FUNCTIONAL FOODS TO ENHANCE HEALTH

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Food Safety
Hippocrates: The Father Of Medicine
(ca. 400 BC)
Nutritional Value: Diet and Disease Prevention

- Historical Identification of Deficiency Disease
  - infectious agent
  - nutrient identification
- Dietary Guidelines
- Food Guide Pyramid
Paracelsus: Father of Toxicology and Pharmacology
(1493-1541)
The Dose Makes The Poison
Ethnobotany: Folk Medicine

- Identification by population (human and animal) use
- Varied chemistry within plant species
- Active components depend on plant cycle, ecology, soil and climate

Therapeutic plants were identified, the active components isolated, and new pharmaceuticals designed to treat specific diseases.
Physiologically Active Food Components Identified by Mechanism of Action

- **antioxidants**, superoxide quencher; modifiers of oxidative damage and detoxification mechanisms related to oxidative stress; NO Synthetase inducer; enhanced DNA repair; decreased DNA damage/modification

- **antimutagens, anticarcinogens**, and inducers of enzymes of xenobiotic phase II metabolism; inhibits tumor promotion; antimetastatic agent; inhibits cell proliferation; inhibits angiogenesis.

- **antimicrobial, antiviral** bioactive substances

- **enhancers of GI function**, and colonic microflora; decreased risk for cancer and cardiovascular disease

- **immunomodulators**; stimulates immune function

- **anti-inflammatory agents**
Physiologically Active Food Components Identified by Mechanism of Action

- **Neuroregulatory substances**: improve psychological condition, memory enhancement
- **Modulation of hormones**: relieves symptoms of menopause
- **Antihypertensives**: control of BP
- **Hypocholesterolemic agents**: lowers serum cholesterol, reduces CHD
- diminishes allergenicity
- **Decreases platelet aggregation**: reduces stroke
- **Stimulates bone repair**: reduces osteoporosis
- inhibits macular degeneration
Cancer Protection Pyramid

On a scale of increasing importance

Garlic
Cabbage
Licorice
Soybeans
Ginger
Umbelliferae (carrots, celery, parsnips)
Onions
Tea
Turmeric
Citrus (orange, lemon, grapefruit)
Whole Wheat
Flax
Brown Rice
Solanaceae (tomato, eggplant, peppers)
Cruciferous (broccoli, cauliflower, brussels sprouts)
Oats
Mints
Oregano
Cucumber
Rosemary
Sage
Potato
Thyme
Chives
Cantaloupe
Basil
Tarragon
Barley
Berries

Anticancer Activity of Phytochemicals

1. Modification of carcinogen activation
   a. Polyphenols  b. Alkyl
   c. Sulfide       d. Isothiocyanates;
   e. Monoterpenes  f. Flavonoids

2. Modification of carcinogen detoxification
   a. Alkyl cysteines  b. Isothiocyanates

3. Blocks initiation
   a. Polyphenols  b. Indole  c. Sulfides
d. Flavonoids   e. Protease inhibitors

4. Blocks DNA reactive species
   a. Carotenoids  b. Polyphenols  c. Flavonoids
d. Terpenes   e. Protease inhibitors
   f. Sulfides  g. Indoles

5. Blocks cell proliferation
   a. Monoterpenes
   b. Vitamin A, precursors and metabolites
Functional Foods Definition
(IFT Panel)

- Functional foods are foods and food components that provide a health benefit beyond basic nutrition (for the intended population).
  - Examples may include conventional foods; fortified, enriched or enhanced foods; and dietary supplements.

- Functional foods provide essential nutrients often beyond quantities necessary for normal maintenance, growth, and development, and/or other biologically active components that impart health benefits or desirable physiological effects.
Food Processing

Functional foods overdose?

Touted as a prescription for profits, some nutraceuticals just might be too good to be true.

Food Technology

ABCs of Nutraceutical Ingredients

Demographic Targeting Comes of Age • Fat Replacers • Fat-Free and Reduced Fat Reach Maturity • Food Labeling in Germany • Trans Fatty Acids
HISTORICAL FUNCTIONAL FOODS

- yogurt
  - anti-aging (Metchnikoff)
  - intestinal enhancement
  - live culture
- fiber
  - bulk (regularity)
  - soluble fiber (viscosity)
**Functional Foods**

- Food that imparts a physiological benefit through crop selection, breeding enhancement, biotechnology, added ingredients, or processing modification.
Design of the Functional Tomato
Selection for Bioactive Agents

- Natural Product Sources:
  - Plant extracts
  - Plant cell cultures
  - Marine organisms
  - Microorganisms

- Selection, Collection, and Initial Screening:
  - Ethnomedicinal
  - Taxonomy

- Biological Screening
  - Actives

- Assay Development

- Bioassay Directed Fractionation

- Structure Modification & Synthesis of Analogues

- Structure Elucidation

- Characterization:
  - Biological
  - Chemical

- Toxicology and Pharmacokinetic Studies

- Drug Candidate
CLASSIFICATION OF BIOACTIVE FOOD COMPONENTS

A. Isoprenoids
   - Carotenoids, Saponins, Tocotrienols, Tocopherols & Simple terpenes

B. Phenolic Compounds
   - Coumarin, Tannins, Lignin, Anthrocyanins, Isoflavones & Flavonols

C. Protein/Amino Acid Based
   - Amino acids, Allyl-S-compounds, Capsaicinoids, Isothiocyanates, Indoles, Folate & Choline; Lactoferrin

D. Complex Carbohydrate
   - Oligosaccharides, Non-starch polysaccharide

E. Fatty Acid Lipids
   - W-3 PUFA, CLA, MUFA, Sphingolipids & Lecithin

F. Microbial
   - Probiotics & Prebiotics
### A. ISOPRENOIDS

Carotenoids – Lycopene, Carotene, Lutein/Zeaxanthin

<table>
<thead>
<tr>
<th>Food Source</th>
<th>Potential Health Benefit</th>
<th>Possible Mechanisms and Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomatoes, carrots, yams, cantaloupe, spinach, sweet potatoes, citrus fruit, apricots, mango, pumpkin, kale</td>
<td>Reduction of cancer and heart disease; reduction the risk of macular degeneration.</td>
<td>Antioxidant activity; Free radical scavenger; Singlet oxygen scavenger; Induction of cell-cell communication, and growth control; Inhibition of the proliferation of acute myeloblastic leukemia; Modulation of mutagenesis, cell differentiation, and proliferation; Differentiation and growth control of epithelial cells.</td>
</tr>
</tbody>
</table>
Carotenoids

- Lycopene
- α-Carotene
- β-Carotene
- Canthaxanthin
- Lutein
- Methyl-Bixin
# Lycopene Content of Various Foods

<table>
<thead>
<tr>
<th>Food</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomatoes, fresh</td>
<td>0.88-4.20</td>
</tr>
<tr>
<td>Tomatoes, cooked</td>
<td>3.70</td>
</tr>
<tr>
<td>Tomato sauce</td>
<td>6.20</td>
</tr>
<tr>
<td>Tomato paste</td>
<td>5.40-150</td>
</tr>
<tr>
<td>Tomato soup, condensed</td>
<td>7.99</td>
</tr>
<tr>
<td>Tomato powder</td>
<td>112-126</td>
</tr>
<tr>
<td>Tomato juice</td>
<td>5.00-11.60</td>
</tr>
<tr>
<td>Sun-dried tomato in oil</td>
<td>46.50</td>
</tr>
<tr>
<td>Pizza sauce, canned</td>
<td>12.71</td>
</tr>
<tr>
<td>Ketchup</td>
<td>9.90-13.44</td>
</tr>
<tr>
<td>Apricot</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Apricot, canned</td>
<td>0.06</td>
</tr>
<tr>
<td>Apricot, dried</td>
<td>0.86</td>
</tr>
<tr>
<td>Grapefruit, raw pink</td>
<td>3.36</td>
</tr>
<tr>
<td>Guava, fresh</td>
<td>5.40</td>
</tr>
<tr>
<td>Guava juice</td>
<td>3.34</td>
</tr>
<tr>
<td>Watermelon, fresh</td>
<td>2.30-7.20</td>
</tr>
<tr>
<td>Papaya, fresh</td>
<td>2.00-5.30</td>
</tr>
</tbody>
</table>
## A. ISOPRENOIDS

*Tocopherols & Tocotrienols*

<table>
<thead>
<tr>
<th>Food Source</th>
<th>Potential Health Benefit</th>
<th>Possible Mechanisms and Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green leaf vegetables</td>
<td>Antioxidant</td>
<td>Lowering free radical; inhibition of lipid peroxidation;</td>
</tr>
<tr>
<td>nuts</td>
<td>Anticancer</td>
<td>Inhibition of proliferation of cancer cells;</td>
</tr>
<tr>
<td>grains</td>
<td>Hypcholesterolemic effects</td>
<td>Inhibition of HMG-CoA reductase (tocotrienols)</td>
</tr>
<tr>
<td>vegetable oil</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Tocopherols and Tocotrienols

**α-Tocopherol**

**α-Tocotrienol**

Fig. 2.1. Molecular structures of α-tocopherol and α-tocotrienol.
Tocopherols and Tocotrienols

- α-Tocopherol is the unit standard for vitamin activity, based on E-deficiency fetal resorption

- All tocopherols and tocotrienols have antioxidant activities: ranking depends on oxidative model used.

- Tocopherols, tocotrienols and metabolites have activities separate from their antioxidant effect

other: α-tocopherol quinone, γ-tocopherol metabolites (γ-CHEC, LLU-γ)
Tocopherols and Tocotrienols

- **Anti-inflammatory**
  - LPS-stimulated macrophage PGE2 synthesis: \( \alpha \)-tocopherol inhibits macrophage but not epithelial cell
  - COX2 activity: I by \( \gamma \)-tocopherol & \( \gamma \)-CEHC -- not antioxidant effect

- **Natriuretic (regulates cellular fluids related to HT and CVD)**
  - LLU-\( \alpha \) is an endogenous natriuretic factor; may I 70pSK channel in apical membrane of kidney
  - \( \alpha \)-tocotrienol increases LLU-\( \alpha \) (mechanism unknown)

- **Signal transduction**
  - tocopherols and tocotrienols I Protein Kinase C (\( \alpha \)-toc>\( \beta \)-,\( \gamma \)-,\( \delta \)-toc and \( \alpha \)-tocotrienol)
  - \( \alpha \)-and \( \gamma \)-tocopherol increase NO generation, NO Synthetase (cNOS); only \( \gamma \)-tocopherol increase cNOS protein expression and I NO\(_2\) formation

- **Platelet adhesion**
  - \( \gamma \)-tocopherol>\( \alpha \)-tocopherol and quinone, but all decrease adhesion
Tocopherols and Tocotrienols

◆ Cholesterol synthesis
  ❖ γ-tocotrienol I HMG-CoA Reductase in vitro and in animal models
  ❖ tocotrienols decrease apoB levels in hypercholesterolemic patients, mixed impact on cholesterol levels.

◆ Cancer cells
  ❖ γ-tocopherol>α-tocopherol I prostate cancer cells in vivo and reduces ras p21 oncogenes in colonocytes
  ❖ γ-tocotrienol I growth of breast, leukemia and melanoma cells
  ❖ α-,γ-, and δ-tocotrienols and α-tocopherol induce apoptosis in cells
B. Phenolics

**Flavonoid Family of Compounds**

- **Anthocyanidins** (oenin, cyanidin)
  - Black grapes, red wine, raspberries, strawberries

- **Flavonols** (quercetin, kaempferol)
  - Onion, apple skin, berries, black grapes, tea, broccoli

- **Flavones** (rutin, luteolin, chrysin, apigenin)
  - Lemon, olive, celery, red pepper, fruit skin, parsley

- **Flavanols** (catechins)
  - Black grapes, red wine, teas

- **Flavanones** (hesperetin, naringin, taxifolin)
  - Citrus fruit, citrus peel

- **Isoflavones** (genestein, diazein)
  - Soybeans, soy foods, legumes

- **Hydroxycinnamates** (ferulic acid, caffeic acid, chlorogenic acid, p-coumaric acid)
  - Grain, tomatoes, spinach, cabbage, asparagus, white grapes, olives, apples, pears, cherries, plums, peaches
ISOFLAVONES
COMMERCIAL SOYFOODS

SOYNUITS
D=563 G=869 GI=193

TEXTURED SOY PROTEIN
D=473 G=707 GI=202

TOFU
D=146 G=162 GI=29 μg/g

DAIDzin
MAL-DIN
AC-DIN
DAIZEIN
GENISTIN
MAL-GIN
AC-GIN
GENISTEIN
GLYCITIN
MAL-GLY
AC-GLY
GLYCITEIN
Principal Polyphenolic Components in Tea

<table>
<thead>
<tr>
<th>Components</th>
<th>Green Tea</th>
<th>Black Tea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catechins</td>
<td>30-42</td>
<td>3-10</td>
</tr>
<tr>
<td>Flavones</td>
<td>5-10</td>
<td>6-8</td>
</tr>
<tr>
<td>Other Flavonoids</td>
<td>2-4</td>
<td>-</td>
</tr>
<tr>
<td>Theogallin</td>
<td>2-3</td>
<td>-</td>
</tr>
<tr>
<td>Gallic acid</td>
<td>0.5</td>
<td>-</td>
</tr>
<tr>
<td>Quinic acid</td>
<td>2.0</td>
<td>-</td>
</tr>
<tr>
<td>Theanine</td>
<td>4-6</td>
<td>-</td>
</tr>
<tr>
<td>Methylxanthines</td>
<td>7-9</td>
<td>8-11</td>
</tr>
<tr>
<td>Theaflavins</td>
<td>-</td>
<td>3-6</td>
</tr>
<tr>
<td>Thearubigens</td>
<td>-</td>
<td>12-18</td>
</tr>
</tbody>
</table>

Source: Katiyar and Mukhtar (1996)
**Flavonols: Quercetin and Myricetin Contents of Wines and Fruit Juices**

<table>
<thead>
<tr>
<th>Beverage</th>
<th>Quercetin (mg/L)</th>
<th>Myricetin (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wine</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red chianti</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>Red Rioja Otoual</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>White Bordeaux</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td><strong>Fruit Juice</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apple</td>
<td>2.5</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Grape</td>
<td>4.4</td>
<td>6.2</td>
</tr>
<tr>
<td>Tomato</td>
<td>13</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Lemon</td>
<td>7.4</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Orange</td>
<td>5.7</td>
<td>&lt;0.5</td>
</tr>
</tbody>
</table>
## B. Phenolics

<table>
<thead>
<tr>
<th><strong>Active Compound</strong></th>
<th><strong>Food Source</strong></th>
<th><strong>Potential Health Benefit</strong></th>
<th><strong>Possible Mechanisms &amp; Functions</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coumarins</strong></td>
<td>Vegetables, Citrus fruits</td>
<td>Reduction in blood clotting; Anticarcinogenic activity</td>
<td>Anticoagulants; Inhibitors and inactivators of carcinogen and mutagen; Scavengers of superoxide anion</td>
</tr>
<tr>
<td><strong>Tannins</strong></td>
<td>Sorghum Hazelnuts Certain berries Grape seed (dry)</td>
<td>Cancer prevention; Reduction of heart disease; Antimicrobial</td>
<td>Antioxidant; Inhibitors of superoxide radicals production and tumor promotion</td>
</tr>
<tr>
<td><strong>Lignan</strong></td>
<td>Oilseeds whole-grain cereals legumes vegetables &amp; fruit</td>
<td>Reduction of heart disease; Reduction of breast cancer risks</td>
<td>Inhibition of the production of oxygen free radicals by PMN leukocytes in hypercholesterolemia; Decrease in serum cholesterol, LDL-C, and lipid peroxidation product and increase in HDL-C and antioxidant reserve; Inhibition of endogenous estrogens for premenopausal women.</td>
</tr>
<tr>
<td><strong>Resveratrol</strong></td>
<td>Grapes Red wine</td>
<td>Anticarcinogenic activity; Cardiovascular protective effects</td>
<td>Antioxidant; Anti-proliferative effect; Induction of growth inhibition and apoptosis; Stimulation of eNOS expression and activity; Phytoestrogen.</td>
</tr>
</tbody>
</table>
C. Protein/Amino Acid Derived

- Amino acids
- Allyl-S-compounds
- Capsaicinoids
- Isothiocyanates
- Indoles
- Folate & Choline
- Lactoferrin
## C. Animal Derived Protein

**Lactoferrin**

<table>
<thead>
<tr>
<th>Food Source</th>
<th>Potential Health Benefit</th>
<th>Possible Mechanisms and Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>Stimulation of immune system; Antimicrobial agent; Healing gastrointestinal wound</td>
<td>Stimulation of a beneficial gut microflora; Increase in the production and release of cytokines, which may affect the immune system; T-cell dependent augmentation of NK cell activity; Inhibition of the cell migration of certain gastrointestinal cell lines.</td>
</tr>
</tbody>
</table>
D. Complex Carbohydrate

- Oligosaccharides
- Non-starch polysaccharides
## E. Fatty Acids

### Conjugated linoleic acid (CLA)

<table>
<thead>
<tr>
<th>Food Source</th>
<th>Potential Health Benefit</th>
<th>Possible Mechanisms and Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy products</td>
<td>Reduction of cancer; atherosclerosis; and obesity.</td>
<td>Reduction of cell proliferation, alteration in the components of the cell cycle and induction of apoptosis;</td>
</tr>
<tr>
<td>Cheeses</td>
<td></td>
<td>Reduction of the LDL cholesterol to HDL cholesterol ratio and total cholesterol to HDL cholesterol ratio in rabbits;</td>
</tr>
<tr>
<td>Meat</td>
<td></td>
<td>Decrease in preadipocyte proliferation and differentiation into mature adipocytes, decrease in fatty acid and triglyceride synthesis, and increase in energy expenditure, lipolysis, and fatty acid oxidation.</td>
</tr>
</tbody>
</table>
Conjugated Linoleic Acid

Dietary Source
- dairy foods, ruminant foods;
- 4-6 mg/g lipid

Dietary Intake
- US 70-120 mg/da greatest in teen and young adults, M＞W
- German 250-450 mg/da
Conjugated Linoleic Acid

- **Impact on Disease**
  - Cancer
    - mice and rats, decrease chemically induced tumors
    - MCF-7 breast cancer cell line
  - Atherosclerosis
    - rabbit, 1% cholesterol diet - decrease Tot-C, LDL/HDL, TG
    - decreased severity of pre-induced lesion (abdominal aorta plaque)
  - Diabetes Mellitus (type 2)
    - Zucker diabetic rats - decrease plasma glucose, insulin, TG & FA
  - Adipose reduction
    - growing animals vs adult humans
    - animal dose (1% of diet) vs 2-3 g human

- **Side Effects**
  - GI disturbance

Yurawecz, Mossoba, Kramer, Pariza and Nelson, AOCS Press, 1999
# E. Fatty Acids

*Omega-3 fatty acids: docosahexaenoic acid / eicosapentaenoic acid*

<table>
<thead>
<tr>
<th>Food Source</th>
<th>Potential Health Benefit</th>
<th>Possible Mechanisms and Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salmon</td>
<td>Reduction in plasma triacylglycerol;</td>
<td>Reduction in the total and LDL-cholesterol: HDL-cholesterol ratios;</td>
</tr>
<tr>
<td>Tuna</td>
<td>Reduction of heart disease;</td>
<td>Increase in serum HDL-cholesterol;</td>
</tr>
<tr>
<td>Other ocean fish</td>
<td>Prevention of sudden cardiac death or fatal arrhythmias;</td>
<td>Reduction in endogenous production of TG-rich lipoproteins and increase in elimination of TG-rich lipoproteins;</td>
</tr>
<tr>
<td>Algae</td>
<td>Anti-inflammatory activity</td>
<td>Blockage of excessive sodium and calcium current in the heart;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Antithrombotic effect;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Decrease in monocyte and neutrophil chemotaxis and decreases in production of proinflammatory cytokines.</td>
</tr>
</tbody>
</table>
## EPA and DHA Content in Fish

<table>
<thead>
<tr>
<th>Fish</th>
<th>(g/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlantic Mackerel</td>
<td>2.5</td>
</tr>
<tr>
<td>Atlantic Salmon</td>
<td>1.8</td>
</tr>
<tr>
<td>Pacific Herring</td>
<td>1.7</td>
</tr>
<tr>
<td>Atlantic Herring</td>
<td>1.6</td>
</tr>
<tr>
<td>Lake Trout</td>
<td>1.6</td>
</tr>
<tr>
<td>Bluefin Tuna</td>
<td>1.6</td>
</tr>
<tr>
<td>Sturgeon</td>
<td>1.5</td>
</tr>
<tr>
<td>Anchovy</td>
<td>1.4</td>
</tr>
<tr>
<td>Sprat</td>
<td>1.3</td>
</tr>
<tr>
<td>Sardines (canned/trained)</td>
<td>1.1</td>
</tr>
</tbody>
</table>

*JADA 91: 331-337 (1991)*
### Fatty Acid (% Total Fat)

<table>
<thead>
<tr>
<th></th>
<th>α Linoleic (18:3n-3)</th>
<th>Eicosapentaenoic (20:5n-3)</th>
<th>Docosahexaenoic (22:5n-3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater fish</td>
<td>1-6</td>
<td>5-13</td>
<td>1-5</td>
</tr>
<tr>
<td>Marine fish</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pacific Anchovy</td>
<td>18</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Mackerel</td>
<td>8</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Cod fish</td>
<td>9</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Herring</td>
<td>3-5</td>
<td>2-3</td>
<td></td>
</tr>
<tr>
<td>Sardine</td>
<td>3</td>
<td>9-13</td>
<td></td>
</tr>
<tr>
<td>Linseed</td>
<td>45-60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rapeseed</td>
<td>10-11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Leaves</td>
<td>56</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Modified from Canadian J. Physiol & Pharmacol. 72:945-953, 1994
### F. MICROBIAL

**Prebiotics: nondigestible but fermentable oligosaccharides**

<table>
<thead>
<tr>
<th>Food Source</th>
<th>Potential Health Benefit</th>
<th>Possible Mechanisms and Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garlic</td>
<td>Intestinal fortification; Stimulation of immune function; Anticarcinogenic effects; Hypolipidemia</td>
<td>Supporting the growth of lactobacilli and bifidobacteria, which are found in the large intestine and are generally considered to be beneficial by stimulating the immune system and protecting body from infection; modulation of lipid metabolism.</td>
</tr>
<tr>
<td>Asparagus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chicory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oatmeal</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Nondigestible Fermentable Oligosaccharides**

- **Fructooligosaccharide (FOS), as example**
- **Physiological Actions**
  - enhances intestinal bacteria
  - lower hepatic glucose production; no effect on fasting plasma glucose or insulin
  - lowered serum cholesterol
  - animal - decreased plasma TG
- **Side Effects**
  - flatus (>30 g FOS/da)
  - abdominal cramps and diarrhea (>50 g FOS/da)
# F. MICROBIAL

*Probiotics: lactobacilli, bifidobacteria*

<table>
<thead>
<tr>
<th>Food Source</th>
<th>Potential Health Benefit</th>
<th>Possible Mechanisms and Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fermented dairy foods:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yogurt</td>
<td>Enhancement of immune function;</td>
<td>Alter the intestinal microflora balance, inhibition the growth of harmful bacteria</td>
</tr>
<tr>
<td>Kefir</td>
<td>Prevention of diarrhea;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Anticarcinogenic effects</td>
<td></td>
</tr>
</tbody>
</table>
The examples of functional food products provided here are only representative of a larger effort to provide a healthy and safe diet.

Some of the functional products identified here are already available in the marketplace, while others are being developed and some indicate opportunities for future project development.

Designing of new delivery systems enables benefits from the use of each active functional food ingredient to be provided to a broader consumer population.

However, the new food products must taste good!
Soy Foods

- Tofu and other soy products are prepared using calcium coagulation of the protein, providing the food products with a ready source of calcium, high quality protein, and phytoestrogens.
- Flavoring of soy milk to enhance consumption.
- Textured soy protein can be formulated into a variety of new products, including meat substitutes.
- Roasted soy nuts (soybeans) as a healthy snack food.
- Soy butter, a substitute for peanut butter.
Dairy Products

milk, cheese, yogurt and protein (casein and whey) isolates

- Phospho-peptides produced by partial hydrolysis of casein enhance calcium absorption.
- A milk based product has been developed, replacing fat with β-glucan + Oatrim (USDA) to lower cholesterol.
- Plant sterols can be added to milk and yogurt beverages to aid lowering of cholesterol.
- Prebiotic oligosaccharides can be added to milk or yogurt; even though not digested, calcium absorption increased an additional 18%.
- The dairy cow can be challenged with specific microorganisms, producing specific gamma globulins.
  - isolated from the milk they can be used in therapeutic situations for calves (currently) and perhaps humans (in the future).
THE WIZARD OF ID

What do you feed your cows, peasant?

Corn oil, sire.

Need any margarine?
**ω-3 Fatty Acids**

may reduce the risk of CHD, ocean fish, algae, in their diet.

- Designer oils containing eicosapentaenoic acid (EPA) and docosahexanoic acid (DHA) can be created and blended with other oils as ingredients to create specialty products, such as salad dressing, cooking oils or margarine.

- Growth incubators have been designed to promote the continuous production of the algae, allowing recovery and extraction of pure ω-3 fatty acids.

- The algae can be incorporated into feed products for egg laying poultry and for fish grown by aquaculture on fish farms.
Delivery Mechanisms for Bioactive Agents

Functional Foods
Designer Food Products
Cereal

- Ready to eat breakfast cereals are one of the early functional foods, delivering the fiber, and nutrient value, in a palatable form.

- RTE cereal is coated with vitamins and some minerals acting as a convenient nutrient delivery system, and should provide a delivery system for functional food ingredients.
**Eggs**

*a nutritionally sound product in a self contained package*

- Addition of cholestyramine to the chicken diet reduces the cholesterol content of eggs. Natural nutraceutical compounds may produce the same effect.

- Chickens fed marigolds or dietary carotenoids, incorporate greater β-carotene levels into their egg yolks (bright red-orange color). Similar feeding of other phytochemicals could transform eggs into a functional food.

- Chickens fed ω-3 fatty acids or algae incorporate the ω-3 fatty acids into the egg yolk, a rapidly growing consumer health product.
Margarines/spreads/cooking oils

- Phytosterols, stanols and sterols have esters that are GRAS approved, food grade ingredients
  - commercially available in margarine.

- Phytosterols can be incorporated into other foods, such as chocolate candy, yogurt and smoothies
  - health stores have added phytochemicals and herbs to smoothies for years.

- Esters of the phytosterols can be created using CLA, DHA or EPA to enhance the delivery of multiple phytochemicals in a single product.
  - The esters are hydrolyzed during digestion releasing the fatty acid ester.
Orange juice

- Calcium fortification of beverages, such as orange juice, and snack foods is not new, but can contribute to bone repair and prevention of osteoporosis.

- Nano-dispersion of phytosterols, imbedded in a lecithin liposome, into orange juice enables more people to benefit from the cholesterol lowering effects of the plant nutraceutical.

- Addition of other phytochemicals could be delivered by a similar mechanism.
one better.

Most people love orange juice and most people need more calcium in their diet. But nature put almost no calcium in ordinary orange juice. That's why Citrus Hill has fortified 100% pure orange juice with calcium. So now there are three reasons to serve Citrus Hill Plus Calcium to your family every day.

One. Citrus Hill Plus Calcium starts with naturally delicious juice, squeezed from the heart of the orange.

Two. Citrus Hill Plus Calcium is a better source of calcium because it has a unique calcium delivery system, CCM, that's even more absorbable than milk. In fact, Citrus Hill Plus Calcium is the first calcium product accepted by the American Medical Women's Association, a national organization of 10,000 leading women physicians.

Which leads to three, why would you want ordinary orange juice on your family's breakfast table?

Citrus Hill Plus Calcium. Treat yourself to a better source of calcium.

Also available in 60% grapefruit juice beverage. Available in limited areas. ©1987 Procter & Gamble
Chewing gum

- Inclusion of zinc allows coating of the throat and possibly decreases colds.

- Inclusion of cinnamic aldehyde was added to provide a cinnamon flavor, but was determined to act as an antimicrobial agent and prevent bad breath.

- Inclusion of oligosaccharides (in Japan) as a prebiotic to promote beneficial bacteria in the gastrointestinal tract.

- Inclusion of vitamins in a chewable form; other functional ingredients could be used as well.
The Value of Efficacious Functional Foods

To date, the average consumer has been willing to pay a higher price for health foods and nutritional and herbal supplement products.

What price the consumer will consistently pay for these and future value-added products remains unknown?

But if the manufacturer can assure the consumer of an efficacious product that will provide an identifiable health benefit, they will spend more of their disposable income on “healthy” functional foods.

(IFT, 2005)
In Closing….

Functional Foods Hold Great Promise

- The criterion for efficacy must be based on the mechanism of action of the specific compound and the lowest possible safe exposure level.

- Over promotion of functional foods before efficacy is established could damage the credibility of the whole category of compounds and their food products, and deter delivery of their potential health benefits.