“Functional” foods are branded foods, which claim, explicitly or implicitly, to improve health or well being. We review typical functional foods and their ingredients, efficacy, and safety. We also review regulations for health claims for foods worldwide. These regulations often allow manufacturers to imply that a food promotes health without providing proper scientific evidence. At the same time, regulations may ban claims that a food prevents disease, even when it does. We offer a plea for regulations that will permit all health claims that are supported by the totality of scientific evidence, and ban all claims that suggest an unproven benefit.

Keywords functional foods, health claims, regulation, supplements, Nutraceuticals

INTRODUCTION

Functional foods are the food industry’s response to the consumers’ demand for foods that are both attractive and healthy. Healthy diets offer a number of proven benefits: epidemiological and clinical studies show that a diet rich in fruits, vegetables, unrefined grains, fish, and low-fat dairy products, and low in saturated fats and sodium can reduce the risk of coronary heart disease and hypertension and perhaps even of some types of cancer (www.health.gov/dietaryguidelines). Some people have changed their diet accordingly, and have benefited from it with a much lower risk of heart disease (Hu et al., 2000). However, for most consumers it is a struggle to meet dietary guidelines. This is where industry steps in with special foods that promise to improve health and well-being with less effort and sacrifice. Such ‘functional’ foods match the spirit of our time. The 1970s saw an upsurge of ‘natural’ and ‘organic’ foods, and the 1980s saw the introduction of ‘low’ and ‘light’ foods with less calories, cholesterol, or salt. Not all of them were palatable, but consumers were willing to make a sacrifice, because at that time, eating for long-term prevention of disease, which is down from 45% in a 1990 survey (Consumer Motivation, 2000). By 1998, 41% are motivated by expectation of short-term benefits. Thus, consumers are less willing to sacrifice taste or convenience for long-term health. This has created a market for foods that combine taste and convenience with the suggestion of short- or long-term health benefits, i.e., for functional foods.

It is often questioned whether individual foods can be healthy or unhealthy, as it is the composition of the entire diet that determines nutritional status. However, changes in diet necessarily involve adding certain foods and leaving out others. We, therefore, suggest that certain foods could be called healthy, but only for, a defined population. For instance, increased consumption of whole-grain foods might prevent constipation and possibly heart disease in adults, but an excess of whole-grain foods may cause malnutrition in rapidly growing infants.

WHAT ARE FUNCTIONAL FOODS?

The definition of functional foods is a contentious issue. Regulatory agencies do not recognize “functional food” as a nutritional entity. Even in Japan, where functional foods originated, the term itself was not adopted because it was agreed that all foods are already functional (Baily, 1999). The International Food Information Council (IFIC), which is supported primarily by food, beverage, and agricultural industries, defines...
functional foods as “foods that provide health benefits beyond
basic nutrition.”

The conundrum that such definitions create is illustrated by
a position paper on Functional Foods of the American Dietetic
Association (Thomson et al., 1999), which appears to accept
the IFIC definition, but also includes “whole foods” with ben-
eficial health effects; examples given are fruits and vegetables,
as well as low fat cheese and low fat snack foods. Such defini-
tions do not provide a clear demarcation between functional
and other foods, because almost any food can have some ben-
eficial effect on some bodily function. By these definitions, even
tap water could be called a functional food, because a liberal
intake of water prevents cystitis, kidney and bladder stones, and
possibly bladder cancer. Therefore, in this study, we avoid def-
nitions of the type “providing a health benefit beyond basic
nutrition.”

A more concrete definition was provided by the Institute of
Medicine of the US National Academy of Sciences, which de-
defined functional foods as, “those foods in which the con-
centrations of one or more ingredients have been manipulated or
modified to enhance their contribution to a healthful diet (Com-
mittee on Opportunities in the Nutrition and Food Sciences,
1994). However, this definition also omits an aspect that is cen-
tral to the functional foods discussion, namely the intimate con-
nection between the term “functional food” and the market-
ing of foods with a health claim. In the reality of the market
place, the term “functional foods” is almost exclusively attached
to branded products that claim or suggest to improve health.
We, therefore, define a functional food as follows: A functional
food is a branded food which claims explicitly or implicitly
to improve health or well-being. This is similar to the defini-
tion given by Nestle (2002), who described functional foods
as, “products created just so that they can be marketed using
health claims.” Most, but not all, of such foods will also meet
the definition of the Institute of Medicine, “foods in which the
concentrations of one or more ingredients have been manipu-
lated or modified to enhance their contribution to a healthful
diet.”

Most of the functional foods that meet our definition are
derived from existing traditional foods by adding ingredients
or modifying the composition. The added ingredients are usu-
ally common food components. However, compounds usually
viewed as drugs may be present in dietary supplements, e.g.,
lovastatin in red yeast rice or ephedrine in Ma Huang tea. The
incorporation of either natural or synthetic drugs into foods may
become an important issue in future. Genetic modification will
also widen the options for the enrichment of foods with existing
or new ingredients. Classical plant breeding has already yielded
healthier crops, such as high lysine corn and low-erucic high-
oleic acid rapeseed oil. Until recently, modern genetic modi-
fication has typically involved pesticide resistance or shelf life
rather than health effects of foods, but the example of Golden
Rice, a genetically engineered rice strain that is high in provita-
m A, shows the potential of genetic modification to produce
new health-promoting foods. The contribution of the present
strain to the eradication of vitamin A deficiency is limited be-
cause both the content and the bioavailability of the vitamin A
in it are low, but it offers ‘proof-of-principle’ for a whole new
class of genetically modified functional foods with great poten-
tial for human health, especially in populations with nutritional
deficiencies.

However, both Golden Rice and most current functional foods
contain food ingredients whose effects on health have been
known for a long time. A new functional food typically does not
represent a breakthrough in nutrition research—these are few
and far between—but rather a creative combination of existing
nutritional knowledge with new food technology and market-
ing. The same active ingredients that go into functional foods
can also be sold in a capsule as a dietary supplement. Although
foods and supplements are treated differently by the law in some
countries, the border between them is vague (Swanson, 2002):
a margarine with plant sterols is clearly a food, and a capsule
with plant sterols is a supplement, but what is a chocolate with
plant sterols—a food, or a chocolate-covered pill? The distinc-
tion is hard to make, and the active ingredients are the same.
Therefore, the present study deals with both functional foods
and supplements.

CAN FUNCTIONAL FOODS PROMOTE HEALTH?

Functional foods tend to be more expensive than their reg-
ular counterparts, but that expense is justified if the product
promotes health. There is an analogy here with the pharma-
ceutical industry: the cost of pharmaceutical drugs includes a
premium that provides the money needed for the research that
leads to new drugs. In the same way, the food industry could use
the profits from functional foods to fund nutrition research that
leads to healthy new foods, and industry also has the know-how
to produce foods that appeal to customers. This could lead to
healthy foods that actually sell, because functional foods have
been engineered to fit consumers’ taste. This engineering is cru-
cial; drugs will sell whatever their look and taste, but foods
need taste, convenience, and appeal, or else they will not be
consumed. A model for such industry-sponsored research is the
development of foods enriched in plant stanols or sterols, which
lower LDL cholesterol. Functional foods can also help the con-
sumer in reaching recommended dietary intakes; for example,
fruit juices enriched with calcium provide this essential nutrient
for children who refuse to or who cannot drink milk. Table 1
lists examples of such ‘traditional’ micronutrients—vitamins and
minerals—that have been used in functional foods. Func-
tional foods can also help to eradicate nutrient deficiencies in
Third World countries. An example is the iodized salt, which has
proved both a public health and a marketing success in India.
Iodination of salt is a simple, but highly effective measure, to
eradicate goiter and other iodine deficiency disorders. However,
the list of functional foods that have actually been shown to im-
prove health is short; many foods with health claims lack proven
utility.


<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Product examples</th>
<th>Health claim</th>
<th>Strength of evidence in humans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Folic acid</td>
<td>Cereals</td>
<td>Protects against neural tube defects</td>
<td>++ (From the Centers for Disease Control and Prevention, 1993)</td>
</tr>
<tr>
<td>Dietary fibre</td>
<td>Drinks</td>
<td>Relieves constipation</td>
<td>++(Marlett et al., 2002; Cummings and Macfarlane, 2002)</td>
</tr>
<tr>
<td>Low in sodium</td>
<td>Drinks, soups</td>
<td>Reduces blood pressure</td>
<td>++ (Sacks et al., 2001)</td>
</tr>
<tr>
<td>Unsaturated fatty acids</td>
<td>Spreads, cookies</td>
<td>Reduces risk of heart disease</td>
<td>++ (Truswell, 1994; Sacks and Katan, 2002)</td>
</tr>
<tr>
<td>Sugar alcohols</td>
<td>Chewing gum</td>
<td>Reduce caries risk</td>
<td>++ (Hayes, 2001)</td>
</tr>
<tr>
<td>Soluble fibre from whole oats or psyllium husk</td>
<td>Cereals, cookies</td>
<td>Reduces cholesterol and risk of heart disease</td>
<td>++ for cholesterol lowering (Truswell, 2002)</td>
</tr>
<tr>
<td>Soy protein</td>
<td>Drinks, bars</td>
<td>Reduce cholesterol and risk of heart disease</td>
<td>+ for cholesterol lowering (Lichtenstein, 1998)</td>
</tr>
<tr>
<td>Calcium</td>
<td>Cereals, fruit juices, milk products, spreads</td>
<td>Protects against osteoporosis/help maintain bone density</td>
<td>+ for consumers with a low calcium intake (Heaney, 2000)</td>
</tr>
<tr>
<td>Folic acid, vitamin B6 (pyridoxine)</td>
<td>Cereals</td>
<td>Decreases homocysteine and risk of cardiovascular disease</td>
<td>++ for homocysteine, but no hard evidence yet for cardiovascular disease (Snyder et al., 2002)</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>Supplements</td>
<td>Antioxidant; prevents cardiovascular disease</td>
<td>+ for observational studies but -- for clinical trials (Asplund, 2002)</td>
</tr>
<tr>
<td>Zinc</td>
<td>Sweets, lozenges</td>
<td>Prevention/cure of common cold</td>
<td>/-- (Marshall, 2000)</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>Drinks, sweets</td>
<td>Protects against cardiovascular disease</td>
<td>/-- in observational studies, -- in clinical trials (Asplund, 2002)</td>
</tr>
</tbody>
</table>

We graded the evidence according to the Australia New Zealand Food Authority criteria for levels and kinds of evidence for public-health nutrition (Truswell, 2001). The evidence consisted of randomized trials in humans, unless indicated otherwise in the Table. (++, proven efficacy, consistent effect seen in multiple high quality studies; +, reasonable evidence for efficacy, effect seen in a limited number of studies, or some inconsistency between studies; 0, no solid data; ––, evidence for no effect, absence of an effect evident from a limited number of studies; --, shown not to be efficacious, absence of an effect evident in multiple high-quality studies.)

**REGULATION OF FUNCTIONAL FOODS**

We consider as the defining characteristic of a functional food that it claims either explicitly or implicitly to improve health or well-being. Most countries have issued regulations to protect the consumer from misleading claims (Table 2). Thus, both the United States and the European Union ban claims that a food can cure a disease. In Europe it is presently also illegal to state that nutrients reduce disease risk, e.g., folic acid supplements prevent neural tube defects. This legislation is now being reconsidered.

The United States does allow claims that foods reduce the risk of disease (US Food and Drug Administration, 2004). The fourteen claims that have been authorized are listed in Table 3. A typical example is, “Frequent between-meal consumption of foods high in sugars and starches promotes tooth decay. The sugar alcohols in [name of food] do not promote tooth decay.” There are strict requirements for the foods that are allowed to carry such claims. [http://www.cfsan.fda.gov/~dms/hclaims.html, 24 July 2003].

In the United States, dietary supplements (but not foods) may carry so-called structure/function claims (e.g., “antioxidants maintain cell integrity”; “tea with Echinacea supports the body’s defense system”) that are largely unregulated. The manufacturer is responsible for ensuring the accuracy and truthfulness of these claims; they are not approved by the FDA. Dietary supplements can, thus, be sold in the United States with very limited evidence for their efficacy and safety. The border between foods and supplements is fuzzy, and companies have repeatedly attempted to market foods as dietary supplements because that gives them more room for health-oriented claims. Examples include drinks, soups and teas with St John’s Wort, Echinacea or Ginkgo Biloba (Center for Sciences in the Public Interest, 1999). Thus, until recently, oversight over claims for foods in the United States was much stricter than oversight over supplements. However, the 1994 Dietary Supplements Health and Education Act, which largely removed FDA control over supplements, started a gradual erosion of the FDA system for health claims for foods as well. In 1997, the Food and Drug Administration Modernization Act opened the way for health claims to be made based on an “authoritative statement” from a United States scientific body, rather than of a formal FDA review. Importantly, the 1999 United States District Court decision in the case of Pearson v. Shalala (Shalala being the United States secretary of Health and Human Services at the time) forced FDA to allow “qualified” claims in the case that there is more evidence for, than against, a relationship between a supplement and a disease. As a result, the FDA now allows foods to make qualified health claims in four categories: (a) for scientifically proven claims; (b) where the science is good but not conclusive; (c) when there’s limited science to support a claim; and (d) when there is little scientific evidence supporting this claim [http://www.cfsan.fda.gov/~dms/hclmgui3.html; visited 10 August 2004]. Originally, supplements could not make explicit claims referring to diseases, but as of 2000, supplements may also claim to help common conditions like acne, morning sickness in pregnancy, or memory loss.

The European Union recently proposed new rules that for the first time would allow claims for foods to reduce risk factors for disease; such claims would be evaluated by the
Table 2  Health claims and their definitions in the United States (US), United Kingdom (UK), European Community (EC) and the Netherlands

<table>
<thead>
<tr>
<th>US, Food and Drug Administration¹</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nutrient content claims</strong></td>
<td>“Low in sodium”</td>
</tr>
<tr>
<td>Describe the level of a nutrient or dietary substance in the product, using terms such as “good source,” “high,” or “free”</td>
<td></td>
</tr>
<tr>
<td><strong>Structure-function claims</strong></td>
<td>“Calcium aids in the growth and maintenance of bones” or “Calcium builds strong bones”</td>
</tr>
<tr>
<td>Indicates that a nutrient plays a role in a particular biological process</td>
<td></td>
</tr>
<tr>
<td><strong>Health claims</strong></td>
<td>“Diets low in sodium may reduce the risk of high blood pressure, a disease associated with many factors”</td>
</tr>
<tr>
<td>Describe a relationship between a food substance and a disease or health-related condition</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>UK, Joint Health Claims Initiative²</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Health claims</strong></td>
<td>“Calcium aids in the development of strong teeth and bones”</td>
</tr>
<tr>
<td>Direct, indirect or implied claims in food labelling, advertising and promotion that consumption of a food carries a specific health benefit or avoids a specific health detriment.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Medicinal claims</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Health claims</strong></td>
<td>“Calcium prevents osteoporosis”</td>
</tr>
<tr>
<td>which state or imply that a food has the property of treating, preventing, or curing human disease (injury, ailment or adverse condition, whether of body or mind) or makes any reference to such a property</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EU, Directorate General Health and Consumer Protection (SANCO D4)³</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nutrition claims</strong></td>
<td>“Low in saturated fat”</td>
</tr>
<tr>
<td>Claims describing the presence, absence or level of a nutrient contained in a foodstuff</td>
<td></td>
</tr>
</tbody>
</table>

| [functional] health claims | “High in protein. Protein helps build and repair body tissues,” |
| Health claims that describe the roles of nutrients or other substances in growth, development and normal physiological functions of the body, based on long-established and non-controversial science |

| Reduction of disease risk claim | “Sufficient calcium intake may reduce the risk of osteoporosis in later life. Food A is rich in calcium.” |
| Any health claim that states, suggests or implies that the consumption of a food category, a food or one of its constituents significantly reduces a risk factor in the development of a human disease |

<table>
<thead>
<tr>
<th>Netherlands, KAG/KOAG⁴</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Health recommendation</strong></td>
<td>“Good for blood pressure”</td>
</tr>
<tr>
<td>Indicates the maintenance or promotion of health, without making or suggesting a medical claim</td>
<td></td>
</tr>
</tbody>
</table>

| Medical claim | “For a good blood pressure” |
| Claim to prevent, treat or cure disease |

⁴Code of practice for advertising and labelling for foods and drugs, as worked out by the industries involved. www.koagkag.nl accessed 17 February 2004.

Proposed European Food Safety Authority. These proposals are a step in the right direction, and they deserve the support of nutrition scientists. However, the existing EU system for nutrition and health claims is complex and fragmented, with different member states having different rules. Changing these rules will take quite a while. In contrast, the EU does have an extensive system for checking the safety of foods, especially of so-called ‘novel foods,’ which include genetically modified foods.

The United States, Europe, and Japan all allow ‘nutrient content’ and ‘structure-function’ or ‘enhanced function’ claims, which require less evidence than do outright health claims [www.cspinet.org/reports/functional_foods/, 11 February 2004]. These claims offer opportunities to mislead the public. Take the statement, “This product is rich in calcium. Calcium helps to build strong bones.” Legally these are two unconnected statements that are both true. One statement is about the composition of the food, and the other about basic physiology. However, consumers may interpret such structure/function claims as claims to reduce the risk of disease (United States General Accounting Office, 2000; Andrews et al., 1998). Therefore they will assume that eating the product will reduce the risk of fractures. In its report on functional foods the US General Accounting Office (2000) stressed that “the differences between health claims and structure/function claims are not apparent to consumers and can lead to possible misuse.” It would be naive to think that manufacturers are unaware of that. It may, in fact, be the reason why the manufacturer put the claim on the package in the first place.
present regulations (Table 2) leave ample room for misleading, but it is unfair to lay the blame entirely with industry. The spread health messages. These methods may seem misleading; it is hard to say whether this leads to fewer healthy eating habits or more concern about excessive intakes of calcium (Giovannucci et al., 1997). For example, mega doses of vitamin B6 are known to cause peripheral neuropathy, and some authors have listed concern about excessive intakes of calcium (Giovannucci et al., 1998).

There are, thus, plenty of opportunities for suggesting that foods promote health without breaking the law, and these opportunities are vigorously exploited (Hagenmeyer, 2000). Thousands of companies offer supplements and “health” foods on the Internet with fanciful and largely unfounded promises. Promotional materials, such as leaflets and press releases, are less regulated than food labels and offer additional possibilities to spread health messages. These methods may seem misleading, but it is unfair to lay the blame entirely with industry. The present regulations (Table 2) leave ample room for misleading health claims, and some companies will inevitably exploit that room.

The fuzziness that surrounds the requirements for health claims is in sharp contrast with government regulations for mandatory food fortification, such as the addition of iodine to bread, fluoride to drinking water, vitamin D to margarines and milk, or folic acid to cereal products. These measures are all based on thorough research; they are effective and safe; they are well policed and maintained. Also, fortified bread, milk, and water reach the entire population, while functional foods do not. A study in Finland showed that stanol-enriched margarines are bought mostly by well-educated, high-income consumers (Anttolainen et al., 2001).

### FUNCTIONAL FOODS IN PRACTICE

Table 1 lists functional foods that use established vitamins and minerals as their special ingredients; we also included our opinion of their effectiveness. The health claims for some of these ingredients are well substantiated, e.g., low-sodium foods reduce hypertension, and high-fiber foods are effective against common forms of constipation. For others, the evidence is weaker; thus, the effect of zinc lozenges in preventing common colds is controversial (Marshall, 2000). Intakes of vitamins and minerals from functional foods, and especially from supplements, may be much higher than from regular foods. Adverse effects of such high intakes are a cause for concern (Hathcock, 1997). For example, mega doses of vitamin B6 are known to cause peripheral neuropathy, and some authors have listed concern about excessive intakes of calcium (Giovannucci et al., 1998).

Table 4 lists more novel or exotic ingredients of functional foods. Most of the claims for the benefits from novel or ‘exotic’ ingredients have not been substantiated in studies of

### Table 4: A selection of newer functional food ingredients, and the authors’ opinion of their efficacy

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Product examples</th>
<th>Health effect or claim</th>
<th>Evidence in humans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant stanols and sterols</td>
<td>Margarine, yoghurt, cereal bars</td>
<td>Lowers cholesterol and risk of coronary heart disease</td>
<td>++ for LDL cholesterol lowering; effect on coronary heart disease is by implication (Katan et al., 2003)</td>
</tr>
<tr>
<td>Lactobacillus GG bacteria</td>
<td>Yoghurt</td>
<td>Reduces diarrhea</td>
<td>+ for rotavirus-induced diarrhea in infants (Isolauri et al., 1994)</td>
</tr>
<tr>
<td>Lactobacillus GG bacteria</td>
<td>Yoghurt</td>
<td>Reduced risk of early atopic disease</td>
<td>+/0 (Kalliomäki et al., 2001)</td>
</tr>
<tr>
<td>Other ‘probiotic’ live bacteria, plus fermentable sugars (‘prebiotics’)</td>
<td>Yoghurt</td>
<td>Enhanced immunity</td>
<td>0 Some effects on biomarkers but none on disease (De Roos and Katan, 2000)</td>
</tr>
<tr>
<td>Isoflavones (phyto-estrogens)</td>
<td>Soy products</td>
<td>Reduce menopausal symptoms; osteoporosis; cardiovascular disease</td>
<td>0 Little evidence from clinical trials (van der Schouw et al., 2000; Glazier and Bowman, 2001)</td>
</tr>
<tr>
<td>Catechins</td>
<td>Tea</td>
<td>Reduce cardiovascular risk</td>
<td>+/0 (Mukamal et al., 2002; Hollman et al., 1999)</td>
</tr>
<tr>
<td>Conjugated linoleic acid (CLA)</td>
<td>Supplements (small amounts occur naturally in milk, beef and lamb)</td>
<td>Reduces body weight; protects against cancer</td>
<td>0/- Minimal effects on body weight in humans (Belury, 2002)</td>
</tr>
</tbody>
</table>

1See footnote to Table 1 for grading criteria. (++, proven efficacy; + reasonable evidence for efficacy; 0, no solid data; --, evidence for no effect; --- shown not to be efficacious).
the kind required to prove efficacy and safety in drugs (Linde et al., 2001). However, a few have been well investigated and show promise of reducing disease risk. One example is sterols and stanols. Margarines and other foods have been enriched with plant stanols or sterols, which lower LDL cholesterol by 10% and could, thus, make an important contribution to the prevention of coronary heart disease. Many well controlled trials have documented the efficacy of sterols and stanols for lowering LDL, and no major adverse effects have been noted. However, long-term safety and clinical efficacy have not been evaluated in large-scale clinical trials of the size and duration customary for new drugs. The Health Council of the Netherlands, therefore, discourages the use of plant sterols by consumers who do not benefit from a cholesterol-lowering effect, especially children and pregnant women (Health Council of the Netherlands, 2001), and other regulatory agencies have suggested similar limitations.

Pre- and probiotics are another example of well-researched functional ingredients. Probiotics are viable bacteria that survive passage through the gastrointestinal tract and exert beneficial effects on the consumer (Schrezenmeir and De Vrese, 2001). Some health effects have been well documented, e.g., foods with lactic acid bacteria may reduce the severity of some types of diarrhea (De Roos and Katan, 2000), and there are indications that they reduce the risk of atopic eczema in high-risk infants (Isolauri et al., 2000; Kalliomäki et al., 2001). However, little evidence is available for effects such as cancer prevention and serum cholesterol lowering (De Roos and Katan, 2000). Prebiotics are nondigestible food ingredients—usually carbohydrates—that beneficially affect the host by selectively stimulating some of the bacterial species already resident in the colon, and thus, attempt to improve host health (Gibson and Roberfroid, 1995). Health effects, however, appear to be limited to improved bowel function; no adequate scientific support in the form of randomized trials in humans exists for other proposed health effects, such as cancer prevention, lipid lowering, and prevention of diarrheal diseases (Duggan et al., 2002).

A third well-investigated ingredient is polyphenols. High intakes of tea rich in catechins and other flavonoid polyphenols have been associated with a reduced risk of coronary heart disease (Mukamal et al., 2002). A clinical trial to evaluate these effects would seem justified and feasible. Whether polyphenols explain the so-called French paradox is questionable, as red wine and olive oil are not particularly good sources of phenolic compounds when compared with tea or coffee (De Vries et al., 2001).

Table 5 lists herbal ingredients that have been used in both supplements and foods, although amounts in foods are usually much lower. Safety is a concern, as exemplified by herbal teas with Aristolochia, which causes renal cancer (Kessler, 2000) and products with ephedra, which causes hypertension, strokes, and seizures (Haller and Benowitz, 2000). The use of herbal medications with Echinacea, ephedra, garlic, ginkgo, ginseng, kava, St. John’s Wort, and valerian is discouraged in presurgical patients (Ang-Lee et al., 2001). Complications may arise from herb-drug interactions, as well as from direct effects such as bleeding and hypoglycemia. A report from the United States General Accounting Office also concluded that unsafe products...
may reach consumers because of a lack of standards, a lack of warnings on the label (for example, St. John’s Wort may decrease the efficacy of HIV drugs), and poor reporting and investigation of health problems caused by supplements and functional foods (United States General Accounting Office, 2000). A new report also recommends caution about the use of herbal “anti-aging” therapies by seniors, especially those who have underlying diseases (United States General Accounting Office, 2001). The same concerns hold for foods containing these ingredients, although supplements are a more important source and provide much higher doses.

The safety situation is not likely to improve, and there is also not much impetus for manufacturers to show that their functional foods are efficacious. There are now functional foods and supplements on the market for just about any disease and organ, including immune response, cancer, gastro-intestinal diseases, mood, memory and alertness, energy, strength and stamina, and aging. Some of these products sell well and create profits for their manufacturers, although evidence for efficacy is marginal. As Southon stated, “Although evidence of benefit is not necessary for effective marketing of a product, marketing would be more ethical if benefit could be demonstrated” (2000). It may seem cynical to market foods with suggestions of health benefits when the evidence is clearly inadequate. But, can we hold food and supplement producers to standards of ethics that society has not codified by law? It takes a lot of money and stamina to prove that a food ingredient really prevents or cures a disease, and recent experience has not been encouraging. For example, beta-carotene was widely believed to reduce cancer risk in smokers, because intake of carotene-rich foods was associated with less cancer, as were high levels of carotene in blood. As it is, carotene supplements increased risk of lung cancer in smokers (The Alpha-Tocopherol Beta Carotene Cancer Prevention Study Group, 1994; Omenn et al., 1996). Large clinical trials of antioxidants have also yielded disappointing outcomes (Yusuf et al., 2000), although a recent high-quality clinical trial showed that they can slow down macular degeneration when taken in combination with zinc (Age-Related Eye Disease Study Research Group, 2001). The most positive exception is fish oil which proved to be remarkably effective in preventing sudden cardiac death (Gissi-Prevenzione Investigators, 1999). Due to the many negative results, manufacturers may think twice before investing huge amounts of money into research that may well kill a successful product. Even if the research shows that the product works, the manufacturer may not recover his investment, because foods are difficult to patent. Again, it is the legislative system that works against the emergence of new health-promoting foods.

**WHAT EVIDENCE SHOULD WE DEMAND FOR FUNCTIONAL FOODS?**

Well tested systems for evaluating the validity of health claims for foods exist in many countries. Examples are the “Significant Scientific Agreement” criteria of the United States Food and Drug Administration (U.S. Food and Drug Administration, 2004), the Dutch Code of Practice (Netherlands Nutrition Centre, 2004), and the UK Joint Health Claims Initiative (Joint Health Claims Initiative, 2004). Such evaluations should become mandatory for all explicit or implied claims that a food promotes health. The criteria for the safety and efficacy of functional foods do not need to be the same as for drugs, because there is an important distinction between food ingredients and drugs. Drug research isolates or synthesizes molecules that are new to human metabolism, but nutrition deals with molecules that have been part of the diet of large populations for many centuries. Studying associations between diet and health in such populations is a powerful way to generate leads for health-promoting foods and to investigate their efficacy and safety. Nutritional epidemiology has generated numerous leads, many of which have led to healthy foods, such as the examples in Table 1. However, controlled experiments must also be used to show that a functional food ingredient is effective and safe. For functional foods that contain widely consumed nutrients in moderate amounts, it may be enough to demonstrate that the nutrients are properly absorbed in humans. Examples are foods fortified with folic acid or calcium. For more exotic components, or for dosages much higher than usual, the evidence required may be closer to that required for new drugs, i.e., short- and long-term controlled experiments showing safety and efficacy in animal models, in healthy volunteers, and in the population at risk to which the functional food is targeted. It is often stated that clinical trials showing actual reduction of disease in humans (so-called ‘phase III trials’) are prohibitively expensive. However, most major food industries or commodity associations could easily bear the cost of such trials, provided that the outcomes would increase sales or profit margins. For instance, epidemiological data (Mukamal et al., 2002) suggest that consumption of tea is associated with a 30% reduction of cardiac death in myocardial infarction survivors. A clinical trial to test this hypothesis would require 2500 patients to reach a power of 80% at α = 0.05. Such a trial might cost about $2 million per year for 5 years. In comparison, the advertising budget of the major United States tea brand in 1998 was $41.8 million in one year (Nestle, 2002). Thus, the worldwide tea industry could easily fund a clinical trial if the outcome were expected to assist marketing. Such research is more likely to happen if governments provide the perspective of a health claim should the trial be successful. Such claims may not be exclusive to the company that funded the research, but that does not necessarily make the research unprofitable. A company may want to prove the health effect of an ingredient because it expects to beat its competitors in creating tasty, convenient, and competitively priced foods with that ingredient. Also, producers may collectively fund research on commodities from which they all may profit.

Proper legislation is essential to the success of evidence-based functional foods. If a claim has been properly proven, e.g., through a clinical trial, then manufacturers should be free to advertise it; if the claim is untrue, it should be suppressed by law.
DO FUNCTIONAL FOODS HAVE A FUTURE?

On a short-term basis, functional foods do have a future. There is plenty of demand. In 1999, United States consumers spent about $15 billion for dietary supplements and $16 billion for functional foods (United States General Accounting Office, 2000). However, the system for ensuring the validity of health claims (or in legal terms: structure/function claims or statements of nutritional support) in the United States is eroding, and regulations in most of the rest of the world are even weaker. As a result, consumers are exposed to unfounded claims and allusions to health benefits of foods and supplements. But, that is not a solid basis for long-term commercial success. Sooner or later, consumers will realize that they have been misled. This may explain why the sales of dietary supplements in the United States have seen some decline since their peak years of the mid-1990s. If governments do not set clear and strict standards for efficacy and safety of functional foods, then the field has no real future.

REFERENCES


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