Focus on
Nutrition and Health

Fortification (R)Evolution

Photo: Purac

By Lynn A. Kuntz
Editorial Director

One hundred or so years ago, food fortification was pretty much a foreign concept, especially in the Western world. Nineteenth-century medical practitioners might whip up a nourishing broth for the sick or concoct a tonic purported to cure various ills. However, those looking to reap a particular nutritional benefit from a food — if indeed they were even aware of them — basically were limited to eating that particular food. But what a difference a century makes.

Solving nutrition's mysteries

Before 1900, early nutritionists had made a few scientific diet/disease connections, though many Asian cultures linked diet and health. In the 1700s, the British Navy recognized that citrus fruits prevented scurvy, and began carrying them on ships. Still, scientists held a widespread belief that many nutritional diseases came from microbial sources until the early 1900s. In 1911, Casimir Funk, Ph.D., a Polish chemist at London's Lister Institute, discovered essential dietary substances he called "vitamines" (revised to "vitamins" when further research found they weren't all amines). By the 1920s and 1930s, researchers confirmed that consuming small amounts of these vitamins could cure deadly diseases such as beriberi, scurvy and pellagra.

These discoveries lead to national fortification programs. The United States began iodine fortification of salt in 1924 to prevent goiter and other symptoms of severe iodine deficiency. Vitamin D was added to cow's milk in the early 1930s to help prevent rickets. Voluntary enrichment of flours and breads to replace nutrients lost in milling was initiated in 1938, which included thiamin, niacin, riboflavin and iron. Mandatory require-

ments went into effect in 1943. Various other fortification programs followed, such as vitamin A in margarine, low- and nonfat milk, and certain other dairy products.

The last FDA mandate for fortification, the folic-acid fortification program, became effective January 1998 in response to the positive effect of folic acid in preventing neural tube defects. (Evidence is strong that this nutrient might also decrease blood homocysteine levels, leading to a reduction of heart disease.) It requires manufacturers to add from 0.43 mg to 1.40 mg of folic acid per pound of product to grain-based products, including enriched flour, bread, rolls and buns, farina, corn grits, cornmeal, rice, and noodle products, so a serving will provide about 10% of the daily value (DV).

Because whole-grain products naturally contain folate, they don't require enrichment. Manufacturers can add folate to other foods, such as breakfast cereals; however, product developers must remember that total folate intake should be kept under 1 mg per day, or it could hide the symptoms of pernicious anemia, a vitamin B_{12} deficiency generally seen in the elderly.

Fortification theory

While the food industry first practiced fortification to address deficiency diseases, the concept has evolved. Scientists, such as Nobel laureate Albert Szent-Györgyi, Ph.D., and Linus Pauling, Ph.D., began to advance theories that vitamins and other nutrients could do more than prevent deficiency diseases; certain levels could lead to optimal health. Over the last several decades, nutrition experimentation has led to innumerable connections between food and/or specific nutrients and better health, and the resulting explosion in the functional-food and dietary-supplement markets.

The link between vitamins and health led to national fortification programs, including the fortification of flours and breads with nutrients lost in milling, such as thiamin, riboflavin and iron.

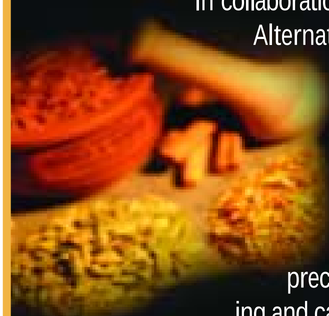
Today's product designers use fortification for many reasons. As mentioned, it can become a tool for public health interventions, e.g. iodized salt for the general population. Fortification can restore nutrients lost during food processing to preprocessing levels (often called enrichment), as occurs in milled grains, such as white rice and wheat flour, to replace nutrients lost when the bran is removed. It can standardize nutrient content, such as vitamin C in orange juice, when changes occur due to seasonal and processing variations. It can make foods nutritionally equivalent in a replacement product; margarine requires vitamin A because it acts as a substitute for butter. Formulators can balance the nutrient content of foods for special dietary purposes, such as meal replacements and nutritional supplements. And increasingly, with the advent of functional foods and nutraceuticals, fortification can supply a perceived or real health benefit to confer a competitive advantage in the marketplace.

Conventionally, foods targeted for fortification should possess some intrinsic nutritional value and not contain components that increase disease risk — high in saturated fat or salt, for instance. This is open to interpretation, but Ram Chaudhari, Ph.D., senior executive vice president, research and development, Fortitech, Schenectady, NY, recommends a logical approach. "You have to look at the nutrient density," he says. "You have to look at what the product is used for. If a beverage low in nutrients displaces something higher in nutrients (in the diet), such as a 100% fruit juice, then it makes sense to fortify that beverage."

As for levels, Chaudhari says that fortification often requires compromises. Companies can target the recommended daily intake (RDI), if one exists, but, in general, he recommends moderation. "Often customers want 100% of the DV in a product, but they might be better of with a lower level, say 35%," he says. "And many of these ingredients don't have DVs or RDIs, so they need to decide on the proper level. If they are looking at carotenoids, for example, they might try to match the levels found in real fruit. But you have to consider how far you can go without negatively affecting the product quality. And you have to look at it for a toxological point of view."

Traditionally, food fortification and dietary supplements involved the essential nutrients — vitamins, minerals and protein. The Dietary Supplement and Health Education act of 1994 (DSHEA) broadened the definition of dietary supplement to include vitamins; minerals; herbs, botanicals and other plant-derived substances; and amino acids and concentrates, metabolites, constituents, and extracts of these substances. Food fortification can also include the addi-

Botanical Research



In collaboration with the National Center for Complementary and Alternative Medicine (NCCAM), the National Institutes of Health's Office of Dietary Supplements (ODS), Bethesda, MD, funds five existing Centers for Dietary Supplement Research. These are charged with identifying and characterizing botanicals, assessing bioavailability and activity, exploring mechanisms of action, conducting preclinical and clinical evaluations, establishing training and career development, and helping to select botanicals to be tested in clinical trials. They include:

Purdue University and the University of Alabama-Birmingham Botanicals Research Center for Age-Related Diseases

Locations: Purdue University, West Lafayette, IN, and University of Alabama, Birmingham.
Center director: Connie Weaver, Ph.D.
Center Website: *http://fn.cfs.purdue.edu/bot*
Research projects:

- Grape polyphenols and neuroprotection.
- Tea catechins and cancer.
- Soy isoflavones and bone resorption.
- Polyphenols and inflammation.

The Arizona Center for Phytomedicine Research

Location: University of Arizona, Tucson.
Center director: Barbara Timmermann, Ph.D.
Center Website: *http://acprx.pharmacy.arizona.edu*
Research projects:

- Chemistry and mechanisms of action.
- Bioavailability.
- Pharmacokinetics.
- Ginger.
- Turmeric.
- Boswellia.

Center for Dietary Supplements Research: Botanicals

Location: University of California, Los Angeles.
Center director: David Heber, M.D., Ph.D.
Research projects:

- Mechanisms of action.
- Chinese red-yeast rice.
- Green tea extract.
- St. John's wort.

tion of healthful components such as fiber, soy isoflavones and any other approved food ingredient that might provide a benefit. This has opened up a whole new era in fortification.

According to the UDSA, in addition to multivitamins with and without minerals, the nutrient supplements Americans use most often include vitamins C and E, and the B complex; calcium; and iron. Botanical supplements showing high use levels include echinacea, garlic, ginkgo biloba, ginseng, St. John's wort and saw palmetto. These trends have been reflected in nutraceutical products from beverages to bars, as well as in mainstream fortified-food products.

The increased scientific evidence of relationships between nutrient intake and the specific benefits unfolding also helps determine the "in vogue" nutrients, says Diane Hnat, marketing manager, Roche Vitamins, Parsippany, NJ. "Fatty acids, such as LC-omega-3 EPA and DHA (long-chain omega-3 fatty acids eicosapentaenoic acid and docosahexaenoic acid), CLA (conjugated linoleic acid), and GLA (gamma-linolenic acid), are definitely remaining on the radar screen," she observes. "Amino acids, such as arginine, taurine and leucine, continue to pique interest. Again, vitamins that we just can't put in every food because of the regulations, especially folic acid or vitamins D and K, are 'extra hot.' New or evolved forms of fiber, such as arabinogalactan, are also making fiber a more positive ingredient to add. Synthesized- and naturally extracted versions of the carotenoids, commonly known as antioxidants — but recently made GRAS as nutrients for selected foods — include lycopene and lutein.

UIC Center for Botanical Dietary Supplement Research in Women's Health

Location: University of Illinois, Chicago.
Center director: Norman Farnsworth, Ph.D.
Center Website: *http://uic.edu/pharmacy/research/diet*
Research projects:

- Standardization.
- Bioassay development: *In vitro* and *in vivo* evaluation.
- *In vitro* studies: Metabolism, absorption and toxicity.
- Clinical evaluation.
- *Cimicifuga racemosa* (Black cohosh).
- *Trifolium pratense* (Red clover).
- *Vitex agnus-castus* (Chaste berry).
- *Humulus lupulus* (Hops).
- *Vaccinium macrocarpon* (Cranberry).
- *Viburnum prunifolium* (Black haw).
- *Angelica sinensis* (Dong Quai).
- *Panax ginseng* (Asian ginseng).
- *Ginkgo biloba* (Ginkgo).
- *Glycyrrhiza glabra* (Licorice).
- *Valeriana officinalis* (Valerian).

MU Center for Phytonutrient and Phytochemical Studies

Location: University of Missouri, Columbia.
Center director: Dennis Lubahn, Ph.D.
Center Website: *http://www.phyto-research.org/*
Research projects:

- Phytonutrients and prostate tumor progression.
- Phytoestrogens and innate immunity in estrogen receptor deficient mice.
- Plant polyphenols neuroprotective effects against oxidative insults.
- Botanical identification characterization.

Additionally, in July, the National Institute of Environmental Health Sciences (NIEHS) and the ODS announced a grant for the establishment of a research center in Ames, Iowa to study *Echinacea* and *Hypericum* (St. John's wort). The new Center combines the resources of Iowa State University, Ames, and the University of Iowa, Iowa City. Diane F. Birt, Ph.D., has been named director. ■

The incorporation of micronutrients into foods is more physically and chemically challenging than supplements. Adding fruits and berries is one way to add nutrition while reducing stability concerns.

Another newly-touted carotenoid being researched for its role in maintaining eye health is zeaxanthin, which is GRAS for supplements now, but most likely will be allowable in certain foods within a year or so."

In addition to these, Chaudhari notes an increased interest in "functional probiotics, zinc and choline. Also, as general categories, many companies are interested in ingredients that promote bone and immune health."

This means that product designers need to be savvy in formulating products with a wide variety of nutritional ingredients. This category of ingredients can, in general, present a number of challenges — everything from choosing and maintaining the correct nutrient level to designing an organoleptically acceptable product to successfully negotiating the legal morass some ingredients bring. As the industry moves to a wider, more esoteric selection of nutrients, it all becomes more difficult. "Overall, not only is the incorporation of micronutrients into foods more physically and chemically challenging than into supplements, but ultimately, the detection of micronutrients in foods is more challenging too," notes Hnat.

Many fortification ingredients can present stability issues. What goes into the product may no longer be there or be usable when it passes the consumer's lips. During processing and storage, factors such as pH, oxygen, light and temperature, as well as certain ingredient interactions, can affect sensitive nutrients. A fairly long history of use has given us a handle on working with vitamins and minerals; however, this may not be true of some of the other ingredients that have become popular in recent years.

Taking vitamins

Vitamins vary in their stability. The sensitivity of vitamins C, A and folate, in particular, can result in significant losses during processing and storage. Vitamin C (L-ascorbic acid) is extremely unstable under many conditions commonly encountered by foods, especially high heat and humidity. It oxidizes easily — light, oxygen, heat, non-neutral pH, elevated water activity, and the presence of copper or ferrous salts all accelerate the process. Since it's a water-soluble vitamin, it can also leach out into cooking water. Some of the same problems plague naturally occurring folates, except that acid and neutral pH accelerates deterioration; however, use of folic acid helps overcome stability problems. Oxidizing agents can degrade vitamin A and other antioxidant vitamins and provitamins, including carotenoids. Other potential chemical reactions include inactivation of thiamin by sulfite ions or tannins.

"While a number of nutrients are relatively stable, others, by their very nature, are highly reactive materials," notes Carl Pacifico, new ventures development leader, Balchem Encapsulates, Slate Hill, NY. "Take, for example, some of the antioxidant vitamins, such as A, E and C. When these vitamins are added in their natural state

Photo: Adams, a division of Pfizer

As consumers increasingly turn to hand-held nutrition bars and snacks to augment or, in some cases, replace, meals, product fortification will become important to manufacturers seeking larger markets.

— not combined with other molecules such as alpha-tocopherol acetate, vitamin A palmitate, vitamin C palmitate — their antioxidant tendencies will transfer over into the functional food in which they are included. For instance, putting vitamin E into potatoes will keep them from turning brown. This is due to the antioxidant effects of vitamin E. However, as the vitamin E reacts to keep the potato from browning, the vitamin E level in the potato is also dropping, and this leads to less vitamin E being delivered to the consumer."

Processing effects also require consideration. As mentioned, heat can degrade certain vitamins, and the severity is related to the time and temperature of the process. Retorting a solid-pack item requires more heat exposure than HTST pasteurization of a liquid. Researchers report some vitamin loss during irradiation, especially thiamin.

To ensure the correct level of sensitive vitamins (and other at-risk nutrients), formulators typically add "overages." An overage uses information on nutrient stability to calculate the amount of added nutrient so that the level of the nutrient at the end of the product's shelf life matches the level on the label. Obviously the food matrix, processing (especially heating), storage and packaging all play into the equation.

Vitamin encapsulation can eliminate or reduce the need for vitamin overages, according to Pacifico. The degree to which this occurs "is a function of the degree of sensitivity of the nutrient, the process being employed, finished-product shelf life, reactivity of all the components in the functional food or supplement, storage conditions of the finished product and site uptake of the nutrient," he says. "The main purpose of encapsulation is the stabilization of the active compound and targeted release to the specific site. The degree to which encapsulation can perform both of these functions directly impacts the initial dosage level."

Depositing minerals

Minerals, on the other hand, tend to come through food processing relatively unscathed, though that's not necessarily true of the food quality when they contain added minerals. Fortifying with minerals can cause problems with color, flavor and texture. For example, calcium may produce a masking effect that adversely affects flavor delivery. Copper has been known to react with certain ingredients and give foods a blue cast. In general, the more bioactive the form, the more likely it is to cause a problem. "Minerals that are more bioactive also tend to be more soluble," says Chaudhari. "While that can be an advantage in many applications, it also means the molecules are very reactive." The selection of an appropriate mineral source for fortification requires an understanding of its physical and chemical properties, and interactions with other components in the food system.

Ferric (iron) ions, for instance, can react with fatty acids in a food. "Iron is highly reactive and causes catalytic oxidation of fats and oils," says Pacifico. "The unencapsulated iron in

New Nutrient Levels

The Food and Nutrition Board of the Institute of Medicine, National Academy of Sciences (NAS), Washington, D.C., in partnership with Health Canada, Ottawa, has formed a Standing Committee on the Scientific Evaluation of Dietary Reference Intakes with the goal of developing and evaluating Dietary Reference Intakes (DRIs) for each nutrient or non-nutrient food component when adequate scientific data is available. DRIs will update and expand the Recommended Dietary Allowances (RDAs) set by the NAS in 1941.

According to the NAS, the DRIs refer to at least three types of reference values:

Estimated Average Requirement (EAR). The intake value that is estimated to meet the requirement defined by a specified indicator of adequacy in 50% of an age- and gender-specific group.

Recommended Dietary Allowance (RDA). The dietary intake level that is sufficient to meet the nutrient requirements of nearly all individuals in the group.

Tolerable Upper Intake Level (UL). The maximum level of daily nutrient intake that is unlikely to pose risks of adverse health effects to almost all of the individuals in the group for whom it is designed.

The panels cover the following groups of nutrients:

- Calcium, vitamin D, phosphorus, magnesium, and fluoride ("Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride" report, issued 1999);
- Folate and other B vitamins ("Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline" report, issued 2000);
- Antioxidants (e.g., vitamins C and E, selenium; "Panel on Dietary Antioxidants and Related Compounds" report, issued 2000);
- Macronutrients (e.g., protein, fat, carbohydrates, fiber; "Panel on Macronutrients" report, pending 2002);
- Trace elements ("Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc" report, issued 2002);
- Electrolytes and water (Report pending); and
- Other food components (e.g., phytoestrogens; report pending).

an infant formula will react with components such as DHA and EPA and cause them to oxidize and turn rancid. In this case, the iron potency is lost along with the EPA and DHA."

The market has seen heightened interest in calcium fortification because of its relation to osteoporosis and because many people do not consume sufficient amounts of calcium. "Once calcium has been put into a formulation it stays in," says Ellis Hogetoorn, market development specialist, PURAC America Inc., Lincolnshire, IL. "It does not evaporate or break down. Calcium can, however, react with other ingredients to form a complex, depending on various factors: the calcium source used, other ingredients present, temperature fluctuations, etc."

As is potentially true with most nutrients, no nutrient is an island, and calcium seems to be evolving as the poster child. It's been known for many years that vitamin D enhances calcium absorption by stimulating transport of calcium in the digestive tract. Therefore, inadequate dietary vitamin D intake, or inadequate exposure to sunlight, reduces calcium absorption down to less than 10%. Calcium from dairy products is more available for absorption in the small intestine, but calcium from plant foods may be absorbed in the colon. Consuming high levels of sodium and protein can significantly increase urinary calcium excretion. In addition, calci-

Photo: Purac

Calcium's relationship to osteoporosis, and the fact that many individuals consume inadequate amounts of the mineral, has heightened manufacturers' interest in the benefits of calcium fortification.

um/magnesium (affects cardiovascular health) and calcium/phosphorus (see **Food Product Design's** September 2002 News) balance issues have implications for fortification using blends. Some animal studies show that excessive calcium intake can have deleterious effects on the nutritional status of magnesium, zinc and iron — trace minerals that benefit bone health, too. This is one reason product formulators are looking at mineral blends, especially those that may occur naturally, such as milk-calcium sources.

Brave new nutrient world

In addition to classic nutrients involved in normal metabolic activity, other components, typically derived from food ingredients, may provide additional health benefits. However, their stability and effects on food systems often have less of a knowledge base behind them. Even more importantly for the consumer, for many ingredients, the effective compound and/or its dose is not well-understood from a scientific perspective. Another stumbling block is deciding what types of ingredients belong in what types of products.

In January 2001, FDA sent a letter to the food industry at-large reiterating the requirements of the Federal Food, Drug, and Cosmetic Act regarding marketing foods containing "novel" or "new" ingredients, including botanicals, and in June, issued warning letters to several manufacturers it deemed had overstepped the bounds. The FDA requires that herbs and other novel ingredients added to food must either be approved as food additives or considered GRAS; otherwise they must be marketed in the form of a supplement as defined by DSHEA.

Manufacturers who take the supplement route have a wider variety of ingredients from which to choose. But although they may not risk the wrath of the FDA, they may face other risks. Herbs may be natural, but they may not be completely safe. For example, consumers take kava kava supplements to relieve anxiety and tension, but high doses may create worse problems, according to reports released from Germany and Switzerland that link it with hepatitis, cirrhosis and liver failure.

Still, many plant-based phytochemicals found in conventional foods, as well as supplements, may offer benefits and can be found ingredient-form-suitable for foods. For example, soy isoflavones have been shown to reduce serum cholesterol levels, leading ingredient suppliers to offer ingredients that can supply higher levels of this compound. People often take ginger to relieve nausea and indigestion, an effect attributed to its sequiterpene hydrocarbons, including zingiberene and bisabolene.

Don't free the radicals

Antioxidants, substances that protect the body's cells from damage caused by free radicals, consist of more than vitamin C, vitamin E, beta-carotene and selenium — a variety of lesser-known

Photo: Cherry Marketing Institute

Antioxidants — including bioflavonoids from cherries, as well as apples, prunes and grapes — help protect the body's cells from damage caused by free radicals and show promise as disease-fighters.

plant-based compounds are gaining some renown.

"At a fundamental level, all plant antioxidants have beneficial nutritional implications because they are all antioxidants," notes Ginny Bank, technical director, RFI Ingredients, Blauvett, NY. "The majority of plant antioxidants are polyphenolic compounds, a large class of phytochemicals that show promise as disease-fighters. Polyphenols act as antioxidants and, in the laboratory, their antioxidant capacity has been shown to have anticarcinogenic, antiatherogenic and antiviral effects. Vegetables, fruits, teas and herbs are all good sources of polyphenols, which is why the ideal diet is rich in fruits and vegetables. However, reinforcing any diet with either fortified foods or supplements containing polyphenolic compounds is a good idea considering the average person doesn't eat the recommended daily 'five-to-nine' servings of fruits and vegetables."

According to Bank, some of the more well-known and studied plant antioxidants include: tea polyphenols (catechins from green or white tea, theaflavins from black tea); anthocyanins from red fruits and vegetables (e.g. elderberry, strawberry, bilberry, blueberry, red cabbage); bioflavonoids from fruit (quercitin from apple, cherries, prune, grapes; hesperidin, isonaringin, rutin from citrus fruits); sulfur compounds from vegetables (allicin from garlic, sulphorophane from broccoli); proanthocyanidins (OPCs) (from grape seed extracts, pine bark extracts); phenolic acids (from rosemary, berries, grapes and red wine, pear, and ellagic acid from pomegranate and raspberries); and isoflavones (from soy).

As for fortification levels for these, Bank says it's tough to generalize because each compound may have suggested levels, but it may vary according to the health effect targeted. ORAC (Oxygen Radical Absorption Capacity) can help. "The ORAC assay is a relatively simple, but sensitive, method suitable for quantifying the antioxidant capacity of a number of products," she explains. "It's a pretty standard method used in the supplement industry. If we know the ORAC value of our products, we can recommend a use rate based to equal the ORAC value of the average serving of vegetables."

Product designers can add these plant antioxidants into numerous products, from beverages to breakfast cereals. But, like all antioxidants, they need care in formulation, processing and packaging. "Heat, light and oxygen affect the stability of plant antioxidants," Bank points out. Beverages usually go through pasteurization, which would have little effect on plant polyphenols since the beverage is only heated for a short period of time, certainly not long enough to

Photo: Oregon Raspberry and Blackberry Commission

The phenolic acids found in berries, including the ellagic acid that exists in raspberries, can reduce oxidation in products ranging from dairy desserts and beverages to breakfast cereals.

cause any degradation. Baking or extrusion may also affect the stability, but probably not too much as even those conditions are not terribly harsh."

Getting protection

Because antioxidants' nature is to sacrifice themselves to oxygen, they need to have some protection from the element. "In packaging that has no oxygen barrier, you may see decreased activity over long storage times, but the length of that storage time would depend upon the plant antioxidants being used," says Bank. Proper packaging also eliminates the effects of light on oxidation.

Since FDA issued a health claim for EPA and DHA omega-3 fatty acids, and reduced risk of coronary heart disease, these too have also become popular fortification compounds. However, omega-3s can present product designers with stability problems, says Chaudhari. "Because of the structure of the fatty acids, the omega-3s do not have good stability to oxidation," he explains. "This especially becomes a problem when products are exposed to high temperatures."

Encapsulation can help with some of these "newer" nutrients, too, Pacifico points out. "Green tea, or the polyphenols found in them, are quite unstable. Probiotics are extremely delicate beneficial microorganisms that are destroyed in the presence of oxygen and elevated temperatures. Additionally, probiotics are destroyed in the stomach acid. Encapsulation is a very effective tool in not only stabilizing these bugs prior to consumption, but also essential in delivering them past the stomach into the lower gastrointestinal tract, where they become most beneficial to the user."

As time goes on, the technology will be further developed to deliver the appropriate fortification nutrients in foods and supplement form. And no matter what the nutrient or what the system for incorporation, 21st-century consumers will reap health benefits their great-great grandparents never even knew existed. ■

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