Development of Functional Foods with Omega-3 Fatty Acids

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Topics

- Human Health and Diet
- Emergence of Functional Foods
- Oils and Fats in Perspective: Fatty Acids and its role in Human Health
- Nutritional Lipids: Strategies
- Conclusions
Human Health and Diet: Deaths attributed to 19 leading risk factors, by country income level.

- High blood pressure
- Tobacco use
- High blood glucose
- Physical inactivity
- Overweight and obesity
- High cholesterol
- Unsafe sex
- Alcohol use
- Childhood underweight
- Indoor smoke from solid fuels
- Unsafe water, sanitation, hygiene
- Low fruit and vegetable intake
- Suboptimal breastfeeding
- Urban outdoor air pollution
- Occupational risks
- Vitamin A deficiency
- Zinc deficiency
- Unsafe health-care injections
- Iron deficiency

WHO Report 2010
The Causal Chain-Causes of Blood Pressure, Cholesterol, Ischaemic heart Disease
Partial Listing of Lifestyle-related and other Disorders/Diseases where Nutraceuticals/Functional Foods can play a Major Role in Prevention/Management

1. Cardiovascular Diseases (CVD) and risk factors (blood lipids, b.p., etc.)
2. Type 2 Diabetes
3. Inflammatory conditions (arthritis, bowel, etc.)
4. Osteoporosis
5. Mental Health and ‘Psychiatric disorders’
6. Digestive Problems/Liver Diseases
7. Cancers (colon, prostate, breast, others)
8. Kidney Disorders
9. Others
Emergence of Functional Foods:
Wellness Food-Drug Interface

Functional foods fall in the grey area between conventional foods and drugs.
“Functional Foods” are foods or dietary components that may provide a health benefit beyond basic nutrition.
Functional food market developed in a way to reduce the high health costs derived from a population with high life expectations.
Oils and Fats in perspective

6.5 b people consume about 120 m tons pa
That is almost 20 kg per capita

Annual value of oils and fats market over €120b

Seed oil (soybean, sunflower seed, rapeseed, mustard, etc.) Tropical oil (palm, coconut, palm kernel, etc.)

Ann Nutr Metab 2009; 54(suppl 1):15–24
Many Different Fat-Rich Products

• Primary:
  – Vegetable/plant oils
  – Butter/milk fats
  – Lard/tallow (derived from animals)
  – Marine

• Secondary: (made from one or more of the above)
  – Margarines, Reduced fat spreads
  – Ghee
  – Vanaspati
  – Cooking fats/white fats/shortenings
  – Mayonnaise
Main Dietary Sources of Fat

- Major contributors to intake of saturated fat
  - Dairy (Ghee, Butter, Milk, Cheese)
  - Meat
  - Baked/Fried foods and snacks
  - Cooking fats/oils (Coconut, Palm, Olive)
- Major contributors to intake of polyunsaturated fat
  - Vegetable oils (Canola, Soyabean, Peanut, Sunflower, Rapeseed)
  - Margarines and mayonnaise
<table>
<thead>
<tr>
<th>Fatty acids</th>
<th>Coconut Oil</th>
<th>Palm kernel oil</th>
<th>Palm oil</th>
<th>Olive oil</th>
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</table>
Comparision of Dietary Fats and Oils

Key:
- Saturated
- Polyunsaturated, omega-6
- Monounsaturated
- Polyunsaturated, omega-3

Animal fats and the tropical oils of coconut and palm are mostly saturated fatty acids.

- Coconut oil
- Butter
- Beef tallow
- Palm oil
- Lard

Some vegetable oils, such as olive and canola, are rich in monounsaturated fatty acids.

- Olive oil
- Canola oil
- Peanut oil

Many vegetable oils are rich in polyunsaturated fatty acids.

- Safflower oil
- Flaxseed oil
- Walnut oil
- Sunflower oil
- Corn oil
- Soybean oil
- Cottonseed oil
Classification of Fatty Acids

Fatty Acids

Saturated Fatty Acids (SFA): Bad Fats
Unsaturated Fatty Acids: Good Fats

Poly Unsaturated Fatty Acids (PUFA)
- w-3 alpha Linolenic acid (ALA)
- Eicosapentanoic Acid (EPA)
- Docosahexanoic Acid (DHA)

Mono Unsaturated Fatty Acids (MUFA)
- w-6 Linoleic Acid (LA)
- Gamma Linolenic Acid (GLA)
- Arachidonic Acid (ARA)
# Classification of Fatty Acids

<table>
<thead>
<tr>
<th>Saturated fat</th>
<th><strong>Unsaturated Fatty Acids</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid or plastic fats:</td>
<td><strong>Poly unsaturated</strong></td>
</tr>
<tr>
<td>shortening, butter, lard</td>
<td>Sunflower, sesame seed,</td>
</tr>
<tr>
<td>or any solid fat</td>
<td>cottonseed, canola,</td>
</tr>
<tr>
<td>usually solid at room</td>
<td>rapeseed, soy oil, marine</td>
</tr>
<tr>
<td>temperature</td>
<td>fish oil</td>
</tr>
<tr>
<td>except palm &amp; coconut oils</td>
<td><strong>Mono unsaturated</strong></td>
</tr>
<tr>
<td></td>
<td>olive oil, canola oil, nuts,</td>
</tr>
<tr>
<td></td>
<td>seeds * cashews</td>
</tr>
</tbody>
</table>

**Trans Fatty Acids** are formed during hydrogenation of oil

**Purpose of hydrogenation:** to prevent rancidity and increase shelf life
Impact of Unsaturation

- **Stability**
  - **Saturated fat** is more resistant to oxidation.
  - **Monounsaturated fat** is slightly less susceptible to spoilage.
  - **Polyunsaturated fat** spoils most readily.

- **Protection from rancidity**
  - Sealed in airtight containers away from light
  - Add antioxidants
  - Hydrogenation

- **Types of PUFA**
  - An omega-3 fatty acid has the location of the double bond in the third position. An example is linolenic acid.
  - An omega-6 fatty acid has the location of the double bond in the sixth position. An example is linoleic acid.
Good Fats / Bad Fats

**GOOD**
- lower total cholesterol
- lower LDL “bad” cholesterol

*Monounsaturated*
Sources: Nuts, canola, olive oil

*Polyunsaturated*
Sources: Seafood (Animal), Corn, soy, safflower, sunflower, rapeseed (Plant)

Omega 3’s = polyunsaturates

**BAD**
- raise LDL
- lower HDL "good“ cholesterol

*Saturated*
Sources: Meat, dairy, and eggs (Animal); coconut, palm oil (Plant)

*Trans*
Sources: Fried foods, processed foods with hydrogenated oils

Trans Fat Is More Dangerous than Saturated Fat

Trans fat

Saturated fat

Good (HDL) Cholesterol

Bad (LDL) Cholesterol
Ratio of SFAs/(MUFAs + PUFAs) in the diet in different regions.

Drivers of Nutritional Improvements for Oil/Fat Based Food Industry

- Replace SFA by MUFA or preferably PUFA
- Practically eliminate TFA
- Ensure delivery of essential Omega 3 and 6
- Fortify with fat soluble vitamins A and D
- Preserve natural antioxidants (e.g. vit E)

WHO Recommendations on the quality of fat in the diet are made for optimal health across the life course worldwide, from an age of about 2 years onwards:

- Fat may provide up to 15–35% of the daily energy intake (at least 15%);
- Saturated fat should provide no more than 10% of the daily energy intake;
- Essential PUFA (w–6 and w–3) should contribute 6–10% of the daily energy intake;
- Trans fats should be less than 1% of the daily energy intake, and
- The remaining of the energy from fat can be provided by monounsaturated fats
- The ratio of linoleic to alpha-linolenic acid in the diet should be between 5:1 and 10:1. Individuals with a ratio in excess of 10:1 should be encouraged to consume more w-3 rich foods such as green leafy vegetables, legumes, fish and other seafood.
Greenland Eskimo Study

- “Eskimo paradox”
  - traditional diet - high in fat and protein, low in fruit, fiber and leafy green vegetables
  - little evidence of heart disease and low blood cholesterol levels.
- Greater intake of seal, whale and fish (all contain high levels of DHA and EPA)
- Lower intake of omega-6 fatty acids
- Lead to interest in omega-3 fatty acids in fish oil for prevention of Cardio Vascular Disease (CVD)

Synthesis of Essential Fatty Acids

<table>
<thead>
<tr>
<th>w-6 fatty acids</th>
<th>Enzymes</th>
<th>w-3 fatty acids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linoleic (LA)</td>
<td>18:2</td>
<td>α-Linolenic (ALA) 18:3</td>
</tr>
<tr>
<td>γ-Linolenic (GLA)</td>
<td>18:3</td>
<td>∆ 6-desaturase</td>
</tr>
<tr>
<td>Dihomo-γ-linolenic</td>
<td>20:3</td>
<td>elongase</td>
</tr>
<tr>
<td>Arachidonic (ARA)</td>
<td>20:4</td>
<td>∆ 5-desaturase</td>
</tr>
<tr>
<td>Adrenic</td>
<td>22:4</td>
<td>elongase</td>
</tr>
<tr>
<td>Tetracosatetraenoic</td>
<td>24:4</td>
<td>elongase</td>
</tr>
<tr>
<td>Tetracosapentaenoic</td>
<td>24:5</td>
<td>∆ 6-desaturase</td>
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<tr>
<td>Docosapentaenoic (DPA)</td>
<td>22:5</td>
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<tr>
<td>Octadecatetraenoic</td>
<td>18:4</td>
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<tr>
<td>Eicosatetraenoic</td>
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<tr>
<td>Eicosapentaenoic (EPA)</td>
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<tr>
<td>Docosapentaenoic</td>
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<tr>
<td>Tetracosahexaenoic</td>
<td>24:6</td>
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</tr>
<tr>
<td>Docosahexaenoic (DHA)</td>
<td>22:6</td>
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Because of critical role in normal retinal and brain development in the human, DHA should be considered conditionally essential during early development. Similarly, EPA+DHA might be considered conditionally essential for life-long health considering intakes required for the prevention of CVD.
Role of w-6 Fatty Acids

- **Linoleic acid (LA C18:2) and gamma-linolenic acid (GLA C 18:3):** Leafy vegetables and unhydrogenated vegetable oils such as corn oil, peanut oil, cottonseed oil, soybean oil

- **Arachidonic acid (ARA;C20:4):** Is obtained from meats, eggs and dairy products.

- **Conjugated Linoleic Acid:** No sufficient evidence to demonstrate that the intake of CLA has a positive effect on weight and body composition in humans

- Excessive amounts of omega-6 (PUFA) and a very high omega-6/omega-3 ratio has been shown to promote the pathogenesis of many diseases: -cardiovascular disease
  - cancer
  - Inflammatory and autoimmune diseases

Omega-3 fatty acids may have positive effects on:

- High blood pressure
- Body TAG and cholesterol
- Abnormal blood clotting (thrombosis)
- Reduced Fat deposition (atherosclerosis)
- Cardiovascular diseases
- Brain growth and development
- Eye Function
Instability of Omega-3 Oils

- Prone to oxidation

\[
\text{EPA/DHA} \rightarrow \text{peroxides} \rightarrow \text{aldehydes, ketones, etc}
\]

Indicators:
- Peroxide Value
- p-Anisidine Value

- Oxidation results in:
  - Loss of EPA% and DHA%
  - Off fishy odor and/or taste
  - Off fishy odor and/or taste

Omega 3 Fatty Acids are sensitive to oxidative damage as well as possessing adverse taste and flavour
Intake Recommendations for w-3 Fatty Acids

• FDA – Should not exceed 3 g per person per day from conventional food and dietary supplement sources

• Simopoulos (1997) recommended daily intakes for EPA + DHA at 650 mg, with at least 222 mg for both EPA and DHA, and 2.22 g/d for ALA.

### TABLE 5. Summary of Recommendations for Omega-3 Fatty Acid Intake

<table>
<thead>
<tr>
<th>Population</th>
<th>Recommendation</th>
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</thead>
<tbody>
<tr>
<td>Patients without documented CHD</td>
<td>Eat a variety of <em>(preferably oily)</em> 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 $\approx 1$ g of EPA+DHA per day, preferably from oily fish. EPA+DHA supplements could be considered in consultation with the physician.</td>
</tr>
<tr>
<td>Patients needing triglyceride lowering</td>
<td>Two to four grams of EPA+DHA per day provided as capsules under a physician’s care</td>
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Improvement on the Nutritional Profile of Fat Based Food Products

- **Nutritional Lipids:**
- **Structuring Edible Oils:** (Chemical and enzymatic inter-esterification)
- **Genetic Modification of Oilseed Crops**
- **Feeding Animals with PUFAs for PUFA enriched Foods**
- **Polyunsaturated Fatty Acid Production and Delivery:**
  - Production of PUFAs by Microorganisms
  - Production and Extraction of PUFAs from Fish Oil
  - Micro-encapsulation of PUFAs
    - (Spray drying, Extrusion, Gelation, Emulsion, Coacervation)
Structuring Edible Oils

Chemical and Enzymatic Esterification:
Potential TAG species from a 1,3-specific lipase-catalyzed trans-esterification reaction between a medium-chain TAG and a long chain TAG.

Selective Enrichment of DHA and EPA Using Lipases Possessing Fatty Acid Specificity
Increasing fish consumption is challenging and may not be possible.
- Difficult to eat amount of fish needed
- Vegetarians/People with fish allergies/Those who don’t like fish
- Contamination with metals

Food fortification with w-3 Fatty Acid is convenient and efficient
- Allows one to eat foods fortified with Omega-3 fatty acids
Production of PUFA (DHA) by Microorganisms

PUFA producing Microbes

- *Phaeodactylum tricornutum*
- *Isochrysis galbana*
- *P. tricornutum*
- *Monodus subterraneus*
- *P. ultimum* (Fungi)

Feasibility of large scale production

Micro-encapsulation offers ability to develop innovative food products

- Spray Drying
- Emulsion
- Coacervation
- Polymerization

Stabilising Shelflife
Prevents oxidation
Provides stable Matrix
Controlled/delayed release of active ingredients

- Encapsulation matrix
- Effects of antioxidants on stability of EPA and DHA

Omega 3 FA have been added to commercial products including milk, cheese, yogurt, bread and juice.
Global Omega-3 Fatty Acid Market (Frost & Sullivan 2005)

Conclusions: Functional Food Development using w-3 Fatty Acids

Critical Factors

• Improvement Of Ratio Of Saturated Fatty Acid To Unsaturated Fatty Acids and w-3:w-6 Fatty Acid Ratio In The Diet
• Development Of w-3 Fatty Acid Supplemented Food Products With Optimal Taste And Functional Properties
• Technology Know-how
• Nutritional And Clinical Scientific Evidence
• Product And Process Development
Thank You for Your Attention.