Seafood Composition
Reasons for studying seafood composition

- To evaluate quality of fish and shellfish
- To determine nutritional attributes of fish and shellfish products
- To predict shelf life and ensure safety of processed fish and shellfish
- To develop processing methods for underutilized fish and shellfish
- To determine the important components affecting sensory attributes (flavor, odor and appearance)
Fish and shellfish as food

**Important things to know:**

- Different from other animal proteins (primarily in muscle structure)
- Specific texture attributes (muscle texture)
- Limited shelf life (fish and shellfish spoil very fast)
- Hundreds of fish and shellfish (to a lesser extent) species with different characteristics and nutritional benefits
Fish and shellfish as food

Important things to know:

- The fat in fish can be very high in omega-3 fatty acids (e.g. Pacific salmon = sockeye, chinook, coho, chum, and pink)
  - Consumption Related to Prevention of Coronary Heart Diseases

- Seafood has balanced amino acids make up and high protein content (healthy + nutritious)

- Shellfish tends to have high sterol levels, mainly cholesterol (e.g. shrimp)
What is in fish muscle?

- Water and fat usually combine for 80% of the total composition of fish muscle.
- Water and fat are interchangeable, that is, higher fat content lower water content and vice-versa.
- Proteins are the building blocks of living organisms.
- Fats (lipids) are the primary energy source for living organisms.
- Fats in terrestrial animals are VERY DIFFERENT from the fats found in marine animals.
Major components of seafoods

- The three major components of fish and shellfish are:
  - Water
  - Protein
  - Lipids (fat)

- These three types of compounds make up as much as 95% of the total gross composition of fish and shellfish

- Average composition of fish muscle

  Water ~ 75%
  Protein ~ 15%
  Lipids (fat) ~ 5%
  Ash (minerals) ~ 5%
Water

- **Muscles contain 50% to 85% water, depending on species and condition**

- **Plays important roles:**
  - solvent for organic and inorganic materials
  - reaction media for enzymes (perfect environment for enzymes to ‘do their work’)
  - hydration of proteins (texture)

- **Water binds with many of the proteins**

- Water also influences proteins and lipids in forming ordered structures
Water

- Free water: is lost during freezing/thawing, muscle storage and handling
- Bound water: is not easily lost (~4-5% of the water in a muscle food)
- Water is critical to:
  - processing characteristics
  - texture
  - nutritive value
  - sensory quality
  - shelf life
Crude Protein

- **Crude protein refers to the total of nitrogen containing compounds in a sample. This includes proteins, enzymes, amino acids (e.g. lysine), nucleic acids (DNA), and nucleotides (e.g. ATP).**

- **Muscle proteins are of three classes:**
  - **Water soluble proteins:** found in abundance in the extra cellular fluid (between cells). Make up ~ 30% of total protein in fish muscle
  - **Salt soluble proteins:** make up the "flesh" and are ~ 40-60% of the total protein in fish muscle (muscle cells)
  - **Collagen:** make up 3% of total protein in fish muscle (connective tissue – ‘cement’, ‘glues’ muscle cells together)
Lipids

Lipid content in fish muscle is often times used to classify fish from ‘lean’ to ‘fatty’

Classification of seafood regarding its lipid content (Ackman, 1990):

- **Lean (<2% fat)** - cod, haddock, shellfish
- **Low fat (2-4% fat)** - sole, halibut, flounder
- **Medium fat (4-8% fat)** - salmon
- **High fat (>8% fat)** - herring, mackerel
**Dark vs. White Muscle**

- Distribution and amounts of dark muscle are different among fish species

Sections through the bodies of several fish showing depth of dark muscle. (a) Herring; (b) Mackerel; (c) Tuna; (d) Haddock; (e) Cod; (f) Whiting. Source: Love, 1988
Dark vs. White Muscle

- Fat content is markedly different between dark and white muscle
- Dark muscle contains:
  - Higher levels of myoglobin (hemoglobin in blood has iron and it promotes oxidation) than white muscle
  - More enzymes present than in white muscle
  - More fat than white muscle
  - Combination of three factors listed above makes dark muscle loose quality faster than white muscle
- Removal of dark muscle is advisable during filleting (whenever possible) to reduce lipid oxidation and consequently development of off flavors
Lipids

- Lipid content of fish muscle refers to the total amount of the following compounds:
  - **Phospholipids** – important constituents of cell membranes (STRUCTURAL LIPIDS)
    - E.g. Lecithin
      - emulsifying agent used in the food industry (e.g. ice cream)
  - **Sterols** – in fish mainly in the form of cholesterol; however, in mollusks and shellfish a wide variety of ‘sterols’ are present
    (cholesterol is related to proper growth and overall health)
Lipids

- **Triglycerides (TAG)** - main source of energy in fish - FAT
  - TAG are mainly stored in the liver of fish classified as lean
  - Fatty fish have TAG reserves mainly in their muscle and belly flap area
- **Wax esters** – used for buoyancy and found in large quantities in deep water fish; present in fish scales (waxes)
  - E.g. Bee wax is composed of wax esters
Lipids - Fatty Acids

- Triglycerides (TAG) are composed of fatty acids.
- Fatty acids are carboxylic acids.
  - E.g. Acetic acid is the carboxylic acid found in vinegar.
- Fatty acid profile of aquatic species is more complex than terrestrial animals and plants.
  - Many more types of fatty acids.
- The omega-3 fatty acids are abundant in fish (good nutritional aspect of fats in fish).
Why are we interested in marine lipids?

Most individuals consume more lipids than recommended daily allowance

- Obesity in adults and children - serious issue!
  - We eat too many calories per day
  - Increased risk of cardiovascular diseases, diabetes, several types of cancer, etc…

- Not all fats are the same
- Not all oils are the same
Importance of lipids in human nutrition

- Lipids ("fats") are an important source of metabolic energy (calories)
- Calories in fat are little over twice the amount of calories found in proteins and carbohydrates (sugars)
  - Fats supply twice the ENERGY!!!
- Essential vitamins such as A, D, E and K are only found in the ‘fatty tissue’ (fat soluble only)
- Fat provides the ‘essential fatty acids’ of the types:
  - Omega-3 fatty acids (ω-3 FA)
  - Omega-6 fatty acids (ω-6 FA)
  - Omega-9 fatty acids (ω-9 FA)
Calories in Fat, Protein and Carbohydrates

1 g Fat = 9 Cal
1 g Protein = 4 Cal
1 g Carbohydrates (sugars) = 4 Cal
Fatty acids ‘omega’ nomenclature: Carboxylic acids

OMEGA: double bond position from terminal methyl group (CH₃)
14:1ω5 = 14:1n5

SYSTEMATIC NAME: 9- Dodecenoic Acid
Structure of acylglycerols (‘glycerols’)

Simple glycerol esters of fatty acids are called tri-, di- or mono-acylglycerol (glycerols = glycerides)

Glycerol
A three carbon Alcohol with three hydroxyl groups One in each carbon

R = saturated or unsaturated carbon chain

Fatty acid moiety
Calories in Fat, Protein and Carbohydrates

Total fat = Sum of saturated and unsaturated fat

Saturated fat = lipids with fatty acids that DO NOT have double bonds

Monounsaturated fat = lipids with fatty acids that have ONE double bond only

Polyunsaturated fat = lipids with fatty acids that have TWO or MORE double bonds
### The $\omega$-6 and $\omega$-3 essential fatty acids families

- **There are two main families of polyunsaturated fatty acids (PUFA):**
  - **PUFA (multiple double bonds):**
    - **The Omega-6 Family**
      - **Linoleic**
        - $18:2 \omega 6$
      - **Gamma-linolenic**
        - $18:3 \omega 6$
      - **Dihomogamma-linoleic**
        - $20:3 \omega 6$
      - **Arachidonic (ARA)**
        - $20:4 \omega 6$
      - **Docosapentaenoic acid**
        - $22:5 \omega 6$
    - **The Omega-3 Family**
      - **Alpha-linolenic**
        - $18:3 \omega 3$
      - **Stearidonic**
        - $18:4 \omega 3$
      - **Eicosapentaenoic (EPA)**
        - $20:5 \omega 3$
      - **Docosapentaenoic (DPA)**
        - $22:5 \omega 3$
      - **Docosahexaenoic (DHA)**
        - $22:6 \omega 3$
**Supplement Facts**
Serving Size 2 softgels (2g)
Servings Per Container: 45 (90-ct bottle), 90 (180-ct bottle)

<table>
<thead>
<tr>
<th>Amount Per Serving</th>
<th>Calories from Fat 18</th>
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<tbody>
<tr>
<td><strong>Calories 20</strong></td>
<td></td>
</tr>
<tr>
<td>% Daily Value – Based on 2,000 calories/day diet</td>
<td>Calorie from Fat 18</td>
</tr>
<tr>
<td><strong>Total Fat 2g</strong></td>
<td>3%</td>
</tr>
<tr>
<td>Saturated Fat 0.5g</td>
<td>2%</td>
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<tr>
<td>Trans Fat 0g</td>
<td>&lt; 3%</td>
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<tr>
<td><strong>Cholesterol 16mg</strong></td>
<td>0%</td>
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<tr>
<td><strong>Sodium 0mg</strong></td>
<td>0%</td>
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<tr>
<td><strong>Total Carbohydrate 0g</strong></td>
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<tr>
<td>Dietary Fiber 0g</td>
<td>0%</td>
</tr>
<tr>
<td>Sugars 0g</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Protein 0g</strong></td>
<td>0%</td>
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<tr>
<td>Polyunsaturated fat: 0.5g</td>
<td>0%</td>
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<tr>
<td>Monounsaturated fat: 1g</td>
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**Total Omega-3 Fatty Acids: 600mg**

**EPA (Eicosapentaenoic Acid): 170 mg**
**DHA (Docosahexaenoic Acid): 220 mg**

http://www.naturalalaskasalmonoil.com/
Fats: Terrestrial vs. marine animals

- **Terrestrial animals feeds either on plant sources (herbivores) or on other herbivore animals (carnivores)**
- **Marine animals feed on planktons, zooplanktons, or other marine animals**
- **“We are what we eat” concept:**
  - Terrestrial animals have fats similar to the fats found in terrestrial plants and animals
  - Marine animals have fats that are similar to the fats found in planktons, zooplanktons and forage fish
Fats: Terrestrial vs. marine animals

- Omega-6 and omega-9 fatty acids are most abundant in terrestrial food sources
- Omega-3 and omega-9 fatty acids are most abundant in marine food sources
- Omega-3 fatty acids (long chain ones) are **NOT** found in the terrestrial sources at quantities that allow for maintenance of good health!!!
- Cholesterol levels in terrestrial animals tend to be higher than in marine animals
  - Some exceptions are shrimp and crab
Good fat versus bad fat

- High levels of cholesterol lead to severe heart problems (cardiovascular disease) = NOT GOOD

- High levels of low-density lipoproteins, also called LDL, lead to severe heart problems (cardiovascular disease) = NOT GOOD
  - Linked to high consumption of omega-6 FA and low consumption of omega-3

- High levels of high-density lipoproteins, also called, HDL, are an indicator of “good fat intake” that is high omega-3 and low omega-6 = VERY GOOD
NOTE 1: In our livers we can make (elongate the shorter chain fatty acids) the very important LONG CHAIN omega-3 fatty acids, but newborns cannot do this!

Breastfeeding is best source of LC ω-3 FA for newborns

NOTE 2: Most important long chain omega-3 fatty acids are: **EPA and DHA** (you will find these listed in the labeling of fish oils sold as nutritional supplements – see previous slide)

**EPA and DHA** are ONLY found in foods from aquatic environment, especially in marine fish species
Why omega-3 fatty acids are good for you?

- In infants the long chain \( \omega -3 \) FA are essential for proper brain and eye development
  - Good sight + ‘smarts’
- Our retina (eye) and brain cells have very high contents of DHA and EPA
- It helps prevent the development of cardiovascular diseases by lowering cholesterol and LDL levels in the blood
  - Dissolves the build up of ‘bad fat’ that accumulates on the inner walls of our veins and arteries
  - Build up of ‘bad fat’ in the cardiovascular system leads to high blood pressure due to a reduction on the volume available for blood to flow freely
Why omega-3 fatty acids are good for you?

- More on DHA and EPA and prevention of CVD
  - Increases heart rate variability
  - Decreases the risk of stroke and heart attack
  - Reduce levels of triacylglycerides in serum
  - Reduces blood pressure
  - Reduces insulin resistance and modulates glucose (sugar) metabolism = helps prevent development of diabetes
Why omega-3 fatty acids are good for you?

- Anti-cancer activity
- Anti-inflammatory activity
- Beneficial effect on patients with attention deficit/hyperactivity disorder (ADHD) and schizophrenia
- Beneficial effect on managing depression in adult patients
The ‘goodies’ in fish oils (fish lipids)

- Very rich source of omega-3 fatty acids, especially DHA (loaded with DHA!!) 😊
- Very poor source of omega-6 fatty acids 😁
- Rich source of omega-9 fatty acids 😁
- Relatively low content of saturated fats when compared to polyunsaturated fats 😊
- Provide dietary source of fat soluble vitamins (A, D, E and K) 😊
- ALL THESE CHARACTERISTICS MAKE FISH OIL A VERY NUTRITIOUS DIETARY ITEM
Increasing fish oil consumption

- Increasing fatty fish consumption
- Fish oil supplement
- Microencapsulation of oils

Photo from Omega Eggs website

Photo from Dairy Crest website

Graph from USA Today

*Estimated
Source: Nutrition Business Journal
The fats in plant oils versus eulachon oil (type of fish oil)

http://www.afsc.noaa.gov
The lipids in some fish oils

High omega-6 content from being fed grain meals such as soybean meal, corn meal, etc...

- Eulachon
- Farmed Salmon
- Capelin

Type of fish oil

Percent (%)

- Omega-3 FA
- Omega-6 FA
- Omega-9 FA
- Saturated FA
<table>
<thead>
<tr>
<th>Population</th>
<th>Recommendation</th>
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<tbody>
<tr>
<td>Patients without documented coronary heart disease (CHD)</td>
<td>Eat a variety of (preferably fatty) fish at least twice a week. Include oils and foods rich in alpha-linolenic acid (flaxseed, canola and soybean oils; flaxseed and walnuts).</td>
</tr>
<tr>
<td>Patients with documented CHD</td>
<td>Consume about 1 g of EPA+DHA per day, preferably from fatty fish. EPA+DHA in capsule form could be considered in consultation with the physician.</td>
</tr>
<tr>
<td>Patients who need to lower triglycerides</td>
<td>2 to 4 grams of EPA+DHA per day provided as capsules under a physician’s care.</td>
</tr>
</tbody>
</table>
Total Omega-3s by Specie

http://www.nal.usda.gov/fnic/foodcomp/
Essential vitamins in fish lipids

- **Fat soluble vitamins**
  - A (retinol) involved in growth and differentiation of tissue, also involved in good eye sight
  - D (cholecalciferol) required for calcium absorption and retention of bone
  - E (tocopherol) powerful antioxidant
  - K (menaquinones) involved in blood clotting

NOTE: fats provide the only natural dietary source of vitamin A and of vitamin E
Minor Components of Seafood

- **Carbohydrates (sugars)**
  - Primarily glycogen, some free glucose
  - Used as energy source in living animals
  - Factor in sweet flavor of some shellfish such as oysters, scallops and shrimp

- **Flavor Compounds (E.g.)**
  - Free amino acids
    - **SWEET:** glycine, alanine, serine and threonine
    - **BITTER:** arginine, leucine, valine, methionine, phenylalanine and histidine (Tuna)
Minor Components of Seafood

- **Flavor compounds (cont.)**
  - **Nucleotides**
  - associated with meaty taste in fish
  - ATP --> --> --> IMP (inosine monophosphate)

- **Volatile (small molecules)**
  - Sulfur Containing Compounds, Amines, Aldehydes, Ketones and Alcohols
Minor Components of Seafood

**Vitamins**
- **Fat Soluble Vitamins (A, D, E and K)**
- **Present in oils, muscle and viscera**
- **Liver oils**
- **Dependent on fat content of the animal**
- **Water Soluble Vitamins (Thiamine)**

**Minerals**
- **Calcium, Phosphorus, Magnesium, Iodine**
- **Zinc (Oysters)**
- **Copper (Shellfish)**
Eat MORE FISH

Increase omega-3's in your diet!