Nutritional Quality of Fruits, Nuts, and Vegetables and their Importance in Human Health

Adel A. Kader[1], Penelope Perkins-Veazie[2], and Gene E. Lester[3]
[1]Department of Pomology, University of California, Davis CA
[2]South Central Agricultural Laboratory, USDA/ARS, Lane OK
[3]Kika de la Garza Subtropical Agricultural Research Center, USDA/ARS, Weslaco TX

Fruits, nuts, and vegetables play a significant role in human nutrition, especially as sources of vitamins [C (ascorbic acid), A, thiamine (B_1), niacin (B_3), pyridoxine (B_6), folacin (also known as folic acid or folate) (B_9), E], minerals, and dietary fiber (Craig and Beck, 1999; Quebedeaux and Bliss, 1988; Quebedeaux and Eisa, 1990; Wargovich, 2000). Their contribution as a group is estimated at 91% of vitamin C, 48% of vitamin A, 30% of folacin, 27% of vitamin B_6, 17% of thiamine, and 15% of niacin in the U.S. diet. Fruits and vegetables also supply 16% of magnesium, 19% of iron, and 9% of the calories. Legume vegetables, potatoes, and tree nuts (such as almond, filbert, pecan, pistachio, and walnut) contribute about 5% of the per capita availability of proteins in the U.S. diet, and their proteins are of high quality as to their content of essential amino acids. Nuts are a good source of essential fatty acids, fiber, vitamin E, and minerals. Other important nutrients supplied by fruits and vegetables include riboflavin (B_2), zinc, calcium, potassium, and phosphorus. For more information on food composition and nutrition, access one of the following Internet websites: http://www.nal.usda.gov/fnic/cgi-bin/nut_search.pl; http://www.nutrition.gov. A recommended daily intake (RDI) for the U.S. of dietary nutrients can be found at http://www.usaid.gov/hum_response/crg/annex-4.htm. Fruits and vegetables remain an important source of nutrients in many parts of the world, and offer advantages over dietary supplements because of low cost and wide availability.

Dietary supplements, while advantageous for conditions where specific nutrients are needed in abundance such as with iron deficiency, may be poorly absorbed, and many are derived chemically rather than from natural sources. Climatic conditions, particularly temperature and light intensity, have an especially strong effect on the nutritional quality of fruits and vegetables oxidation (Mozafar, 1994). Low temperatures favor synthesis of sugars and vitamin C (glucose being the precursor to ascorbic acid) and at the same time decrease the rate of ascorbic acid oxidation. Maximum β-carotene (vitamin A) content in tomatoes occurs at a temperature range of 15 to 21 ºC, (59 to 70 ºF) but β-carotene content is reduced if temperatures are higher or lower than this range, principally due to the temperature sensitivity of lycopene, the precursor to β-carotene and lutein.

The B vitamins are crop specific when it comes to temperature sensitivity. Warm season crops (beans, tomatoes, peppers, melons, etc.) produce more B vitamins at high (27 to 30 ºC; 81 to 86 ºF) versus low (10 to 15 ºC; 59 to 70ºF) temperatures. Conversely, cool season crops (broccoli, cabbage, spinach, peas etc.) produce more B vitamins at low versus high temperatures. Light intensity has little effect on the B vitamins, but as light intensity increases, vitamin C increases and total carotenoids (vitamin A precursors) and chlorophyll decrease (Gross, 1991). Higher light intensities produce more sugars, leading to more vitamin C, and also increase plant temperatures, inhibiting beta carotene (vitamin A) production, which protects chlorophyll from photo bleaching. Soil type, the rootstock used for fruit trees, mulching, irrigation, fertilization, and other cultural practices influence the water and nutrient supply to the plant, which can affect

the composition and quality attributes (appearance, texture, taste and aroma) of the harvested plant parts (Goldman et al., 1999). Other environmental factors that impact fruit and vegetable nutritional quality are altitude, soil pH and salinity, production practice (organic versus conventional, and greenhouse versus field), ozone, insect injury, and plant diseases. Maturity at harvest, fruit size and harvesting method influence the commodity's quality and extent of physical injuries. Delays between harvest and consumption or processing can result in losses of flavor and nutritional quality. The magnitude of these losses increases with exposure to temperatures, relative humidities, and/or concentrations of O_2, CO_2, and C_2H_4 outside the ranges that are optimum for each commodity during the entire postharvest handling system (Lee and Kader, 2000). Furthermore, processing and cooking methods can greatly affect the nutritional value of fruits and vegetables. For instance, water-soluble vitamins such as vitamin C and folate are lost at high rates when cooking water is discarded, while fat-soluble compounds such as lycopene may be stabilized or enhanced by cooking.

Fruits, nuts, and vegetables in the daily diet have been strongly associated with reduced risk for some forms of cancer, heart disease, stroke, and other chronic diseases (Goldberg, 2003; Hyson, 2002; Prior and Cao, 2000; Produce for Better Health Foundation, 1999; Quebedeaux and Bliss, 1988; Quebedeaux and Eisa, 1990; Southon, 2000; Tomas-Barberan and Espin, 2001; Wargovich, 2000). Some components of fruits and vegetables (phytochemicals) are strong antioxidants and function to modify the metabolic activation and detoxification/disposition of carcinogens, or even influence processes that alter the course of the tumor cell (Wargovich, 2000). Although antioxidant capacity varies greatly among fruits and vegetables (Prior and Cao, 2000; Perkins-Veazie and Collins, 2001; Kalt, 2002) it is better to consume a variety of commodities rather than limiting consumption to a few with the highest antioxidant capacity. The USDA 2000 Dietary Guidelines (USDA, 2000) encourage consumers to: (1) enjoy five a day, ie., eat at least 2 servings of fruits and at least 3 servings of vegetables each day, (2) choose fresh, frozen, dried, or canned forms of a variety of colors and kinds, and (3) choose dark-green leafy vegetables, orange fruits and vegetables, and cooked dry beans and peas often. In some countries, consumers are encouraged to eat up to 10 servings of fruits and vegetables per day.

There is increasing evidence that consumption of whole foods is better than isolated food components such as dietary supplements and nutraceuticals. For example, increased consumption of carotenoid-rich fruits and vegetables was more effective than carotenoid dietary supplements in increasing LDL oxidation resistance, lowering DNA damage, and inducing higher repair activity in human volunteers who participated in a study conducted in France, Italy, Netherlands, and Spain (Southon, 2000). In another study, adding antioxidant (vitamins A, C and E) dietary supplements into the diet of cancer treatment patients, who were eating a balanced diet of fruits and vegetables, negatively impacted their radio- and chemotherapies (Seifried et al, 2003). High consumption of tomatoes and tomato products has been linked to reduced carcinogenesis, particularly prostate cancer, and has been thought to be due to the presence of lycopene, which gives red tomatoes their color (Giovannucci, 2002). However, use of tomato powder effectively reduced prostate carcinogenesis in rats, while lycopene supplements, considered the primary active ingredient of tomatoes, had no effect (Boileau et al., 2003). Similar comparative studies are needed on other constituents of fruits and vegetables and on the bioavailability of nutrients taken as dietary supplements or as foods that contain these nutrients.

Examples of the phytochemicals in fruits and vegetables that have established or proposed positive effects on human health and their important sources are shown in Tables 1 and 2. Some changes in these tables are likely as the results of additional studies on effects of phytochemicals

and their bioavailability on human health become available in the next few years. Meanwhile it is important to evaluate the validity and dependability of the results of every study before reaching conclusions for the benefit of consumers.

Table 1. Nutritive constituents of fruits and vegetables that have a positive impact on human health and their sources

Constituent	Sources	Established or proposed effects on human-wellness
Vitamin C (ascorbic acid)	broccoli, cabbage, cantaloupe, citrus fruits, guava, kiwifruit, leafy greens, pepper, pineapple, potato, strawberry, tomato, watermelon	prevents scurvy, aids wound healing, healthy immune- system, cardiovascular-disease
Vitamin A (carotenoids)	dark-green vegetables (such as collards, spinach, and turnip greens), orange vegetables (such as carrots, pumpkin, and sweet potato), orange-flesh fruits (such as apricot, cantaloupe, mango, nectarine, orange, papaya, peach, persimmon, and pineapple), tomato	night blindness prevention, chronic fatigue, psoriasis, heart disease, stroke, cataracts
Vitamin K	nuts, lentils, green onions, crucifers (cabbage, broccoli, brussel sprouts), leafy greens	synthesis of pro-coagulant factors, osteoporosis
Vitamin E (tocopherols)	nuts (such as almonds, cashew nuts, filberts, macadamias, pecans, pistachios, peanuts, and walnuts), corn, dry beans, lentils and chickpeas, dark-green leafy vegetables	heart-disease, LDL-oxidation, immune-system, diabetes, cancer
Fiber	most fresh fruits and vegetables, nuts, cooked dry beans and peas	diabetes, heart disease
Folate (folicin or folic acid)	dark-green leafy vegetables (such as spinach, mustard greens, butterhead lettuce, broccoli, brussels sprouts, and okra), legumes (cooked dry beans, lentils, chickpeas and green peas), asparagus	birth defects, cancer heart disease, nervous system
Calcium	cooked vegetables (such as beans, greens, okra and tomatoes) peas, papaya, raisins, orange, almonds, snap beans, pumpkin, cauliflower, rutabaga	osteoporosis, muscular/ skeletal, teeth, blood pressure
Magnesium	spinach, lentils, okra, potato, banana, nuts, corn, cashews	osteoporosis, nervous system, teeth, immune system
Potassium	baked potato or sweet potato, banana & plantain, cooked dry beans, cooked greens, dried fruits (such as apricots and prunes), winter (orange) squash, and cantaloupe	hypertension (blood pressure) stroke arteriosclerosis

Table 2. Non-nutritive plant constituents that may be beneficial to human health

Constituent	Compound	Sources	Established or proposed effects on human-wellness
Phenolic compounds			
Proanthocyanins	tannins	apple, grape, cranberry, pomegranate	cancer
Anthocyanidins	cyanidin, malvidin, delphinidin, pelargonidin, peonidin, petunidin	red, blue, and purple fruits (such as apple, blackberry, blueberry, cranberry, grape, nectarine, peach, plum & prune, pomegranate, raspberry, and strawberry)	heart disease, cancer initiation, diabetes, cataracts, blood pressure, allergies
Flavan-3-ols	epicatechin, epigallocatechin catechin, gallocatechin	apples, apricots, blackberries, plums, raspberries, strawberries	platelet aggregation, cancer,
Flavanones	hesperetin, naringenin, eriodictyol	citrus (oranges, grapefruit, lemons, limes, tangerine)	cancer
Flavones	Luteolin, apigenin	celeriac, celery, peppers, rutabaga, spinach, parsley, artichoke, guava, pepper	cancer, allergies, heart disease
Flavonols	quercetin, kaempferol, myricetin, rutin	onions, snap beans, broccoli, cranberry, kale, peppers, lettuce	heart disease, cancer initiation, capillary protectant
Phenolic acids	Caffeic acid, chlorogenic acid, coumaric acid, ellagic acid	blackberry, raspberry, strawberry, apple, peach, plum, cherry	cancer, cholesterol
Carotenoids			
Lycopene		tomato, watermelon, papaya, Brazilian guava, Autumn olive, red grapefruit	cancer, heart disease, male infertility
α-carotene		sweet potatoes, apricots, pumpkin, cantaloupe, green beans, lima beans, broccoli, brussel sprouts, cabbage, kale, kiwifruit, lettuce, peas, spinach, prunes, peaches, mango, papaya, squash and carrots	tumor growth

β-carotene		cantaloupes, carrots, apricots, broccoli, leafy greens (lettuce, swiss chard), mango, persimmon, red pepper, spinach, sweet potato	cancer
Xanthophylls	Lutein, zeaxanthin, β-cryptoxanthin	sweet corn, spinach, corn, okra, cantaloupe, summer squash, turnip greens	macular degeneration
Monoterpenes	limonene	citrus (grapefruit, tangerine)	cancer
Sulfur compounds	glucosinolates, isothiocyanates, indoles, allicin, diallyl isulphide	broccoli, Brussels sprouts, mustard greens, horseradish, garlic, onions, chives, leeks	cancer, cholesterol, blood pressure, diabetes

References

Boileau, T.W., Z. Liao, S. Kim, S. Lemeshow, J.W. Erdman and S.K. Clinton. 2003. Prostate carcinogenesis in N-methyl-N-nitrosourea (NMU)-testosterone-treated rats fed tomato powder, lycopene, or energy-restricted diets. J. Natl. Cancer Inst. 95:1578-86.

Craig, W. and L. Beck. 1999. Phytochemicals: health protective effects. Can. J. Diet. Pract. Res. 60:78-84.

Giovannucci, E. 2002. A review of epidemiologic studies of tomatoes, lycopene, and prostate cancer. Exp. Biol. Med. (Maywood) 227:852-9.

Goldberg, G. (ed). 2003. Plants: Diet and Health. The report of a British Nutrition Foundation Task Force. Blackwell Science, Oxford U.K., 347 pp.

Goldman, I.L., A.A. Kader and C. Heintz. 1999. Influence of production, handling, and storage on phytonutrient content of foods. Nutr. Rev. 57:S46-S52.

Gross, J. 1991. Pigments in vegetables: Chlorophylls and carotenoids. AVI Book, Van Nostrand Reinold Pub. New York NY.

Hyson, D. 2002. The health benefits of fruits and vegetables. A scientific overview for health professionals. Produce for Better Health Foundation, Wilmington DE, 20 pp.

Kalt, W. 2002. Health functional phytochemicals of fruits. Hort. Rev. 27:269-315.

Lee, S.K. and A.A. Kader. 2000. Preharvest and postharvest factors influencing vitamin C content of horticultural crops. Postharv. Biol. Technol. 20:207-220.

Mozafar. A. 1994. Plant vitamins: Agronomic, physiological and nutritional aspects. CRC Press, Boca Raton FL.

Perkins-Veazie, P. and J.K. Collins. 2001. Contribution of nonvolatile phytochemicals to nutrition and flavor. HortTechnology 11:539-546.

Prior, R.L. and G. Cao. 2000. Antioxidant phytochemicals in fruits and vegetables; diet and health implications. HortScience 35:588-592.

Produce for Better Health Foundation. 1999. Dietary guidelines: the case for fruits and vegetables first. Produce for Better Health Foundation, Wilmington DE (http://www.5aday.org).

Quebedeaux, B. and F.A. Bliss. 1988. Horticulture and human health. Contributions of fruits and vegetables. Proc. 1st Intl. Symp. Hort. and Human Health. Prentice Hall, Englewood NJ.
Quebedeaux, B. and H.M. Eisa. 1990. Horticulture and human health. Contributions of fruits and vegetables. Proc. 2nd Intl. symp. Hort. and Human Health. HortScience 25:1473-1532.
Seifried, H.E., S.S. McDonald, D.E. Anderson, P. Greenwald and J.A. Milner. 2003. The antioxidant conundrum in cancer. Cancer Res. 63:4295-4298.
Southon, S. 2000. Increased fruit and vegetable consumption within the EU: potential health benefits. Food Res. Intl. 33:211-217.
Tomas-Barberan, F.A. and J.C. Espin. 2001. Phenolic compounds and related enzymes as determinants of quality in fruits and vegetables. J. Sci. Food Agric. 81:853-876.
USDA. 2000. Nutrition and your health: dietary guidelines for Americans. Home and Garden Bull. 232, USDA, Washington D.C. (www.usda.gov/cnpp).
Wargovich, M.J. 2000. Anticancer properties of fruits and vegetables. HortScience 35:573-575.