Nutraceuticals and Functional Foods

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Objectives

- Understand the terms Supplements, Nutraceuticals, Functional Foods, Organic Foods and GMF
- Know what claims are allowed.
- Know the pros and cons of organic versus conventional foods
- Understand the risk and benefits of GMFs

Supplement/Nutraceutical/Functional Food—Background Definitions

Hippocrates “Let food be thy medicine and medicine thy food” (~440BC)

Nutraceuticals is defined “as a food or part of a food, that provide medical or health benefits, including the prevention and/or treatment of disease”. However this term has no regulatory definition.

* DeFelice, Scrip Mag 9; 1992 http://www.aapsj.org/view.asp?art=ps050325

Link Nutrition and Medicine

Nutritional sciences is primarily focused on:
1) detection and understanding of nutritional deficiencies
2) diet and risk/prevention for certain disease

Recent link between nutrition and medicine focuses on the molecular mechanisms and how nutrients behave as pharmaceuticals, e.g. the term nutraceuticals

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Food as Medicine is Not New!!

- “Magic potions” were many times combinations of herbs by trial and error.
- Evidence of phytochemical use dates back 60,000 years to Neanderthal burial ground.
- 4000 B.C. Sumerians developed medicinal uses for licorice, opium, thyme and mustard.
- Babylonians had plant formularies to include senna leaves, coriander, cinnamon and garlic.

Phytonutrients (primary metabolites) and phytochemicals (secondary metabolites) help plants survive and flourish!!

Pen Tsao, the earliest Chinese Pharmacopeia describes, among many supplements, uses for ma huang in treatment of fever, coughs and lung ailments.

Even today more than half of the worlds population derives its medicines from plants.

Phytonutrients (primary metabolites) and phytochemicals (secondary metabolites) help plants survive and flourish!!

Food as Medicine is Not New!!

- Earliest medical textbook was likely written by the Egyptians, the Eber Paprus, and contained approximately 800 recipes and referenced over 700 drugs. Among the drugs were aloe, wormwood, peppermint, hemane, myrrh, mandragora and hemp.
- Pen Tsao, the earliest Chinese Pharmacopeia describes, among many supplements, uses for ma huang in treatment of fever, coughs and lung ailments.
- Even today more than half of the worlds population derives its medicines from plants.
- Phytonutrients (primary metabolites) and phytochemicals (secondary metabolites) help plants survive and flourish!!

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Historical Evolution of Medicinal Nutrients.

- The origin of functional foods is probably a combination of at least two things.
  - First, our distant ancestors probably noticed that when animals were ailing, they often ate certain plants that they would not otherwise eat.
  - Second, for our distant ancestors the activities of plants and other aspects of nature probably seemed magical.

Plant Products

- Plant cells products that have direct relevance to the processes of the plants growth and development are referred to as primary metabolites e.g. amino acids, chlorophyll, nucleotides, simple carbohydrates, and membrane lipids.
- Secondary plant metabolites are those products which cannot be directly linked to processes such as photosynthesis, respiration, solute transport, translocation, and nutrient utilization.
  - The secondary metabolites can be divided into three groups:
    * terpenes (isoprenoids)
    * phenolic compounds (flavonoids)
    * nitrogen-containing compounds (alkaloids)

Dietary Supplement

The Dietary Supplement Health and Education Act (DSHEA) formally defined "dietary supplement" using the following criteria.

A dietary supplement:

- is a product (other than tobacco) that is intended to supplement the diet that bears or contains one or more of the following dietary ingredients: a vitamin, a mineral, an herb or other botanical, an amino acid, a dietary substance for use by man to supplement the diet by increasing the total daily intake, or a concentrate, metabolite, constituent, extract, or combinations of these ingredients.
- is intended for ingestion in pill, capsule, tablet, or liquid form.

http://www.fda.gov/opacom/laws/dshea.html
http://nccam.nih.gov/health/supplement-safety/

Dietary Supplement - continued

- is not represented for use as a conventional food or as the sole item of a meal or diet.
- is labeled as a "dietary supplement."
- includes products such as an approved new drug, certified antibiotic, or licensed biologic that was marketed as a dietary supplement or food before approval, certification, or license (unless the Secretary of Health and Human Services waives this provision).

Nutraceutical

- Chemicals found as a natural component of foods or other ingestible forms that have been determined to be beneficial to the human body in preventing or treating one or more diseases or improving physiological performance (also called ergogenic aids). Essential nutrients can be considered nutraceuticals if they provide benefit beyond their essential role in normal growth or maintenance of the human body, e.g. Vit E and C as antioxidants.
Nutraceutical vs Supplement

- Nutraceuticals must not only supplement the diet but should also aid in the prevention and/or treatment of disease and/or disorder.
- Nutraceuticals are represented for use as a conventional food or as the sole item of meal or diet.

Functional Food

- A food, either natural or formulated, which will enhance physiological performance or prevent or treat disease and disorders. Functional foods include those items developed for health purposes as well as for physical performance. The Institute for Medicine’s Food and Nutrition Board defined functional foods as “any food or food ingredient that may provide a health benefit beyond the traditional nutrients it contains”.

Teleology: Examples of Useful Plant Chemicals: Carotenoids

- Carotenoids
  - include among many molecules the carotenes and xanthophylls, and fall into a larger class of molecules called terpenoids or isoprenoids

Teleology: Examples of Useful Zoochemicals: CLA

- Conjugated Linoleic Acid (CLA)
  - is found primarily in beef and milk and its products.
  - CLA is produced by specific bacteria in the rumen via modification of linoleic acid in the animal’s diet
  - is mainly 18:2 ω-9(cis), 11(trans) (80% of total CLA) and 18:2 ω -10(trans), and 12(cis)
  - May be useful in cancer prevention

Teleology: Examples of Useful Plant Chemicals: Flavanoids

- Flavonoids produced by plants appear to have nutraceutical potential by lowering blood cholesterol levels, osteoporotic and carcinogenic events, as well as perhaps enhancing antioxidant capacity.
- Plant flavonoids also inhibit undesirable bacterial infection. In this role they function as antibiotics (phytoalexins).

Teleology: Examples of Useful Plant Chemicals: Nitrogen- and Sulfur-Containing Amino Acid Derivatives

- Plants produce metabolites that contain nitrogen.
- Examples are alkaloids and cyanogenic
- Alkaloids appear in ~ 20% of the species of vascular plants and include substances such as cocaine, nicotine, morphine, and caffeine.
- Alkaloids are thought to be defense molecules against predators, especially mammals, due to their general toxicity.
**Teleology: Nitrogen- and Sulfur-Containing Amino Acid Derivatives**

- Capsaicinoids are also alkaloid structures produced by pepper fruits from phenylalanine and valine or leucine as well as branch chain fatty acids.
- Capsaicinoids can irritate the dermal surface of animals and this can deter animals from consuming the fruit. Effective in pain management.
- Cruciferous vegetables contain glucosinolates that are by themselves inert, but can be converted to toxic metabolites when plant tissue is traumatized - these substances are responsible for the smell associated with some cruciferous vegetables such as cabbage, broccoli, and radishes.

**Teleology: Examples of Useful Plant Chemicals: Omega 3 Fatty Acids**

- Plants make fatty acids such as palmitic acid (16:0), linoleic acid (18:2 w-6), and linolenic acid (18:3 w-3).
- The lipid composition is a primary response to chilling temperatures.

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**Relationship of Food, Nutrition, and Health**

<table>
<thead>
<tr>
<th>Sanitation: Role of contamination in illness</th>
<th>Excess: Diet linked with chronic diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germ Theory</td>
<td>Vitamin Theory</td>
</tr>
</tbody>
</table>

- Deficiency: Role of inadequate intake in illness
- Health & Well-being

http://medocu.ucdavis.edu/imdbcm/419/Syllabus/04/Lec5-Functional.ppt

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**Why the Growing Interest in Nutraceuticals and Functional Foods?**

- Collective health consciousness grows with more-advanced age.
- With age comes an increased incidence of disease
- By the year 2020, 16% of the American population will be over the age of 65
- More newspaper and magazine articles are dedicated to the relationship between diet and health, nutraceutical concepts.
- More television programs address topics of disease and prevention/treatment.
- Public awareness via the Internet (World Wide Web) regarding the etiology, prevention, and treatment of various diseases is most significant.
- Dissatisfaction with current western medical services

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**Why the Growing Interest in Functional Foods?**

- General dietary recommendations for disease risk reduction, e.g. more fruits, vegetables and whole grains is well accepted.
- The emerging concept is that intact foods are probably more powerful than individual components.
- As a response, the functional food market has increased from $5.4 billion in 1992 to $8.9 billion in 1996 to $17.3 billion in sales in 2000.
- Nutrition Business Journal predicts the functional food market in the US will double, to $34 billion by 2010, representing 5.5% of the total food market.
- Thus, availability of functional foods will continue to grow because it is sought after and very profitable.

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**Questions raised by emergence of “Functional Foods”**

- What types of claims related to nutrition and health are allowed?
- What is the nature of evidence used to support claims?
- How is safety considered in the evaluation of functional foods?
- Is a functional food different from a dietary supplement or drug?
Nutraceuticals

- Nutraceuticals are considered components of traditional and non-traditional foods that have the potential to benefit human health. The substance may
  - (1) be part of an intact food source, such as the lycopene naturally occurring in a tomato
  - (2) be part of a processed food, such as lycopene from tomatoes in the recipe of catsup or sauces
  - (3) be a fortified or enriched substance in a food, such as lycopene added to a fruit juice
  - (4) be provided in supplemental form.

Nutraceuticals are components of plants, animals, yeast, and fungi as well as bacteria. These are termed:
- phytochemicals (flavonoids)
- zochemicals (conjugated linoleic acid)
- phungochemicals (cyclopentinoids)
- and bacteriochemicals (epothilone-D)

Examples of Nutraceutical Substances Grouped by Food Source

<table>
<thead>
<tr>
<th>Plants</th>
<th>Animal</th>
<th>Microbial</th>
</tr>
</thead>
</table>
| β-Glucan | Conjugated Linoleic Acid (CLA) | Saccharomyces
| Ascorbic acid | Eicosapentaenoic acid (EPA) | boulardii (yeast)
| Docosahexaenoic acid (DHA) | | Bifidobacterium
| Tocotrienol | Sphingolipids | bifidum
| Quercetin | Choline | B. longum
| Luteolin | Lecithin | B. infantis
| Cellobiose | Calcium | Lactobacillus
| Lutein | Ubenigensene (coenzyme Q10) | acidophilus
| 
| Tocopherol | Selenium | L. acidophilus
| Tocotrienol | | Streptococcus
| 

Examples of Foods That Have Higher Content of Specific Nutraceutical Compounds

<table>
<thead>
<tr>
<th>Nutraceutical Substance</th>
<th>Foods with High Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allyl sulfur compounds</td>
<td>Onions, garlic</td>
</tr>
<tr>
<td>Isoflavones</td>
<td>Soybeans and other legumes, apios</td>
</tr>
<tr>
<td>Capsaicinoids</td>
<td>Capsicum</td>
</tr>
<tr>
<td>EPA and DHA</td>
<td>Fish oils</td>
</tr>
<tr>
<td>Lycopene</td>
<td>Tomatoes and tomato products</td>
</tr>
<tr>
<td>Isothiocyanates</td>
<td>Cruciferous vegetables</td>
</tr>
<tr>
<td>β-Glucan</td>
<td>Oat bran</td>
</tr>
<tr>
<td>CLA</td>
<td>Beef and dairy</td>
</tr>
<tr>
<td>Resveratrol</td>
<td>Grapes (skin), red wine</td>
</tr>
</tbody>
</table>

Examples of Nutraceuticals Grouped by Mechanisms of Action

<table>
<thead>
<tr>
<th>Antioxidant</th>
<th>Positive Influence on Blood Lipid Profile</th>
<th>Antioxidative</th>
<th>Anti-inflammatory</th>
<th>Bone Protective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resveratrol</td>
<td>Tocotrienol</td>
<td>CLA</td>
<td>Linoleic acid</td>
<td>CLA</td>
</tr>
<tr>
<td></td>
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</tr>
</thead>
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<tr>
<td>β-Carotene</td>
<td>Citrus fruit, carrots, squash, pumpkin</td>
</tr>
<tr>
<td>Carnosol</td>
<td>Rosemary</td>
</tr>
<tr>
<td>Catechins</td>
<td>Teas, berries</td>
</tr>
<tr>
<td>Adenosine</td>
<td>Garlic, onion</td>
</tr>
<tr>
<td>Indoles</td>
<td>Cabbage, broccoli, cauliflower, kale, Brussel sprouts</td>
</tr>
<tr>
<td>Curcumin</td>
<td>Tumeric</td>
</tr>
<tr>
<td>Ellagic acid</td>
<td>Grapes, strawberries, raspberries, walnuts</td>
</tr>
<tr>
<td>Anthocyanins</td>
<td>Red wine</td>
</tr>
<tr>
<td>3-o-tyethyl phthalate</td>
<td>Celery</td>
</tr>
<tr>
<td>Cellulose</td>
<td>Most plants (component of cell walls)</td>
</tr>
<tr>
<td>Pectins</td>
<td>Most plants, apples</td>
</tr>
</tbody>
</table>
Why the interest in organic foods?

- The fastest growing sector of the food industry.
- Profits are high and growing for many organic producers in the USA.
- Why do consumers seek organic foods?
  - 1. Health/nutrition: 66 percent
  - 2. Taste: 38 percent
  - 3. Food safety: 30 percent
  - 4. Environment: 26 percent
  - 5. Availability: 16 percent

Organic Industry Stats

- Fastest growing U.S. food segment (20% annually)
- 2003 sales approximately $10 billion
- Accounts for 1-2% total U.S. food sales
- U.S. market projected at more than $30.7 billion by 2010
- Certified cropland in 2001: 2.35 million acres
- Organic products sold in 73% of mainstream supermarkets

What is an organic food?

- Organic is a production claim.
  - Organic is about how food is produced and handled.
- Organic is not a content claim.
  - It does not represent that a product is “free” of something.
- Organic is not a food safety claim.
  - Organic is not a judgment about the quality and safety of any product.
  - Organic does not mean a product is superior, safer, or more healthful than conventionally produced food.

What is an organic food?

- “100% Organic” *(may use USDA seal)*
  - Just that, including all processing aids
  - May use USDA seal
- “Organic” *(may use USDA seal)*
  - At least 95% organic agricultural ingredients
  - Remaining 5% on the National List
  -May use USDA seal
- “Made with Organic (Ingredients)”
  - From 95% to 70% organic agricultural ingredients

Total Foods and Organic Food Sales, 1997-2003

<table>
<thead>
<tr>
<th>Year</th>
<th>Organic Food Sales ($ mil)</th>
<th>Organic Food Growth (%)</th>
<th>Total Food Sales ($ mil)</th>
<th>Organic Percent (% of Total Food Sales)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>3,566</td>
<td>--</td>
<td>443,724</td>
<td>0.8</td>
</tr>
<tr>
<td>1998</td>
<td>4,272</td>
<td>19.8</td>
<td>454,071</td>
<td>0.9</td>
</tr>
<tr>
<td>1999</td>
<td>5,043</td>
<td>18.1</td>
<td>474,478</td>
<td>1.1</td>
</tr>
<tr>
<td>2000</td>
<td>6,184</td>
<td>21.0</td>
<td>498,379</td>
<td>1.2</td>
</tr>
<tr>
<td>2001</td>
<td>7,359</td>
<td>20.6</td>
<td>521,831</td>
<td>1.4</td>
</tr>
<tr>
<td>2002</td>
<td>8,624</td>
<td>17.2</td>
<td>538,033</td>
<td>1.6</td>
</tr>
<tr>
<td>2003</td>
<td>10,381</td>
<td>20.4</td>
<td>554,830</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Source: The OTA 2004 Manufacturer Survey Overview

Andrew Barkley, Agricultural Economics

USDA’s Role

- Accredit certifying agents
- Compliance and enforcement
- Promulgate new and amended regulations
- Recognize foreign governments
- Perform equivalence determinations
- Approve State organic programs
Certification Basics

- **Organic systems plan**
  - Crops: build soil fertility, use few synthetics, minimize pollution
  - Livestock: origin, feed, healthcare, living conditions
  - Handling/processing: pest management, prevent commingling
- **Use only approved substances/practices**
  - No genetic engineering, irradiation, sewage sludge
  - National List: all naturals allowed & all synthetics prohibited except for what’s on the NL
- **Mandatory verification through inspections**
  - Initial site inspection
  - Annual site inspection
  - As many as needed to determine compliance

National Organic Standards

- **Crop Production**
  - No prohibited substances for 3 years prior to harvest
  - Establish buffer zones
  - Maintain or improve soil condition
  - Minimize soil erosion
  - Rotations, cover crops, and application of plant and animal material
  - No contribution to environmental contamination through application of plant and animal material

National Organic Standards

- **Origin of livestock**
  - Organic management from last third of gestation (poultry 2d day of life)
  - 100% organic feed
  - Synthetic vitamins and trace minerals allowed
- **Prohibited substances**
  - No synthetic hormones or growth promoters
  - No antibiotics
- **Animal health and safety**
  - Accommodate the health and natural behavior of the animal

Cost of Organic!

- $1.15/lb
- $0.56/lb

Organic - is it Better and Safe?

- **Two Interpretations of the Same Study – both true!**
- “One-Quarter of Organic Produce Contains Pesticides. Study Finds. Think Organic Fruits and Vegetables are Free of Pesticides? Think Again.”
- “Study Confirms Organic Foods Have Fewer Pesticides. Researchers Reveal Organic Produce Helps Consumers Avoid Dietary Pesticide Exposure.”


What the Study Found!

- Organic produce is less likely to have detectable pesticide residues than conventionally grown produce.
- Among samples with any residues, conventional foods are more likely to have multiple residues in a given sample than organic foods are.
- When present, residues in organic foods are likely to be at lower levels than those in non-organic foods.
What the Study Found!

- Organically grown food samples contained residues about one-third as often as conventional samples did. For example, the USDA data showed 23% of organic and 73% of conventional foods had at least one pesticide residue.
- Conventionally grown crops were six times as likely as organically grown foods to contain multiple pesticide residues. For example, USDA data showed 46% of conventional samples and 7% of organic samples had multiple pesticide residues.
- Residues of pesticides in organic samples were lower than the same residues in conventional samples about two-thirds of the time.

Is Organic More Nutritious?

- For most nutrients the answer is no!
- Recent report reviewed nutrient analysis of 41 studies to determine if organic had higher nutrient value than conventional fertilized crops.
- Found that:
  - Organic contained higher amounts of
    - Vitamin C
    - Iron
    - Magnesium

Food Safety!

- National Food Safety Programs
  http://www.foodsafety.gov
- Healthy People 2010 Food Safety
  Data Progress Review: Food Safety Education Examples
- Thoroughly WASH all fruits and vegetables
- WASH all surfaces with which meat was in contact – cook thoroughly.

Recommendation!

- Conventionally grown foods may be cheaper and more accessible for many consumers
- Increased consumption of fruits and vegetables, regardless of how they are grown, should be encouraged.

Genetically Modified Foods: Background

- Agricultural practices began over 10,000 years ago
- Humans during this time have been breeding plants and animals to obtain desired characteristics for growth, production, taste, etc.
- Selective breeding is a form of genetic manipulation and has been practiced for thousands of years!
- Through selective breeding plants and animals may become quite different from their original wild ancestors
Genetically Modified Food (GMF) or Genetically Modified Organisms (GMO): First Thought!!

Consumers Know Little about GMF

Food Policy Institute Survey, 2003

Common GMFs
- Vegetables
- Tomatoes
- Potatoes
- Rice
- Cheese
- Meat

How much of the food is GMF?

Regulation

- GM foods in the United States are required to be labeled only if the nutritional value is changed or a new allergen is introduced.

Potential Benefits!
- Insect resistant corn
- Cheaper food
- Improved farming
- More food
- Reduced world hunger and improving world health
- Increased nutrition
- Edible vaccines
Potential Risk!

- U.S. Food and Drug Law – requires food products to be safe
- Traditional foods – considered safe, long history
- Exceptions
  - Some “safe” foods affect specific individuals – e.g. wheat
  - “Safe” foods may contain small amount of natural toxins – peanuts/aflatoxin
- New foods – developed with conventional breeding, or from other parts of the world considered safe

Potential Risk!

- Toxicants
- New Substances
- Nutrients
- Allergenicity
- Loss of Biodiversity
- Other Effects - Unintended


Economic Impact!

- Elimination of competition
  - GM seeds are patented
- Suicide seeds
  - Plants with sterile seeds that are infertile are created
  - Farmers are forced to buy seeds every year

GMFs Healthful or Harmful?

- It depend on each individual case.
- Consumers, the government and scientists working together should be responsible for weighing the benefits against the risks and costs.

Health risks
Environmental risks
Economic risks
Resistance to disease
Reduced use of chemicals
Improved Nutrition

Diet May Influence Genetic & Epigenetic Events Associated with Several Disease Processes

- Carcinogen Metabolism
- Cell Cycle
- Apoptosis
- DNA Repair
- Inflammatory Response
- Hormonal Regulation
- Bioactive Food Components
- Differentiation
- Credentialing of nutrients and targets – the future?

References

A Pronunciation Guide for Beneficial Phytochemicals
Found Naturally in Fruits and Vegetables

- allicin (al’-la-sin)
- anthocyanin (an-tho-sigh’-a-nin)
- beta carotene (bay’-ta care’-a-teen)
- betacyanin (bay-ta-sigh’-a-nin)
- carotenoid (care-a’-ton-oid)
- chlorophyll (klor’-a-fill)
- cruciferous (crew-sif’-fer-us)
- edamame (ed’-a-mommy)
- ellagic (ee-ladgeladge’-ic)
- flavonoid (flaive’-annoyed)
- folic (fole’-ic)
- genistein (j en’-is-steen)
- geraniol (ger-an-oil)
- glutathione (gloot-a-thigh’-own)
- indole (in’-doal)
- isoflavone (eye-so-flave’-own)

A Pronunciation Guide for Beneficial Phytochemicals
Found Naturally in Fruits and Vegetables

- isothiocyanate (eye-so-thigh-o-sigh’-a-nate)
- jicama (hick’-ah-ma)
- isoprenoid (eye-so-pren-oyd)
- limonoid (lime’-annoyed)
- lutein (lue’-teen)
- lycopene (lye’-coe-peen)
- nutraceutical (new-tratra-sue’-tictic-cull)
- phytoestrogen (fight-o-es’-tro-e-jen)
- polyacetylene (poly-a-set’-a-teen)
- polyphenol (poly-fee’-nol)
- quercitin (kwhe’-sit-ten)
- resveratrol (res-ver’-a-trol)
- saponin (sah-poe’-nin)
- sulforaphane (sul-four’-a-fane) tannin (tan’-nin)
- terpenoid (ter-pen-oyd)
- zeaxanthin (zee-a-zan’-thin)