Innovative Dietary Sources of Omega-3 Fatty Acids
or
“The challenges of monitoring intake of LC N-3 PUFAs”

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**n-6 Family**

- LA (linoleic acid)
  - delta-6 desaturase
  - elongase
- GLA (gamma-linolenic acid)
  - delta-5 desaturase
- DGLA
  - elongase
- AA (arachidonic acid)
  - COX-1
  - COX-2
- Prostaglandins
- Thromboxane
- Prostacyclin
- Cancer
- CVD
- Inflammation

**n-3 Family**

- ALA (alpha-linolenic acid)
  - SDA (stearidonic acid)
  - 20:4 n-3
  - elongase
  - delta-5 desaturase
  - EPA (eicosapentaenoic acid)
  - DPA (docosapentaenoic acid)
  - 24:5 n-3
  - elongase
  - delta-6 desaturase
  - peroxisomal oxidation
- DHA (docosahexaenoic acid)
- Whelan et al., 2005

**Sources**
- Vegetable oils: i.e., canola, soybean, flax
  - Specialty oils: i.e., borage and evening primrose oils
- Fish & fish oil, Echium oil, Black current oil, GMO veg oils
- Terrestrial meats
- Vegetable oils, meats, eggs
- Vegetable oils: i.e., canola, soybean, flax
- Fish & fish oil, Terrestrial meats
- Fish & fish oil, Terrestrial meats
### The Effect of EPA/DHA (fish & fish oil) Consumption on CVD Mortality

<table>
<thead>
<tr>
<th>Study</th>
<th>N-3 PUFA g/day</th>
<th>Effect on CVD Mortality (RR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascherio (1995)</td>
<td>70 mg/d vs 580 mg/d</td>
<td>NS (n=44,895)</td>
</tr>
<tr>
<td>Singh (1997)</td>
<td>+1.08 g/d (EPA)</td>
<td>↓ (n=122)</td>
</tr>
<tr>
<td>Albert (1998) (Physicians Health Study)</td>
<td>10 mg/d vs ≥247 mg/d</td>
<td>NS (n=20,551)</td>
</tr>
<tr>
<td>Marchioli (2002) (GISSI Prev. Trial)</td>
<td>+1 g/d (EPA+DHA)</td>
<td>↓ (n=11,323)</td>
</tr>
<tr>
<td>Hu (2002)</td>
<td>67 mg/d vs 533 mg/d</td>
<td>↓ (n=84,688)</td>
</tr>
<tr>
<td>Hu (2003) (Nurses Health Study)</td>
<td>40 mg/d vs ≥250 mg/d</td>
<td>↓ (n=5,103)</td>
</tr>
<tr>
<td>Mozaffarian (2005)</td>
<td>&lt;250 mg/d vs ≥250mg/d</td>
<td>↓ (n=45,722)</td>
</tr>
<tr>
<td>Yzebe (2004)</td>
<td>Meta-Analysis</td>
<td>↓ (n=13,780)</td>
</tr>
</tbody>
</table>
Risk of Developing Cancer: Highest Group vs Lowest Group of Omega-3 Fatty Acid
“Based on analysis of a single 24 hour recall in NHANES III, only 25% of the US population reported any amount of daily EPA or DHA intake.”

Translation: 75% of the US population is VEGANS

http://www.ahrq.gov/clinic/tp/o3cardtp.htm
Can it be related to reported levels of long chain highly unsaturated fatty acid compositions, i.e., AA, EPA, DPA, DHA?
Why is this important?

• The USDA database is the gold standard database for nutrient composition

• The USDA database is the primary source for most of the food analysis software used in research

• It is used in setting public policy with regards to recommendations
Beef, rib eye, small end (ribs 10-12), separable lean and fat, trimmed to 0" fat, all grades, cooked, broiled

Refuse: 8% (Bone and connective tissue)
NDB No: 13952 (Nutrient values and weights are for edible portion)  
(as of April 22, 2007)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Units</th>
<th>Value per 100 grams</th>
<th>Number of Data Points</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Proximates</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>g</td>
<td>57.52</td>
<td>20</td>
<td>0.591</td>
</tr>
<tr>
<td>Protein</td>
<td>g</td>
<td>27.27</td>
<td>20</td>
<td>0.378</td>
</tr>
<tr>
<td>Total lipid (fat)</td>
<td>g</td>
<td>14.74</td>
<td>20</td>
<td>0.788</td>
</tr>
<tr>
<td>Ash</td>
<td>g</td>
<td>1.10</td>
<td>20</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>Fatty acids, total polyunsaturated</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18:2 undifferentiated</td>
<td>g</td>
<td>0.402</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>18:3 undifferentiated</td>
<td>g</td>
<td>0.093</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>18:4</td>
<td>g</td>
<td>0.000</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>20:4 undifferentiated</td>
<td>g</td>
<td>0.053</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>20:5 n-3 (EPA)</td>
<td>g</td>
<td>0.000</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>22:5 n-3 (DPA)</td>
<td>g</td>
<td>0.000</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>22:6 n-3 (DHA)</td>
<td>g</td>
<td>0.000</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

However, 8 oz of Rib Eye contains 67 mg EPA/DPA/DHA!

And ~70% of that is DPA, not EPA or DHA!

Taber et al., Lipids 33:1151, 1998
DPA: the forgotten n-3 PUFA?

- DPA (22:5 n-3) is a major LC n-3 PUFA in terrestrial meats and maybe of particular importance in assessing risk for chronic diseases.

- For example, Howe et al. estimates
  - that 43% of the LC n-3 PUFA in the Australian diet is derived from land-based meats
  - DPA is the major LC n-3 PUFA in those food sources

18:3 (ALA)  
20:5 (EPA)  
**22:5 (DPA)**  
22:6 (DHA)
Current estimates for the amounts of EPA+DHA in the diets of various countries:

<table>
<thead>
<tr>
<th>Country</th>
<th>Amount (mg/d)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>~100-200 mg/d</td>
<td>(Kris-Etherton 2003)</td>
</tr>
<tr>
<td>Canada</td>
<td>143 mg/d (pregnant women)</td>
<td>(Holub 2005)</td>
</tr>
<tr>
<td>Australia</td>
<td>246 mg/d</td>
<td>(Howe 2004)</td>
</tr>
<tr>
<td>Germany</td>
<td>215/315 mg/d (women/men)</td>
<td>(Linseisen 200)</td>
</tr>
<tr>
<td>France</td>
<td>400/500 mg/d (women/men)</td>
<td>(Astorg 2004)</td>
</tr>
</tbody>
</table>
Problems with modifying foods with LC n-3 PUFA:

• Our food supply is rapidly changing with regards to n-3 PUFA content and this complicates our inability to accurately assess n-3 PUFA intake because
  1. We lack appropriate tools to do this now
  2. Enriching/fortifying non-traditional foods will provide a continually moving target
## Non-Traditional Dietary Sources of N-3 PUFA

<table>
<thead>
<tr>
<th>Food</th>
<th>Serving</th>
<th>ALA (mg)</th>
<th>EPA+DHA (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breads and Pasta</td>
<td>100 g</td>
<td>113-1600</td>
<td>8-80</td>
</tr>
<tr>
<td>Cereals (and granola bars)</td>
<td>1 cup (55 g)</td>
<td>1000-4900</td>
<td>--</td>
</tr>
<tr>
<td>Milk</td>
<td>250 ml</td>
<td>--</td>
<td>10-190</td>
</tr>
<tr>
<td>Eggs</td>
<td>1 egg (50 g)</td>
<td>100-600</td>
<td>86-150</td>
</tr>
<tr>
<td>Processed Meats</td>
<td>100 g</td>
<td>490</td>
<td>88-190</td>
</tr>
<tr>
<td>Salad Dressing</td>
<td>14-31 g</td>
<td>2000-4000</td>
<td>700</td>
</tr>
<tr>
<td>Margarine spreads</td>
<td>10-100 g</td>
<td>300-1000</td>
<td>60-150</td>
</tr>
<tr>
<td>Pizza</td>
<td>1 slice</td>
<td>--</td>
<td>32</td>
</tr>
<tr>
<td>Nutrition Bars</td>
<td>50 g</td>
<td>70-2200</td>
<td>3-115</td>
</tr>
<tr>
<td>Juices</td>
<td>6 oz</td>
<td>--</td>
<td>100</td>
</tr>
</tbody>
</table>
Tip-Top Bakeries
• Australia

Wegman’s n-3 Breads
• microencapsulated powder
  (80 mg LC n-3)

Omega 3 Super Eggs
Flax fed chickens
• Texas
  per egg
  - OMEGA 3 DHA 150 mg

Parmalat Omega 3 Milk
• Europe/S.A
  per slice
  - OMEGA 3 121 mg
  - OMEGA 3 ALA 84 mg
  - OMEGA 3 EPA 6 mg
  - OMEGA 3 DHA 27 mg
  per 200 ml
  - OMEGA 3 120 mg
  - OMEGA 3 EPA 60 mg
  - OMEGA 3 DHA 60 mg

Pasta with Omega 3 eggs
• France
Microencapsulated Tuna oil (Nu Mega)

Cheeses

Orange Juice with MEG-3* (fish oil and fish gelatin)

- OMEGA 3

per slice
- OMEGA 3 32 mg

per serving
- OMEGA 3 50 mg
The primary ways that these products are being enriched/fortified with n-3 PUFA:

• Bio-delivery: feeding an animal the n-3 PUFA precursor (i.e., ALA) and enriching their tissues with LC n-3 PUFA (i.e., EPA, DPA in meats, and DHA in eggs)

• Adding the n-3 PUFA rich/enriched oils directly to foods (post-harvest modification of the foods)

• Post harvest modification of the oils: Micro-encapsulation of the oil to maintain stability and mask flavors

BASF, Roche, Clover, Nu-Mega, Wudel, Inc and Ocean Nutrition Canada (ONC), have created microencapsulated fish oil powders for use in food products.

These companies used spray dried emulsion technology or a process involving complex coacervation to form powders to create the shell of the microcapsule.

A powder you add to foods to supplement the diet

Omega-3 Fish Oil Powder you can add to juice or food

- 500mg Omega-3 (DHA + EPA) per serving
- No fish taste or smell
- No large fish oil capsule
- No unpleasant fish burps
- Convenient delivery system for adults and children
Ubisol-Aqua™ using nanotechnology has generated a water soluble fish oil/ n-3 PUFA • by Zymes LLC

Ideal for fish oil / omega 3-fortified fruit juices, i.e., grape juice or in apple juice
Development of plant sources LC n-3 PUFA

• DHA generated from algae, i.e., Martek’s DHASCO oil (40% DHA)

• Genetically modified plant oils, (i.e., Monsanto’s SDA-enriched canola oil, and genetically-modified soybean by a number of companies)
SUMMARY

• These changes further exacerbate our inability to maintain accurate, up-to-date food composition databases for n-3 PUFA, and further challenge the ability of scientists to ascertain true health risks associated with their consumption.

• With the ability to provide cheaper and safer sources of LC n-3 PUFA (compared to fish), along with the technological advances that improve palatability and stability, commercial development of non-traditional foods that are enriched/fortified with n-3 PUFA will only increase.

• The Result: Quantifying LC n-3 PUFA intakes in the US will become even more daunting.
Thank You

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