying properties
- Absorb and retain/hold oil
- Gel forming ability
- Cryoprotective properties
- Protect proteins on drying

**Nutritional properties**
- High nutritional value
- Easy digestible proteins/peptides
- Amino acid composition

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SINTEF Fisheries and Aquaculture
Bitterness of the FPH from herring

Relative bitterness level

Pa+Br  Endogenous  Flavourzyme  Bromelain  Protamex  Papain  Promod  Alcalase

Bitterness
Reduction of oxidation (oxygen uptake rate (OUR) - effect of pH

Fe³⁺

Haemoglobin

Inhibition of oxidation, %

Inhibition of oxidation, %

liposomes (lipid concentration 6mg/mL)

Protein concentration

1.25mg/mL

4 mg/mL
Model food system for evaluation of effect of added fish proteins

Salmon pate

Concentration test  Sensory test  Storage test
Primary oxidation products – Peroxide value

Secondary oxidation products TBARS
Concluding remarks

- Norway has huge amounts of available herring rest raw material for production of:
  - Ultra fresh marine oils
  - Herring has a high concentration of cetolic acid, C22:1, n11.
  - Functional and bioactive peptides/proteins

- Ultra fresh marine oils will have higher price in the market

- Peptides/proteins from fish rest raw materials can be used for human consumption

- FPH show antioxidative activity which is beneficial in industrial product formulations
Thank you for your attention