Health Research & Studies Center

Health Benefits of Sun-Dried Raisins

Review of the Scientific Literature
through July 2008

Health Benefits of Sun-Dried Raisins

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Summary of Sun-Dried Raisin Components of Physiologic Interest

Component	Bioactive Classification	Potential Benefit[†]
Boron	Mineral	• Supports growth of healthy bones • Maintains healthy bones and joints
Fiber, including Pectin	Non-digestible carbohydrate	• Colon cancer protection • Cholesterol lowering • Protection from cardiovascular disease • Support of colon health and function
Pectin	Non-digestible carbohydrate	• Cholesterol lowering
Fructans	Prebiotic	• Stimulation of health-promoting colonic microflora • Support of colon health • Stimulation of calcium and magnesium absorption • Colon cancer protection
Tartaric acid		• Support of colonic health and function • Enhance mineral absorption
Flavonols **(e.g. quercetin and kaempferol)**	Flavonoids (Polyphenols)	• Antioxidants, protection from oxidative stress • Cardiovascular disease protection • Cancer protection • Anti-inflammatory • Protection from age-related neurological degeneration

[†] In many cases, research is still in preliminary stages.

Hydroxycinnamic acids and derivatives **(e.g. caftaric and coutaric acids)**	Phenolic acids	• Antioxidants, protection from oxidative stress • Cancer protection • Anti-inflammatory
Isoflavones: **Daidzein and genistein**	Phytoestrogens (Polyphenols)	• Antioxidants, protection from oxidative stress • Cancer protection (breast, prostate, colon) • Cardiovascular disease protection • Osteoporosis protection • Alleviate menopausal symptoms
Betulin, oleanolic and betulinic acids	Triterpenes	• Anti-cavity, gum disease protection

I. Introduction

Raisins are naturally endowed with both an array of valuable nutrients and a pleasantly sweet flavor. Raisins as part of the daily diet provide essential nutrients, soluble and insoluble fiber and health protective bioactive compounds, or phytochemicals. This combination of nutritional bounty and enjoyable taste is the reason raisins have been popularly considered a healthy food for millennia. Raisins' natural resistance to spoilage and ease of storage and transport only serve to strengthen their appeal and widespread consumption.

The relationship between diet and health has been recognized since ancient times. Until as recently as the early 20th century, physicians prescribed specific foods and diets as remedies for illness and for their disease preventive value. Over the last 30 years food and nutrition research has focused on the role of certain foods and diets in lowering the risk of degenerative and chronic disease, and nutritionists have broadened their understanding of what makes up an optimal diet: one that does more than simply just provide sufficient nutrients to sustain growth and reproduction, but also promotes health and longevity and lowers disease risk. While the composition of an adequate diet is widely known and agreed upon, that of an optimal diet remains elusive.

Recent research suggests that diets largely based on plant foods, such as the Mediterranean diet, may be the best model to follow. Epidemiological studies have shown a consistent, inverse relationship between a diet rich in fruit and vegetables and a lower risk for many chronic diseases including cancer,[1,2,3] heart disease[4,5] and stroke.[6] Researchers are also investigating the beneficial role of fruits and vegetables in inflammatory diseases[7] such as arthritis; in lowering the incidence of obesity and controlling diabetes;[8,9] and in age-associated neurological problems such as Alzheimer's and Parkinson's Disease.[10,11] Fruits and vegetables also appear to have a role in the prevention of cataracts and macular degeneration,[12] and may also protect from osteoporosis.[13] Finally, they may enhance the immune system and potentially modulate certain aspects of immune function. The protective effect of an abundance of fruits and vegetables in the diet is long lasting. Higher intake of fruits[14] and vegetables[15] during childhood is associated with a lower incidence of cancer and stroke, respectively, during adulthood.

The strength of the association between fruit and vegetable consumption and health has led organizations around the world to recommend that populations increase their daily fruit and vegetable intake. In the United States, dietary guidelines issued since 1977 by health agencies have vigorously endorsed and promoted this message.[16] In 1982, the National Academy of Sciences published a report on diet and cancer that emphasized the importance of fruits and vegetables in the diet.[17] In 1989, they expanded their message in another report**, *Diet and Health***, which promoted the consumption of at least 5 servings of fruits and vegetables per day in order to reduce risk of both cancer and heart disease.[18] In 1991, the National Cancer Institute started the national "5 A Day for Better Health" program (Produce for Better Health, PBH), which called for 5 or more daily servings of fruits and vegetables. In 2003, the recommendations were expanded to encourage people to eat from 5 to 9 servings a day: "Eat 5 to 9 A Day for Better Health".[19] The most recent Dietary Guidelines for Americans, published by the United States Department of Agriculture (USDA) in 2005, recommends that adults eat 7 to 13 servings, according to their caloric expenditure, and children eat 4 to 10, depending on their age.[20] This has prompted the new message: "Fruits & Veggies – More Matters," beginning in early 2007.[21]

Despite these campaigns and educational efforts, Americans' fruit and vegetable consumption has not increased during the past two decades.[22] A significant gap still remains between the amount of fruits and vegetables recommended by the USDA and PBH campaigns and the quantities Americans actually eat. Looking at fruit intake specifically, in the period from 1988 to 1994 only an estimated 27% of adults met the USDA guidelines of two servings or more.[23] From 1999 to 2002, only 28% of adults met these guidelines. During the past 15 years, reports put the mean fruit daily intake at 1.8,[24] 1.4[25] and 1.2[26] servings (including fruit juices) for 4 to 5 year olds, 11 to 18 year olds and adults, respectively. Clearly, American eating patterns have yet to reflect an appreciation for the benefits of a diet rich in fruits.

Fruits and vegetables are not only important sources of vitamins, minerals and fiber in the diet but also provide a wide array of bioactive components or phytochemicals. These plant compounds are not designated as traditional nutrients since they are not essential to sustain life, but play a role in health and longevity and have been linked to a reduction in the risk of major chronic diseases. It is estimated that more than 5,000 individual phytochemicals have been identified but a large percentage still remain unknown. Convincing evidence suggests that the benefits of phytochemicals in fruits and vegetables may be even greater than is currently understood, since they affect metabolic pathways and cellular reactions believed to be involved in the etiology of a wide range of chronic diseases. However, the precise mechanisms by which specific compounds exert their observed biological effects remain largely hypothetical and are thus still the subject of intense investigation.

Raisins should be of particular interest in these investigations due to their unique phytochemical composition and the natural qualities that make raisins an appealing source of nutrients. Raisins, like other fruits, are devoid of fat, saturated fat and cholesterol. They provide both soluble and insoluble fiber at levels that represent a meaningful contribution to daily fiber intake and at levels that benefit cardiovascular health. They are a source of fructooligasaccharides (fructans), which act as prebiotics, contributing to colonic health, and are a major dietary source of tartaric acid, a fruit acid that is fermented by colonic bacteria and has been shown to have a beneficial role in intestinal function. In the American diet, raisins are also among the richest sources of boron, a recognized essential trace element that may have an important role in bone health.

It is in their phenolic content, however, where raisins may prove to have the most important health effect. Raisins are rich in phenolic compounds: flavonoids and phenolic acids. Flavonoids are not only potent antioxidants but also have a multitude of functional capabilities, which may have an effect on health. Raisins provide the flavonoids quercetin, kaempferol and rutin, and are among the richest fruit sources of the isoflavones daidzein and genistein. Raisins are also a good dietary source of the phenolic acids caftaric and coutaric

acids. By virtue of their antioxidant activity, these raisin constituents may lower oxidative stress in humans and thereby lower risk of chronic disease.

Raisins are a fruit rich in cultural and nutritional value that may offer a convenient step toward healthier eating and a means to bridge the gap between recommended intake of fruits and the amount Americans actually consume. The raisin's unique flavor and nutritional qualities are reaffirmed by its prevalence throughout human history. Wherever viticulture flourished, it seems, raisins soon followed, and they eventually became popular in countless cultures and societies around the world. Even in areas where the climate did not support the sun-drying process, raisins were imported and included in local cuisines.

II. Etymology

The term "raisin" dates back to its use in Middle English, having been borrowed from Old French. In French, the word ***raisin*** actually refers to fresh grapes, whereas ***raisin sec***, literally translating to "dry grape," refers to the raisin. The French word itself comes from the Latin term ***racemus***, meaning "a bunch of grapes."[27]

III. Why Raisins

Since ancient times, raisins have been valued as a form of preserving grapes so they would last through the winter months and could be more easily stored and transported.[28] Grapes were considered to be a nutritious and healthful food and raisins a good source of energy because of their high sugar content. Sun drying was seen as a natural way to produce raisins that not only gave them a particular intense flavor, but also maintained the delicate balance of nutrients of the original fruit. Some saw this age-old process as an extension of the natural ripening cycle of the grape. Indeed, it is almost certain that raisins and grapes occurred naturally before men intended to cultivate them.

IV. Raisins in World History

The consumption of grapes and raisins, in particular, dates back to prehistoric times. Wild grapes existed as far back as 35,000,000 BC, when the species ***Vitis sezonnensis*** was known to grow in what is now southern France.[29] Hunter-gatherers likely recognized the healthful qualities of wild grapes and may have noticed that grapes took on an edible dried form after having fallen off the vine and lain in the sun.[30] Following this natural example, grapes were probably dried for storage and travel in the Neolithic period, leading to the early production of raisins.[30] There is evidence of early use of raisins as food and decorations, from prehistoric murals in the Mediterranean region to Bronze-Age archaeological finds at Lachish in Israel.[31]

Grape cultivation first began in Armenia and the eastern regions of the Mediterranean, including ancient Phoenicia and Persia. Grapes were also important in Anatolia, where the Hittites regularly offered them to the gods.[32] In the near east, raisins were sometimes made by burying grapes in the desert sands. Viticulture soon spread to the Tigris-Euphrates region of North Africa, where raisins were made as early as the fourth millennium BC, owing to ideal environments and the already established tradition of drying fruits.[33] Grapes and raisins spread next to the Far East and the rest of North Africa, such as Morocco and Tunisia. The early Phoenicians and Egyptians, however, were eventually the ones to popularize the production and use of raisins and spread them throughout the western world, where they were valued for easy storage and transport.

In the European regions along the Mediterranean, the transition to increased production of raisins was particularly easy because of the preexisting tradition of viticulture and the existence of countless vineyards.[29] Sun drying had already become a custom there, making raisins and other preserved fruits easy to store and grind after harvest. Raisins were seen as a key source of nutrition that complemented the grains, beans, and cultured milks forming the foundation of the Mediterranean diet when Roman and Greek civilizations were at their peak. In fact, Ancient Greece and Rome represented the first major markets for raisins.[34] The cultivation of grapes in

Corinth in 500 BC later led to the naming of an early raisin variety as “currants,” deriving from “raisins of Corinth” and “black Corinth.”[29]

Ancient Romans ate raisins in spectacular quantities and all strata of society, included them as a major part of common meals, along with olives and bread. They picked the sweetest and plumpest grapes to dry, and featured them as a key part of the menu at Bacchanalian celebrations. Roman doctors also promoted the medicinal properties of raisins, prescribing them as a cure for a wide variety of ailments. Raisins were so valued that they transcended the food realm and became rewards for successful athletes as well as a premium barter currency. With the help of Roman legionnaires, vineyards and their products spanned the reaches of the empire, and remained a vital crop throughout Europe long after its fall.[29]

The history of raisins becomes a bit hazy until their reappearance in the 12th century AD. For the next 200 years of the Crusades, increased trade and movement between Europe and the East reinforced the popularity of the raisin, which was especially valued by traveling soldiers and adventurers.[29] This became especially important with the coming of the Age of Exploration. Spain in particular began to export raisins during the late 13th century. Soon afterwards, raisins became a popular luxury food in 14th century England. During the reign of Queen Elizabeth I, currants were used as a form of currency. Raisins later held an integral role in international markets as part of the "Triangular trade" in the 1700s between Europe, Africa and the Americas. Modern Europeans continued to value raisins as durable sources of energy and nutrients. In the two World Wars, raisins were seen as an ideal food for soldiers, and also helped to enliven “war cakes” and breads during times when eggs and sugar were in short supply.[29]

V. Raisins in California History

California is today’s largest and most important sun-dried raisin provider, and has a history in raisin production originating with the state’s own colonization. In the early 1500s missionaries sponsored by Queen Isabella established an important grape industry in Mexico near the American border. By the late 18th century, the missionaries had become experts at viticulture as well as the production of Muscat raisins. When they began to travel northward to build missions and settlements in California, missionaries such as Father Serra brought their agricultural techniques with them. The result was a tradition of grape and raisin production throughout California that was all the more ready to expand and develop when the US later developed a taste for the dried fruit.[29 32 35]

The California raisin industry in the San Joaquin Valley began to experience rapid growth in the 1870s and 1880s. In 1877, one of the first plantings was harvested in Fresno County (now the largest growing region in the US). The raisins were sold in San Francisco as an exotic food – quickly gaining popularity. The early agricultural centers for raisins were in Southern California and areas near Sacramento, but soon migrated to the warm, dry and fertile Fresno area. From there, raisins were sold and shipped throughout the US and later overseas. The industry grew rapidly due to the convenience of its location, as well as the fact that raisins were an alternative raw material for wine when fresh grapes were unavailable. During Prohibition, the opposite occurred when wine grape farmers produced raisins from their otherwise unusable crops. While the Muscat grape started as the predominant raisin grape variety, the Thompson Seedless soon became the preferred variety due to its seedless attributes.[36]

VI. Raisin Production

Most of today's raisins – approximately 95% – are dried 'Thompson Seedless' grapes, ***Vitis vinifera L.*** This variety is followed by the 'Fiesta' (3%), and the 'Zante Currant' (1.5%). The term 'currant' is used to describe its small berry size, but it is a true grape and not a member of the ***Ribes*** species.[37] The terms "sultanas" and "raisins" are used inconsistently and sometimes interchangeably, from country to country. Outside the US, some make a distinction between these terms, generally using the former to refer to the naturally sun-dried Californian product and the latter to raisins that have been dried after treatment in various dipping solutions.

There are two methods for drying grapes to produce raisins. One involves natural sun drying for a period of 2 to 3 weeks, either in trays on the ground between the vines or hanging on the vines themselves. Another involves a short (15 to 20 seconds) exposure to hot water (87 to 93^{o}C) and then placement in a dehydration tunnel (71^{o}C) for 20 to 24 hours.

Raisins acquire their dark brown coloring from an accumulation of brown-black melanin pigments produced by polyphenol oxidase activity and non-enzymatic reactions. Golden raisins are Thompson Seedless grapes that have been dipped in hot water and treated with sulfur dioxide to prevent these darkening reactions.

Today, worldwide production of raisins and sultanas alone exceeds 1 million tons. Dried fruit is produced in most geographic regions of the world, and consumption occurs in all cultures and demographic segments. The US is the world's leading raisin producer. California accounts for over 90% of the total US grape production, using almost 3 million tons of grapes to produce approximately 400,000 tons of raisins per year.[37]

VII. Nutrient Composition:

i. Carbohydrates, vitamins and minerals

Raisins, like most fruits, possess a combination of an appealing, sweet taste and nutritional value. Raisins provide essential nutrients, soluble and insoluble fiber, and health protective bioactive components, or phytochemicals. Table 1 shows selected nutrient compositions of raisins and of Thompson Seedless grapes as a reference.[38] ***Both raisins and grapes provide similar amounts of sugar (19.6g and 21.4g, respectively), divided almost equally between fructose and glucose with minimal amounts of sucrose. Raisins, like all fruits, are high in potassium and low in sodium. Compared to other fruits, they are high in magnesium and iron.***

Table 1. Selected Essential Nutrients in Grapes and Seedless Raisins[38] [*]

Nutrient	Units	Values per Serving Seedless Raisins (32.5g)	Values per Serving Thompson Seedless Grapes (135g)
Water	g	5	108.6
Energy	kcal	97.5	93
Carbohydrate	g	25.7	24.6
Sugars (total)	g	19.6	21.4
Glucose	g	9	9.8
Fructose	g	9.7	10.9
Sucrose	g	0.14	0.2
Iron	mg	0.6	0.48
Magnesium	mg	10.6	9.6
Potassium	mg	243	258

ii. Boron

Raisins are among the 50 major food contributors of boron in the American diet, having the highest concentration of boron at 2.2mg per 100g.[39] Boron, a putative essential trace element[†] is crucial for the growth and maintenance of healthy bones and joints.[40] [41]

[*] The serving sizes used in Table 1 reflect a 4.15 to 1.00 dry away ratio commonly observed when Thompson Seedless grapes are dried into raisins.

Controlled animal studies have shown that boron is essential for normal growth of both bone and cartilage and appears to have a role in the maturation of the bone growth plate. [42] Boron supplementation in rats and chicks has been shown to increase bone strength. [43] Boron deprivation, on the other hand, affects the skeletal system, the effect being most evident when the animals are simultaneously exposed to a nutritional stress, such as a deficiency in vitamin D, calcium, magnesium or potassium. Boron thus appears to positively affect vitamin D, calcium and magnesium metabolism. Boron deficiency has been reported in studies of rats and chickens and in three human clinical studies.[44]

Boron may also have a preventive or therapeutic effect on osteoporosis by reducing bone calcium loss in postmenopausal women. Controlled boron deprivation studies indicate that boron has an essential role in maintaining bone density. In clinical studies including both men and women, boron supplementation after consumption of a low-boron diet increased previously suppressed 25-hydroxycholecalcipherol (vitamin D) levels. Supplementation of a low-boron diet with an amount of boron commonly found in diets high in fruits and vegetables induced changes in postmenopausal women consistent with the prevention of calcium loss and bone demineralization.[45] In one study, estrogen therapy increased serum 17-beta-estradiol in postmenopausal women but not if they were fed low-boron diets. Although a mechanism that explains how boron affects bone formation and remodeling has yet to be defined, it appears that dietary boron may be required to convert estrogen and vitamin D to their more active form (17-beta-estradiol and 1,25-OH2D3, respectively). Recent animal studies support this hypothesis as results indicate that boron works synergistically with estrogen to exert its beneficial role on calcium and magnesium homeostasis. Investigators believe that ***boron may be an important nutritional factor determining the incidence of osteoporosis.***

[†] Two expert scientific committees have reviewed literature on the significance of boron in human nutrition. A World Health Organization Expert Committee on *Trace Elements. In: Human Nutrition* has concluded that boron is "probably essential." Additionally, a workshop on recommended intakes for trace elements sponsored by the USDA proposed that a provisional Recommended Dietary Allowance should be established for the mineral.

***Boron may also play a role in preventing arthritis*.**[46] People suffering from osteoarthritis have been shown to have lower boron concentrations in femur heads, bones and synovial fluid than those without the disorder. In areas of the world where boron intake is usually 1mg or less per day, the estimated incidence of arthritis ranges from 20 to 70%, whereas in areas where boron intake is usually 3 to 10mg, the estimated incidence of arthritis ranges from 0 to 10%. In Australia, where much of the produce is grown in boron-deficient soil, there is a high occurrence of osteoarthritis, and boron supplements have been widely considered an effective treatment.[47] Experimental evidence suggests that boron is also involved in the inflammatory process, or immune function. When an antigen was injected in rats to induce arthritis, those given boron supplements exhibited less swelling of the paws and lower circulating neutrophil concentrations than did those deficient in boron.[48]

In conclusion, raisins are rich in boron, a mineral which is important for bone growth and maintenance. Boron in raisins may protect against osteoporosis by preventing bone loss and may have a role in preventing arthritis.

iii. Fiber

High fiber diets have been promoted to help reduce the risk of developing various conditions, including constipation, heart disease, diabetes, diverticular disease, colon cancer and obesity. The Institute of Medicine and the Dietary Guidelines for Americans 2005 recommends that children (ages 1 and up) and adults consume 14g of fiber for every 1,000 calories of food they eat each day.[49][50] However, most Americans consume far less fiber than the recommended amount. Dietary fiber intake among adults in the US averages about 15g. Raisins are a good source of soluble and insoluble fiber and help meet dietary fiber recommendations.

The total dietary fiber content of raisins is 3.7g/100g, according to the USDA Nutrient Database.[38] However, ***other investigators have reported higher fiber levels for sun-dried,***

dipped and golden raisins: 5.05g 100g, 5.37g/100g and 5.05g/100g, respectively (Table 2).[51] Soluble fiber accounts for about 30% of total fiber, golden raisins having slightly higher values. Mannose is the predominant sugar in the soluble fiber. Insoluble fiber contains slightly more glucose than mannose residues. Pectin (measured as uronic acids) accounts for over 50% of total fiber. Lignin levels are low in all types of raisins.

It is important to be aware that raisins provide over 5g of fructans per 100g (Figure 1). Fructans, also known as fructooligosaccharides (FOS), are fructosyl units bound by a beta (2-1)-glycosidic linkage. They are formed from the sugars in the grapes during the dehydration process. Fresh grapes themselves have no detectable fructans.[51] Both the American Association of Cereal Chemists and the Food and Nutrition Board definitions include fructans as components of dietary fiber. Yet, compounds in this group, which includes inulin, are soluble in aqueous ethanol and thus are not recovered in the Association of Official Analytical Chemists dietary fiber methods. ***Adding fructans to total fiber values of raisins nearly doubles their fiber content, suggesting that raisins can provide more fiber in the diet than was previously believed.***

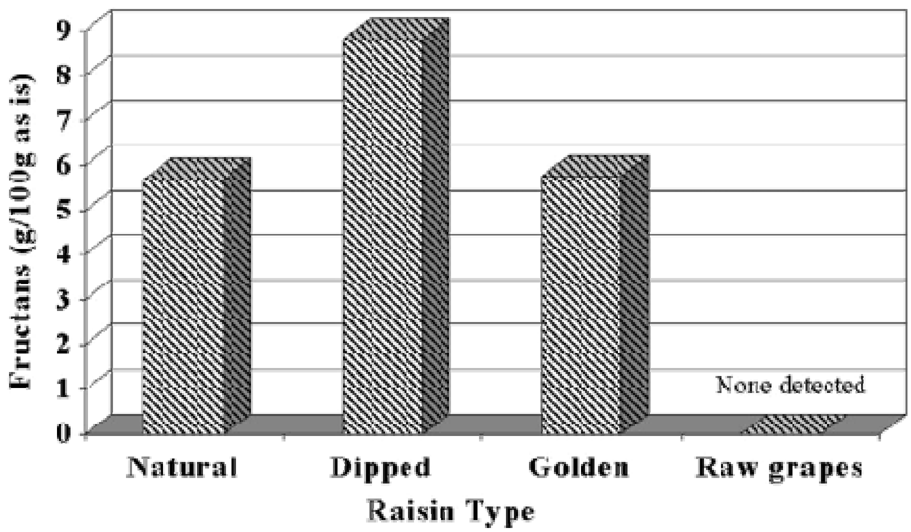
Table 2. Raisin Dietary Fiber Composition (grams per 100g)[a] [51]

Raisin type	Soluble fiber			Insoluble fiber				total fiber
	uronic acids	Neutral PS[b]	total	uronic acids	Neutral PS	lignin	total	
Sun-dried	0.74	0.68	1.42	2.06	1.56	0.01	3.63	5.05
Golden	0.88	0.64	1.52	2.23	1.61	0.01	3.85	5.37
Dipped	1.07	0.69	1.76	1.67	1.62	nd	3.29	5.05

[a] Average of 3 determinations, AACC method 32-25 [b] Polysaccharide residues

Studies have reported that dietary patterns, lifestyle exposure patterns, physical inactivity and obesity all increase colorectal cancer risk, especially in genetically predisposed populations. One element in the diet that has been strongly associated with protection from colorectal cancer is fiber.[52] [53] [54] The mechanisms for the beneficial effect of fiber in humans are still being elucidated and seem to be manifold. The presence of fiber in the diet decreases stool transit time, and so may hasten the elimination of carcinogens.[55] The addition of 120g of raisins (3 servings) to a daily diet shortened transit time by 14 hours.[56] Another mechanism involves the fermentation of fiber by colonic bacteria to produce short-chain fatty acids (SCFA). These acids are beneficial substrates for colonic epithelial cells and have a positive impact on the cells' resilience. *In vitro* studies using colon cancer cell lines have shown that butyrate may be potentially chemo protective by inhibiting cell proliferation, stimulating cell differentiation, and inducing apoptosis. [57] [58] Fibers that promote a butyrate-producing colonic ecosystem would thus have a protective effect against the developing of colorectal cancer. A study by Beyer-Sehlmeyer *et al*[59] showed that the effects of butyrate are enhanced *in vivo* by the mixture of products derived from the fermentation of fibers in the colon.

Figure 1. Fructan Content of Raisins and Grapes[51]



The increased concentration of acids in the colon would also inhibit the conversion of primary bile salts (cholic acid and chenodeoxycolic acid) to secondary bile acids (deoxycholic and lithocholic acids). A number of studies have shown that colorectal cancer patients have a higher level of secondary bile acids both entering and leaving the colon. Inclusion of raisins in the diet reduced the ratio of secondary to primary bile acid salts in the stools.[60] Thus, the acidic environment might be protective against the development of colon cancer.

In conclusion, raisins are a high fiber food. Even a single serving of raisins provides a significant amount of fiber in a daily diet and can have beneficial effects on colon health. Adding fiber from high fiber foods such as raisins is preferable to using isolated fiber supplements because raisins deliver additional nutrients and phytochemicals that may also help to lower disease risks in other ways.

VIII. Phytochemicals and Other Raisin Components of Physiologic Interest:

i. Prebiotics, Raisins and Health

Raisins, unlike grapes, are a significant source of prebiotic compounds in the American diet. An important effect of increasing fiber in the diet is its impact on the intestinal microflora. The growth of bacteria in the colon depends on the substrates that are available to them, i.e. compounds that have not been digested in the small intestine. ***A prebiotic has been recently defined as "a non-digestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon."***[61] ***Sun-dried raisins contain 5.7g fructans per 100g of fruit***,[51] ***higher than all commonly consumed fruits.***[62] Fructans escape digestion in the upper g.i. tract and reach the large intestine practically intact. Here they are fermented by bacteria that can cleave the beta (2-1)-glycosidic bonds between fructosyl units and act as prebiotic compounds by selectively stimulating the growth of beneficial intestinal microflora, namely bifidobacteria and lactobacilli. Clinical studies have shown that when taken in the diet, even at relatively low levels (5-20g/day), fructans increase manifold the numbers of these bacteria in the colon mucosa.[63]

A balanced microbiota in the intestinal track is essential for health and well being. Prebiotics, such as fructans, help keep this balance by selectively stimulating the growth of health-promoting bacteria. The products of colonic fructan fermentation are lactic acid and short-chain fatty acids (SCFA), mainly acetate, propionate and butyrate, which play a significant role not only in colonic health but also the well being of the entire organism. ***The production and presence of SCFA and lactate in the colon alter the surroundings, creating a bacteriocidal environment for enteropathogens such as Escherichia coli and Clostridium perfringes. Including 120g of sun-dried raisins for 9 weeks in the diet of healthy adults increased total SCFA excretion.***[60]

Prebiotics in raisins may play a role in colorectal cancer protection. Research using experimental animal models indicates that fructans have anticarcinogenic properties. For example, in rats, dietary fructans inhibit the formation of chemically-induced aberrant crypt foci. These are neoplastic lesions in the colon from which adenomas and carcinoma may develop.[64] [65] [66] The growth of bifidobacteria, have been shown to modify ras ocogene activity. Ras-gene activation is one of the earliest and most frequent genetic alterations associated with human cancers, specifically with colon cancer. Elevated levels of ras-p21 (the ras gene product) have been correlated with increased cell proliferation. Studies in rats have shown that ***Bifidobacteria longum*** can significantly suppress the expression of ras-p21 in the colonic mucosa and reduce tumor incidence.[66] In studies using human cell lines, fructan fermentation products have been shown to inhibit tumor cell growth, modulate differentiation and reduce metastatic activities.[59]

Prebiotics in raisins may offer cardiovascular benefits through a triglyceride- and cholesterol-lowering effect. A recent meta-analysis of 16 clinical studies[67] showed that dietary fructans significantly reduce serum triglycerides. The mechanism for this effect is still not clear, but it appears that fructans, like other soluble dietary fibers, reduce the capacity of hepatocytes to synthesize triglycerides from palmitate[68] and so lower net hepatic triglyceride synthesis. Given that fructans are not absorbed, how this effect is mediated is still a matter of speculation. One possible mechanism involves its fermentation products: an increased production of SCFA in the large intestine, particularly of propionic acid. This fatty acid has been shown to inhibit lipogenesis in isolated hepatocytes.[69] Other mechanisms involve modification of intestinal synthesis of cytokines and incretins, which enhance postprandial insulin secretion and so affect hepatic lipogenesis.

Studies on the cholesterol-lowering effect of fructans are not consistent, but encouraging results have been observed among hyperlipidemic subjects. Fructans, like fiber, may bind bile acids and increase their excretion in the feces. A continual depletion of bile in this manner may lower serum cholesterol levels by diverting cholesterol for bile acid synthesis. It is also possible that propionic acid, which increases with fructan colonic fermentation, inhibits hepatic cholesterol synthesis.[69]

Prebiotics in raisins may stimulate calcium and magnesium absorption and so increase bone mineral content, bone density and maintain bone structure. Both animal and human studies have shown that non-digestible oligosaccharides can enhance mineral absorption, calcium retention and bone mineralization. In humans, the most convincing data comes from studies in young adolescents[70] and postmenopausal women.[71] The proposed mechanisms are manifold and include: increased solubility of minerals due to higher levels of SCFA generated by intestinal bacteria; increased surface area for mineral absorption via enhanced proliferation of enterocytes by fermentation products (lactate and butyrate); and increased expression of calcium-binding proteins in the large intestine.[72 73 74] Other methods by which fructans may increase mineral absorption include: modulating expression of bone-relevant cytokines; degradation of mineral-complexing phytic acid; increasing bioavailability of bone-modulating factors such as phytoestrogens from foods; and improving overall intestinal health. These hypotheses have the experimental support of animal studies and continue to evolve.[73]

In conclusion, fructooligosaccharides (fructans), formed from grape sugars during dehydration, give raisins a unique set of health benefits. Not only do they increase dietary fiber content and help regulate bowel functions, but acting as prebiotic agents, they stimulate health-promoting intestinal flora, maintain intestinal balance, may contribute to cardiovascular health, may protect from colon cancer, may increase absorption of calcium and magnesium and so enhance bone mineralization during growth and protect from osteoporosis after menopause. Humans have shown beneficial effects of fructans at doses as low as 7g per day. A single serving of raisins provides about a third of this amount.

ii. Tartaric Acid

Sun-dried raisins have beneficial effects on colonic function that go beyond those due to their fiber content alone. Grapes and raisins are the only fruits that contain significant levels of tartaric acid (TA) in temperate regions of the world. Because of its low solubility in water, some of the TA in grapes is lost during processing of grape juice and wine, and so ***grapes and raisins remain the most practical sources of tartaric acid in the American diet***. Grapes contain 0.6-0.9g/100g of TA and raisins contain 2.0-3.5g/100g of TA.[56] Studies on tartaric acid have shown that its presence in the diet has a positive impact on colonic health. A study comparing the effect of a low-fiber, grape-free diet to one containing either 120g of sun-dried raisins or 5g cream of tartar (approximately equivalent to the amount of TA in the raisins) on intestinal function in healthy adults found that both diets shortened intestinal transit time.[56] The effect was greater among those in the raisin diet. Because of the higher fiber content of this diet, fecal bulk and fecal moisture content also increased. In a second study by the same investigators, participants consumed diets containing 84g, 126g or 168g of sun-dried raisins daily.[56] Transit time decreased and fecal weight increased with increasing content of raisins in the diet. Both studies found that sun-dried raisins and TA lowered total fecal bile acid concentration, mainly due to a reduction in lithocholic and deoxycholic acid. All these parameters of intestinal function may play a role in the prevention of colon cancer. A shortened transit time may hasten the elimination of carcinogens, toxic compounds and byproducts of metabolism and an increased fecal weight may result in dilution of fecal carcinogens – either endogenous or exogenous. Fecal bile concentration has been directly associated with colon cancer risk, both lithocholic and deoxycholic acid acting as co-mutagenic compounds in a variety of *in vitro* assays. The results of these studies suggest ***that tartaric acid and fiber in raisins work synergistically to maintain a healthy digestive system. They also make a strong case for the advantages of combining foods with beneficial effects, such as raisins with high cereal fiber foods***.

Tartaric acid has also been shown to help increase the bioavailability of minerals in the diet, such as calcium and iron. *In vitro* studies indicate that tartaric acid increases the uptake of iron by Caco-2 cells by lowering intestinal pH and by forming soluble iron-acid complexes, especially with ferric ion.[75 76] Studies using *in vitro* simulated gastrointestinal digestion showed that tartaric acid increases the calcium availability from vegetables.[77] Investigators trying to find a way to reduce the rates of anemia in India developed an iron-fortified biscuit and tested iron bioavailability with and without tartaric acid. They found that by adding tartaric acid, they were able to increase iron availability by 338%.[78] ***Tartaric acid content of grapes and raisins make a strong case for adding these fruits to foods where minerals are poorly absorbed. Raisins paired with iron-fortified cereals will enhance iron absorption; raisins in vegetable salads may not only add zest but may enhance calcium absorption.***

Unlike other fruit acids (such as malic and citric acid), tartaric acid bypasses the small intestine and is fermented by colonic bacteria to produce short-chain fatty acids (SCFA). As discussed in the previous section, these acids play a significant role not only in colonic health but also in the well being of the entire organism. ***Tartaric acid may act synergistically with fructans to enhance the potential of raisins as a prebiotic food.***

iii. Polyphenols in Sun-Dried Raisins

Raisins are an excellent source of polyphenols in the American diet. Polyphenols make up the largest group of phytochemicals in the diet and they appear to be, at least in part, responsible for the potential health benefit associated with the consumption of diets abundant in fruits and vegetables.

Polyphenols are synthesized by all vascular plants and are therefore present in all plant foods contributing to their color and taste. Polyphenols have many functions essential to plant growth and survival. In animals and humans who consume them, they affect cellular biochemistry. They are potent antioxidants and may protect cell constituents against oxidative damage. They chelate metals, modulate enzymatic activity, inhibit cellular proliferation and alter signal transduction pathways. Current evidence strongly supports a role for polyphenols in the prevention of cardiovascular disease, cancer and osteoporosis and suggests a role in the prevention of neurodegenerative diseases, diabetes and inflammatory disorders.

Total polyphenol content can be estimated from absorbance measures at 280 nm or by using specific agents such as Folin Ciocalteu.[†] Using this assay, raisins, figs and prunes show similar total phenolic content ranging from about 9mg to 12mg of gallic acid equivalents per gram of fruit (Table 3).[79] Values are higher for dried fruit than the corresponding values for fresh fruit because the phenols are concentrated during the dehydration process. However, total phenolic values are still higher when expressed on a per serving basis (from NLEA defined serving size).[38]

Table 3. Total Phenolics of Dried Fruits and Grapes[79] [a]

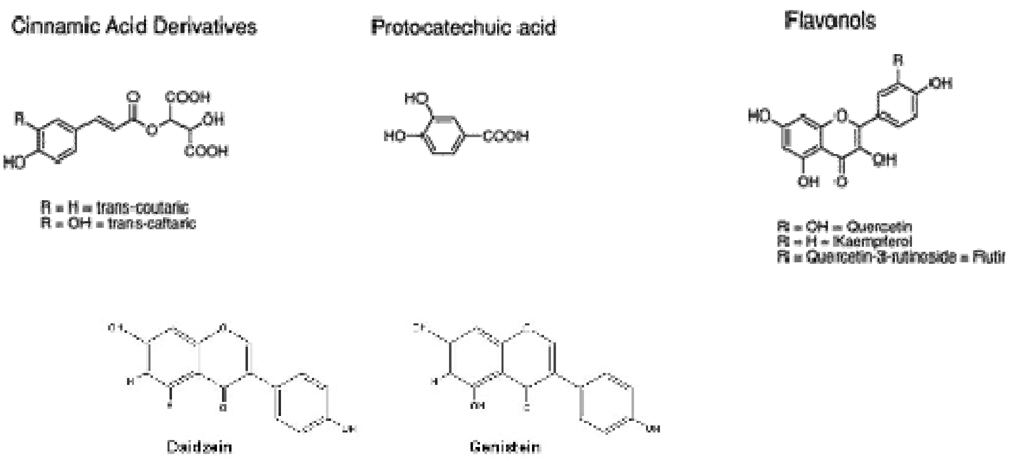
Food	Total Phenolics[b] (mg of GAE/g)	Serving Size NLEA (grams)	Total Phenolics Per Serving (mg of GAE)
Dates:			
Deglet Noor	6.61 ± 1.11	40	264
Medjool	5.72	40	228
Figs	9.60 ± 0.07	40	384
Prunes	11.95 ± 1.56	40	478
Raisins	10.65 ± 1.59	43	458
Green Grapes	1.45 ± 0.11	126	183

[a] Data presented as mean ± SD for sample numbers, expressed on a “as consumed” weight basis. [b] Total phenolics data expressed as milligrams of gallic acid equivalents per gram (mg of GAE/g).

[†] This assay is based on an oxidation reaction. Although it is used to compare samples with similar composition, it is imprecise in assays of extracts of different polyphenol structures.

Plant polyphenols are very diverse and have complex chemical structures. They can be classified into flavonoids and phenolic acids. There are several subclasses of flavonoids in foods. ***In raisins, the most abundant are the flavonols quercetin and kaempferol. Raisins are unique among fruits and nuts in their relatively high content of the isoflavones daidzein and genistein. In addition, raisins are rich in the phenolic acids caftaric and coutaric acid.***[†] Figure 2 shows the structure of selected polyphenols in raisins.

Figure 2. Structures of Selected Polyphenols Found in Raisins



While the phenolic composition of grapes, grape juices and wines have been investigated by many researchers, there are only two reports in print on the polyphenol composition of raisins (Karadeniz *et al*[80] Parker *et al*[81]) in addition to the USDA Database for the Flavonoid Content of Selected Foods.[82] Raisin polyphenolic profile is strikingly different from that of Thompson Seedless grapes (Tables 4, 5 and 6). This is due to both enzymatic oxidation and non-enzymatic browning reactions that happen during dehydration of grapes. Both reports show similar trends: the concentration of quercetin glycosides are the highest among flavonols followed by that of kaempferol glycosides. The content of rutin is relatively low among the flavonols determined

[†] Caftaric and coutaric acids are the tartaric acid esters of hydroxycinnamic acids p-coumaric acid and caffeic acid.

and was detected only in raisins by Parker *et al.*[81] On the other hand oxidized cinnamics and protocatechuic acid were only detected in sun-dried[81] and dipped raisins.[80] Golden raisins contained the highest amount of *trans*-caftaric and *trans*-coutaric acids.[80] Sulfur dioxide curtails oxidation in these raisins resulting in a higher phenolic content. When compared to fresh grapes, Karadeniz reported a loss in phenolic acids of up to 90% and a loss of flavonols in the order of 60%.[80] This is not consistent with Parker's report, who reports lower losses. According to Karadeniz, procyanidins and flavanols are completely degraded during raisin formation.[80] This is also inconsistent with the USDA database which lists raisin catechins content of 0.42mg/100g, epicatechins at 0.10mg/100g and cianidin at 0.03mg/100g of fruit.[82] Unfortunately, the original report from which these results are based is not yet in print.[83] Finally, Karadeniz detected no resveratrol or ellagic acid in fresh grapes or raisins.[80] While the many changes that grape polyphenols undergo during their conversion into raisins is out of the scope of this paper, one should be aware that they yield highly complex structures, many flavonoids (e.g. flavanols) condensing into large molecules or polymers (tannins). The difficulty in working with the raisin matrix and interference with non-phenolic compounds may explain the difference in the reported values.

Table 4. Phenolic Acid Compositions of Raisins and Grapes*[80]

Sample	Oxidized Cinnamics A	Oxidized Cinnamics B	Caftaric acid cis	Caftaric acid trans	Coutaric acid cis	Coutaric acid trans	2-*S*-glutathionyl caftaric acid	Protocatechuic acid
Sun-dried raisins (*n* = 10), mean	3.7	6.1	nd	39.6	nd	6.7	nd	6.8
Dipped raisins (*n* = 5), mean	2.9	5.1	nd	45.2	nd	7.7	8.1	2.8
Golden raisins (*n* = 5), mean	nd	nd	nd	84.3	nd	27.3	nd	nd
Fresh grapes	nd	nd	2.7	100.7	8.0	31.8	nd	nd

* mg/kg of sample

Table 5. Flavonol Glycoside Composition of Raisins and Grapes*[80]

Sample	Rutin	Quercetin glycoside A	Quercetin glycoside B	Kaempferol glycoside A	Kaempferol glycoside B
Sun-dried raisins (*n* = 10), mean	5.2	7.3	34.7	11.2	23.7
Dipped raisins (*n* = 5), mean	6.5	20.6	39.0	16.7	29.5
Golden raisins (*n* = 5), mean	3.5	41.5	37.1	6.5	7.6
Fresh grapes	0.9	21.9	3.9	nd	19.4

nd = not detected   * mg/kg of sample

Table 6. Flavonoid, and Phenolic Composition of Grapes and Raisins[*] [81]

	Raisin		Grape	
	golden (n = 4)	sun-dried (n = 3)	fresh (n = 3)	frozen (n = 3)
trans-caftaric acid	130.4 ± 7.0	41.4 ± 5.8	7.9 ± 1.5	7.9 ± 0.19
trans-coutaric acid	34.1 ± 8.8	nd	14.8 ± 1.0	nd
2-*S*-glutathionyl caftaric acid	nd	nd	8.8 ± 0.9	12.1 ± 4.4
protocatechuic acid	nd	4.4 ± 1.2	nd	nd
rutin	14.4 ± 0.9	8.3 ± 1.6	trace	trace
quercetin glycoside A	65.7 ± 13.7	15.6 ± 2.8	15.2 ± 3.1	21.5 ± 4.7
quercetin glycoside B	43.4 ± 5.2	6.5 ± 0.3	25.6 ± 3.7	27.7 ± 6.5
kaempferol glycoside A	9.8 ± 0.5	7.0 ± 3.1	trace	trace
kaempferol glycoside B	14.3 ± 2.9	9.3 ± 2.6	trace	trace

nd = not detected [*]mg/kg of sample ± SD

Daidzein and genistein are isoflavones with estrogenic activity in humans, and therefore are known as phytoestrogens. Structurally they resemble 17β estradiol and in *in vivo* assays they compete with the hormone at the receptor level. As other flavonoids, they may act as cellular antioxidants; they are potent tyrosine kinase inhibitors[†] and affect cell cycle. They have been shown to protect against breast, prostate and other cancers, lower risk of cardiovascular disease and alleviate menopausal symptoms.

[†] Tryosine kinase activity leads to the activation of multiple cellular pathways involved in tumor growth, differentiation, transformation, proliferation, metastasis, and inhibition of apoptosis. The TK proteins comprise the largest family of oncogenes that are altered in many cancers.

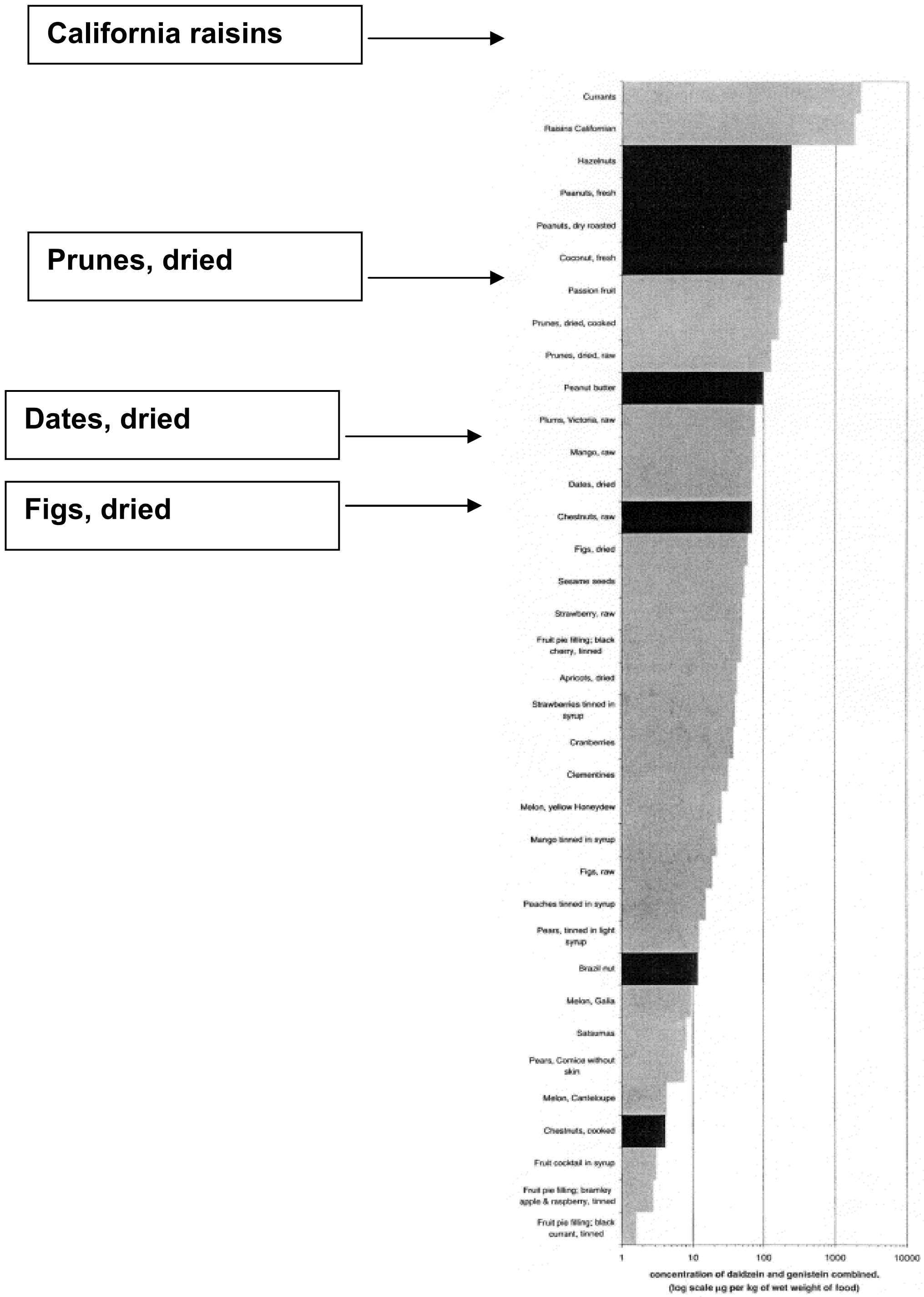


Figure 3. Comparison of the combined concentration of daidzein and genistein in different fruit (grey) and nuts (black)[84]

The concentrations of daidzein and genistein have been determined in a variety of fruits and nuts commonly eaten in Europe.[84] ***Of the 36 samples of fruits and nuts that contain daidzein or genistein, currants and California raisins are the richest sources, containing 2.25 and 1.84mg/kg, respectively***. The other 34 foods contain between 0.250 and .001mg/kg wet weight of food (Figure 3). In comparison, soybeans contain approximately 2g/kg wet weight.[85] While even a small portion of a soy product in the diet adds very significant concentrations of daidzein and genistein, ***inclusion of raisins in the diet will contribute to the daily intake of these protective phytochemicals.***

IX. Health Effects

i. Antioxidant Capacity of Sun-Dried Raisins

By virtue of their high polyphenol content, raisins are an important source of antioxidants in the American diet. These phytochemicals are believed to account for a major portion of antioxidant capacity in plant foods. Antioxidants can lower oxidative stress and so prevent oxidative damage to critical cellular components.

Current scientific thought regards oxidative stress as an important contributing factor in the development of heart disease and cancer, the two leading causes of death in the US. It is also implicated in the development of neuronal degeneration such as in Alzheimer's and Parkinson's disease as well as in the aging process itself.[86] Oxidative stress is an imbalance between the production of reactive oxygen species (ROS) and the antioxidant defense system and can result from either a deficiency in the antioxidant defense mechanism or from an increase in ROS levels. ROS is a collective term that includes oxygen and non-oxygen radicals and comprises superoxide, hydroxyl, peroxyl, alkoxyl and nitric oxide derived products. They are generated as byproducts of normal cellular respiration that is essential to life and by the immune system and so contribute to our defenses. Higher levels can be generated from excessive activation of ROS systems, such as those mediated by chronic inflammation and infection or by instances of increased oxygen uptake such as in strenuous exercise. Exposure to ROS-generating chemicals and environmental toxins (i.e. tobacco smoke, pollutants, food constituents, ethanol and radiation) contribute to the total burden. Organisms have developed a very delicate system to eliminate or neutralize ROS, but it is not 100% effective. In addition to endogenous antioxidant enzymes, they can be scavenged by antioxidants obtained from the diet. The term "antioxidant" has been defined by the Institute of Medicine of the National Academy of Sciences as "a substance in foods that significantly decreases the adverse effects of reactive species, such as reactive oxygen species, on normal physiological functions in humans." Examples include phenolics, carotenoids and vitamins E and C found predominantly in plant foods.

Many *in vitro* methods have been used to compare the oxidation/reduction potential of foods and their phytochemicals. These include the oxygen radical absorbance capacity (ORAC), total radical-trapping antioxidant parameter (TRAP); Trolox equivalent antioxidant capacity (TEAC); and the ferric reducing/antioxidant power (FRAP). These assays are based on different mechanisms using different radical or oxidant sources and therefore generate different values and cannot be compared directly. In general, a food that has a high value for one measure of antioxidant capacity will also be high for another measure. The ORAC assay is considered by some to be a preferable method because of its biological relevance to the *in vivo* antioxidant efficacy.[87] Researchers at the USDA have measured both lipophilic (L-ORAC) and hydrophilic (H-ORAC) antioxidant capacities of common foods in the US using the ORAC assay. They have calculated total antioxidant capacity (TAC) by combining L-ORAC and H-ORAC, and a database is available.[79] Most recently, the cellular antioxidant activity assay (CAAA) has been developed to measure antioxidant activity in cell culture. It is a more biologically relevant assessment because it takes into account some aspects of antioxidant cellular uptake, metabolism and location within cells.[88]

Values for antioxidant capacity of raisins and/or grapes assessed by different methods are listed in Table 7. ***TAC per 100g of fruit in sun-dried raisins is higher than in fresh Thompson Seedless and red grapes due to the concentration of antioxidants during dehydration (3037,***

1118 and 1260 µmol/100g of fruit).[79] This is consistent in all dried fruits. Other than the phenolic compounds, several components of raisins and dried fruits can contribute to their antioxidant potential such as organic acids and Maillard Reaction products. However, this has not yet been investigated. It is interesting to note that the ORAC for golden raisins is much higher per gram than the value for sun-dried raisins (10,480 versus 3,740 µmol/100g, respectively).[81] Golden raisins are treated with hot water and $S0_2$ to inactivate polyphenol oxidase and to inhibit nonenzymatic browning, probably allowing the raisin to retain the phenolic antioxidants of the original grape, which are then concentrated during drying. Total antioxidant activity in dried fruits, much like in all fruits, parallels their phenolic content.

Fruits are among the major antioxidant sources in our diet. Grapes and raisins on a per serving basis have intermediate to high values of TAC among fruits commonly consumed in the US, lower than berries and plums and higher than all melons, bananas, peaches, nectarines, apricots and many citrus fruits. ***When fruits and vegetables are categorized into groups ranked by their H-ORAC expressed on a per serving basis, raisins are grouped within the highest quartile (Table 8).***[79] ***Because H-ORAC makes up most of the TAC, the foods in this group can be regarded as the best source of total antioxidant capacity.*** Lipophilic values are very low in most fruits and vegetables compared to hydrophilic ones, which make up ≥90% of TAC. ***The contribution of L-ORAC to TAC is similar in fresh and dried fruits indicating that the drying process does not change the proportion of hydrophilic and lipophilic ORAC.***[79]

Table 7. Antioxidant Capacity of Raisins and Grapes Reported in the Literature

Method/Investigator	Sun-Dried Raisins	Golden Raisins	Thompson Seedless Grapes	Red Grapes
ORAC (µmol TE/100 g fruit ±SD) Parker, 2007[81]	3740 ± 370	10480 ± 870	1080 ± 490	-
Cellular Antioxidant Activity (µmol QE/100 g fruit) Wolfe, 2007[88]	-	-	939 ± 48	2410
Lipophilic ORAC (µmol TE/100g) Wu, 2004[79]	35 ± 13	-	NA	NA
Hydrophilic ORAC (µmol TE/100g) Wu, 2004[79]	3002 ± 523	-	1118 ± 166	1260 ± 317
Total ORAC (µmol TE/100g) Wu, 2004[79]	3037	-	1118	1260
FRAP (mmol Fe2+/kg) Pellegrini 2006[89]	23.26	-	-	-
TRAP (mmol Trolox/kg) Pellegrini 2006[89]	6.7	-	-	-
TEAC (mmol Trolox/kg) Pellegrini 2006[89]	6.63	-	-	-
FRAP (mmol antioxidant content/100g) Halvorsen 2006[90]	0.78	-	0.133	0.316

Data presented as mean ± SD ORAC$_{FL}$ data expressed as micromoles Trolox equivalents per gram (µmol of TE/g).

Table 8. Common Foods Categorized into Four Groups Ranked by Their Hydrophilic $ORAC_{FL}$ (H-$ORAC_{FL}$) per Serving[a] [79]

H-$ORAC_{FL}$[b] (μmol of TE/serving)	Foods
14000-2000	bean, small red; blueberry, wild; bean, red kidney; bean, pinto; blueberry, cultivated; cranberry; artichoke (C); blackberry; prune; strawberry; raspberry; apple, Red Delicious and Granny Smith; pecan; cherry, sweet; plum, black; potato, russet; potato, russet (C); plum; bean, black; apple, Gala; walnut; apples, Golden Delicious and Fuji; date, Deglet Noor; pear, Green and Red Anjou cultivars; hazelnut; orange, navel; raisin; fig; avocado, Haas; broccoli raab (R); cabbage, red (C); potato, red; potato, red (C); potato, white; pistachio; date, Medjool; bean, navy; grape, red
1999-1000	asparagus; pea, blackeye; beet; grapefruit, red; potato, white (C); grape, green; pepper, yellow; peach; pepper, orange; mango; asparagus, (C); apricot; tangerine; cereal, low-fat granola with raisin (K); onion, yellow (C); broccoli raab (C); almond; pineapple; sweet potato, (C); cereal, squares toasted oatmeal (Q); lettuce, red leaf; sweet potato; radish; pepper, red; eggplant; cereal, toasted oatmeal (Q); cereal, oat bran (Q)
999-500	nectarine; banana; broccoli, (C); onion, red; spinach; cereal, oat bran hot (Q); peanut; onion, yellow; cabbage, red; cereal, oat, quick 1-min (Q); carrot; cereal, corn flakes Total (GM); kiwifruit; pepper, green; snack, fruit and oatmeal, strawberry (Q); broccoli; cereal, Original Shredded Wheat (P); pepper, red (C); cereal, instant oatmeal (Q); lettuce, green leaf; cereal, oats old fashioned (Q); bread, butternut all whole grain wheat; bread, pumpernickel (B); snack, oatmeal raisin cookie (PF); tomato, (C)
499-0	pumpkin; cantaloupe; onion, sweet; cabbage; bread, oatnut (B). corn; cereal, Life (Q); cashews; pepper, green (C); peach, canned; snack, chewy low-fat granola bar (Q); macadamia; pea, green and frozen; lettuce, butterhead; honeydew; tomato; corn, canned; corn, frozen; bread (HC); lettuce, romaine; celery; cauliflower; bean, lima and canned; pea, green and frozen; Brazil nut; carrot, baby; watermelon; carrot, (C); bean, snap and canned; popcorn, buttered, premium (PS); lettuce, iceberg; pine nuts; bean, snap and fresh; cucumber, peeled and with peel

[a] Foods are listed in order within each group from highest to lowest ORAC value per serving.

Tables 9 and 10 show antioxidant capacity of dried fruits measured by different investigators using different techniques. Prunes consistently have the highest antioxidant values followed by dried apricots and Deglet Noor dates. Sun-dried raisins have intermediate values. The higher antioxidant activity of prunes is probably due to its higher phenolic content and to the high levels of caffeoylquinic acid isomers which have been shown to have high antioxidant capacity.[91]

Table 9. Lipophilic (L-ORAC$_{FL}$), Hydrophilic (H-ORAC$_{FL}$), Total Antioxidant Capacity (TAC), of Dried Fruits (Expressed on "As Consumed" Weight Basis) [a] [79]

Food	Moisture (%)	L-ORAC$_{FL}$ [b] (µmol TE/g)	H-ORAC$_{FL}$ (µmol TE/g)	TAC [c] (µmolTE/g)	TAC/serving (µmol TE)
Dates:					
Deglet Noor (*n* = 7)	20.0	0.32 ± 0.16	38.63 ± 3.21	38.95	3467
Medjool (*n* = 2)	21.3	0.27	23.60	23.87	2124
Figs (*n* = 7)	30.1	1.83 ± 0.13	32.00 ± 3.31	33.83	2537
Prunes (*n* = 8)	32.7	1.79 ± 0.56	83.99 ± 16.56	85.78	7291
Raisins (*n* = 8)	17.7	0.35 ± 0.13	30.02 ± 5.23	30.37	2490

[a] Data presented as mean ± SD for sample numbers >2. [b] ORAC$_{FL}$ data expressed as micromoles Trolox equivalents per gram (µmol of TE/g). [c] TAC = L-ORAC$_{FL}$ + H-ORAC$_{FL}$.

Table 10. Antioxidant Activity of Dried Fruits as Measured by FRAP, TRAP and TEAC Assays[a b] [89]

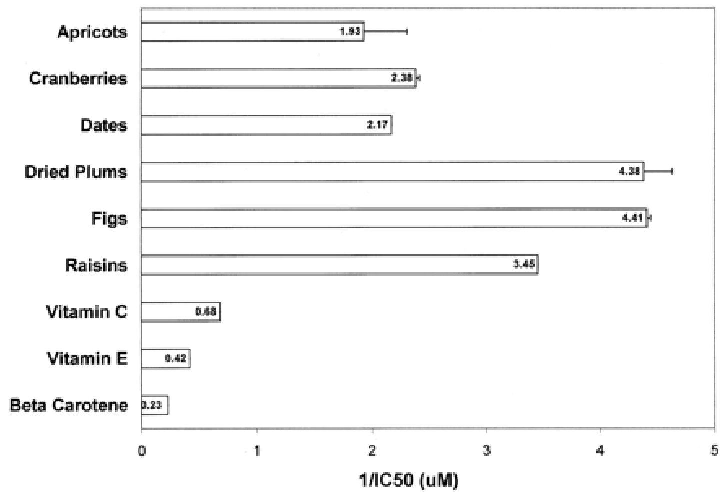
Dried Fruit	FRAP (mmol FE2+/kg)		TRAP (mmol Trolox/kg)		TEAC (mmol Trolox/kg)	
	Value	**Rank**	**Value**	**Rank**	**Value**	**Rank**

Apricot	**36.64**	**2**	**13.33**	**2**	**12.87**	**2**
Chestnut	**20.63**	**4**	**12.85**	**3**	**4.40**	**5**
Fig	**14.43**	**5**	**1.96**	**5**	**5.02**	**4**
Prune	**60.54**	**1**	**23.00**	**1**	**14.82**	**1**
Raisin	**23.26**	**3**	**6.17**	**4**	**6.63**	**3**

[a b] Values are mean, n=3. Values represent the sum of water and lipid soluble extracts.

Antioxidant quality is a measure of the effectiveness of the antioxidant(s) present as a pure compound or a mixture. Investigators have estimated the quality of antioxidants in fruits and vegetables extracts by determining the IC_{50} (the concentration to inhibit *in vitro* oxidation of LDL particles by 50%) of the pooled phenol extracts. Figure 4 compares antioxidant quality of dried fruits to that of antioxidant vitamins expressed as $1/IC_{50}$. The higher the value, the better the antioxidant quality. ***The antioxidant quality of phenols in the dried fruits is significantly higher than that of vitamins by nearly a factor of 10***. These investigators have shown that phenolic antioxidant quality seems to improve during the drying process.[92] The $1/IC_{50}$ values for fresh cranberries, green grapes and plums are 1.16, 1.32 and 1.42, respectively.[93] Those for dried cranberries, raisins and dried plums are 2.38, 3.45 and 4.38, respectively. They contend that the quality of antioxidants is important since polyphenols are usually present in plasma at concentrations not exceeding 10 µM after eating fruits. The average $^{1/}IC_{50}$ was 3.3 µM for the dried fruits. ***Thus the polyphenols from dried fruits can be potent antioxidants at physiological concentrations***.

Figure 4. Comparison of Quality of Antioxidants of Vitamins and Dried Fruits[92] *



* Dried fruit extracts from several sources of dates and raisins were pooled prior to assay.

Sun-dried raisins increase blood antioxidants and antioxidant capacity in healthy adults. As with plasma phenolic content, plasma antioxidant capacity increases following consumption of phenolic-rich foods.[94] Diets containing 10 servings of fruits and vegetables daily for 15 days significantly increased fasting baseline plasma ORAC of 35 healthy adults.[95] However, as with plasma phenolic levels, the changes are transient unless phenolic antioxidants have a high lipid solubility (e.g. soy isoflavones). Therefore, changes are more difficult to observe after an overnight fast and are most evident immediately after consumption of phenol rich foods. Keene fed 59g, 104g or 163g of sun-dried raisins per day to healthy adults for 4 weeks.[96] Plasma antioxidant activity increased as measured by the FRAP assay (but not the TRAP assay) after 2 and 4 weeks. In another study, 210g of sun-dried raisins homogenized in water (equivalent to 3570 µmol TE) were fed to 12 healthy adults.[97] Their plasma ORAC was measured at fasting (baseline) and 15, 30 and 60 minutes after drinking the raisin preparation. Blood ORAC levels were higher at the three testing times, reaching peak values at 30 minutes and declining after 60 minutes, while still remaining higher than baseline values. In the most recent study, healthy adults were fed 250g Thompson Seedless grapes, 50g of sun-dried raisins or 50g golden raisins for 4 weeks.[81] Serum ORAC was measured after a 12-hour fast and 1 and 2 hours after eating the test sample with a bagel and water. There was an apparent trend toward increasing serum antioxidant capacity by the second and third week of sample consumption, although values fell again in the fourth week (Figure 5). Authors speculated that there may be a physiological plateau approximately 2 or 3 weeks after consistent consumption. Participants however were free living and no restrictions were made on their diets during the study, so many explanations are possible. No consistent serum ORAC changes were seen 1 and 2 hours after grapes/raisins and bagel consumption. Other studies have shown that antioxidant rich foods are able to increase postprandial antioxidant capacity.[98] For example, feeding Sprite™ lowers plasma antioxidant capacity, but feeding Sprite™ plus dried figs raises plasma antioxidant capacity above baseline levels for up to 4 hours, overcoming the pro-oxidant effect of the sugar consumption.

A recent study[99] found that eating raisins daily raises serum ORAC in healthy but overweight individuals. ORAC measures the combined capacity of antioxidants, particularly water soluble ones, to lower levels of oxidants that may damage susceptible molecules. ORAC is thus influenced by blood levels of vitamin C, uric acid and flavonoids. In this study, 17 overweight men and women either ate 90g raisins or isocaloric placebos for 14 days in a randomized, cross-over design while following a low-flavonoid diet. After the raisin intervention, individuals had higher blood ORAC levels (Table 11). This suggests that the antioxidants in raisins, probably phenolic compounds and flavonoids, may raise the antioxidant defense capacity of blood either through direct scavenging or by modulating the activity of other antioxidants. It has been hypothesized that fruit consumption may also raise total blood antioxidant capacity because of the higher uric acid levels resulting from fructose metabolism.

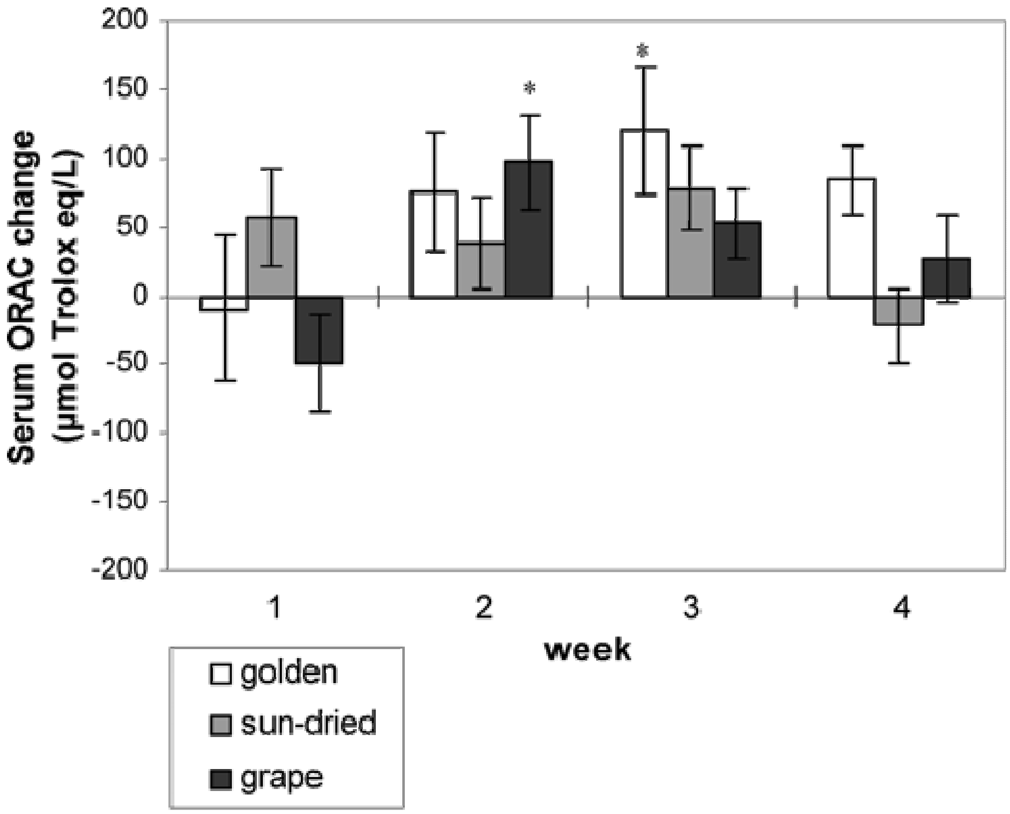
While blood ORAC increased with the raisin intervention, urinary 8-epi $PGF_{2\alpha}$ level, a measure of oxidative stress, did not change. This lack of consistency between measures of antioxidant capacity and markers of oxidative stress have previously been reported. Because of the complex relationship between the two, future studies that include a range of oxidative stress markers may be necessary to fully investigate the potential antioxidant effects of raisin consumption.

Table 11. Fasting ORAC values before and after raisin and placebo intervention‡

Variable	Pre-raisin	Post-raisin	Pre-placebo	Post-placebo
ORAC total (μmol/L TE)*,†	7163 (6479–7919)	7614 (6887–8417)	8336 (7540–9215)	8403 (7601–9290)
ORACpca (μmol/l TE)*,†	886 (823–954)	932 (866–1004)	980 (910–1055)	1015 (94–1093)
Urinary 8-epi $PGF_{2\alpha}$ (pg/mg CR)*	4164 (3538–4901)	3108 (2641–3657)	4298 (3665–5040)	3485 (2972-4087)

8-epi $PGF_{2\alpha}$ = 8-epi-prostaglandin-$F_{2;}$; values are means with 95% CI.
*Significant effect of pre/post when interventions combined.
†Significant difference for raisin and placebo treatment; ‡ Adapted from Rankin *et al*

Figure 5. Long-term Serum ORAC (Oxygen Radical Absorbance Capacity) Change Over 4 Weeks of Daily Consumption of Golden Raisins, Sun-dried Raisins or Grapes [81]



Note: Higher values indicate a higher serum antioxidant capacity. Baseline is zero. Baseline raw values: golden, 1113; sun-dried, 1155; and grape, 1095 μmol TE/L. *$p < 0.05$. Shown as means ± SEM ($n \geq 9$).

Investigators have looked at the effect of feeding different antioxidant vitamins and diets high in certain fruits and vegetables on levels of 8-hydroxy-2-deoyguanosine (8OHdG) in the urine or in leukocytes.[100 101] 8OHdG is a product of free radical oxidative damage to DNA or to the DNA precursor pool. Studies looking at the effect of pure antioxidants such as the vitamins E and C, beta-carotene or coenzyme Q10 do not change 8OHdG,[102] whereas feeding polyphenol-rich fruits and vegetables such as wine, Brussels sprouts[103] and mixed diets high in phenolics.[104] Intense physical activity increases oxygen uptake with a potential for increased formation of reactive oxygen species. These can cause damage to large biomolecules such as proteins and DNA if such an increase exceeds the protective capacity of the antioxidant defense mechanisms.[105 106] Oxidative stress therefore points to a risk of degenerative disease and premature aging from extreme exercise. ***Foods high in phenolic antioxidants can protect against DNA damage during intense physical activity by counteracting oxidative stress.*** Feeding 170g of sun-dried raisins prior to and during a triathlon to trained athletes significantly lowered 8OHdG urine levels compared to feeding of a glucose drink with the same amount of calories.[107] This suggests ***that during strenuous exercise, foods rich in phenolic antioxidants such as sun-dried raisins can protect from DNA damage due to oxidative stress.***

Another measure of oxidative stress is a measure of circulating oxidized LDL particles (ox-LDL). They can provide a measure of tissue damage and can be a useful marker for identifying patients with a high risk for coronary artery disease (CAD) since 94% of the subjects with high ox-LDL have cardiovascular disease. Many studies have shown that diets high in polyphenols reduce the susceptibility of LDL oxidation in CAD patients.[108] A diet providing 2, 3.5 and 5.5 ounces of raisins per day for 4 weeks lowered ox-LDL levels.[96]

In conclusion, because of their high phenolic content, raisins are an important source of antioxidants in the diet. Raisins have higher polyphenol antioxidant content than Thompson Seedless grapes. In terms of their antioxidant capacity (as measured by H-ORAC) raisins are ranked within the highest quartile among fruits and vegetables. This is important because the antioxidant effect of polyphenols has been suggested as an explanation for the protective effect of fruits and vegetables. Raisins not only have high antioxidant capacity in vitro but also have been shown to raise blood antioxidant capacity and to protect against a marker of oxidative stress: oxidative damage to DNA and oxidation of LDL particles.

ii. Raisins and Cardiovascular Health

Raisins are a good source of fiber and polyphenols in our diet. Both of these food components are important for cardiovascular health.

Cardiovascular disease (CVD), primarily from heart disease (CHD) and stroke, is the leading cause of death in the United States for both men and women among all racial and ethnic groups. More than 850,000 Americans die each year from CVD accounting for nearly 40% of all deaths. The cost of heart disease and stroke in the United States in 2005 is estimated at $393 billion, including health expenditures and lost productivity. These costs are expected to increase by 2010.[109]

Many studies have established that high plasma levels of total cholesterol and LDL cholesterol are among the most important modifiable risk factors for heart disease. While the mechanisms through which these factors lead to atherosclerosis and heart disease are not completely understood, evidence points to the oxidation of LDL particles by either free radical byproducts, or by mediators of inflammatory processes, as a probable causative process.

Large epidemiological studies, such as the Nurses' Health Study[110] and the Scottish Heart Health Study[111] show that individuals who consume diets high in fiber have a lower risk for heart disease. Soluble fiber may be of particular preventive value since it appears to lower plasma cholesterol levels. The mechanisms which may explain how fiber lowers serum cholesterol have been extensively reviewed and include: lower cholesterol absorption, higher bile acid excretion, changes in bile-acid type present in the intestinal tract, and influences of short-chain fatty acid production by intestinal flora.[112] [113]

Epidemiological and experimental evidence suggests a protective effect of polyphenol-rich foods against CHD and stroke.[114] Polyphenols in fruits, vegetables and beverages may protect from atherosclerosis because of their antioxidant potential and through their anti-inflammatory activity. Flavonoids are known to react with a variety of disease promoting free radicals and to induce antioxidant enzymes. While human data is limited, *in vitro* and *in vivo* studies have shown that many polyphenols, quercetin among them, and polyphenol-rich foods, inhibit LDL oxidation. They can modulate nitric oxide synthesis, promote vascular relaxation and inhibit platelet adherence to the vascular endothelium. Atherosclerosis is now viewed as a chronic inflammatory disease. Recent studies suggest that flavonoids protect from initiation and progression of atherosclerosis by modulating inflammatory pathways. They have been shown to inhibit mast cell secretion of pro-inflammatory cytokines and inhibit TNF-stimulated induction of endothelial cell adhesion molecules. Many excellent reviews on flavonoids and heart health have been published.[115] [116]

Raisins as part of a diet high in unrefined foods have been shown to have a beneficial effect on blood lipid levels. Spiller *et al*[117] [118] were the first to study the hypocholesterolemic effect of plant-based diets, which included more than one serving of sun-dried raisins daily. They fed hypercholesterolemic adults Mediterranean-style diets high in whole grains and nuts, and that provided 84g raisins daily, for 4 weeks. By the end of the study total cholesterol and LDL cholesterol were 9% and 15% lower, respectively, than at baselines. There were no significant changes in HDL levels. Bruce *et al*[119], in a crossover study, showed that a diet rich in unrefined foods, that also provided 126g of raisins daily, lowered total cholesterol and LDL cholesterol by 13% and 16%, respectively, in hyperlipidemic volunteers. In a randomized study, Gardner *et al*[120] showed that a plant-based, low-fat diet (which included raisins as snacks) significantly lowered total and LDL cholesterol levels among moderately hypercholesterolemic volunteers compared to those who consumed a more conventional, low-fat diet based on convenience foods. ***While many foods can account for the observed hypolipidemic effect of the experimental diets, these findings show that sun-dried raisins can be consumed as part of a cholesterol-lowering, plant-based diet.***

In a recent study, Puglisi *et al* [121] showed that raisins alone could have a beneficial effect on blood lipids. Thirty four volunteers were assigned to consume 1 cup of raisins daily, increase the number of steps walked in a day or a combination of both for 6 weeks. Raisins substituted for other foods to ensure weight maintenance. Both interventions alone or in combination lowered plasma LDL cholesterol and increased LDL receptor expression (Table 12). Triglyceride levels did not change among the volunteers in the raisin and in the raisin and exercise group. This study also looked at the effect of these interventions on inflammatory cytokines. Subjects in the raisin group had significantly lower levels of TNF-α and sICAM-1. TNF-α is a powerful pro-inflammatory cytokine. Reducing TNF-α could potentially prevent progression of inflammatory damage. sICAM-1 is a cellular adhesion molecule. Lower levels of this sICAM-1 could potentially prevent progression of atherosclerosis by decreasing adhesion of monocytes to the vascular endothelium.

None of the diets containing raisins mentioned above increased triglyceride levels. This is important because it is often assumed that increasing intake of carbohydrates, often consumed in their refined, low-fiber form, and lowering intake of fat adversely affect serum triglycerides. However, carbohydrates rich in fiber and phytochemicals do not have this effect. Spiller *et al*[122] fed volunteers a typical Western diet for 3 weeks and then switched their diet to a NCEP (National Cholesterol Education Program) Step 1 diet supplemented with raisins and whole wheat raisin bread for 13 weeks. Triglyceride levels were 19% lower (non-significant) than baseline values. ***These results suggest that carbohydrates rich in fiber and phytochemicals such as sun-dried raisins do not increase triglyceride levels.***

In summary, raisins are a good source of both fiber (soluble and insoluble) and polyphenols. Raisins, as part of a diet high in whole and unrefined foods, have a beneficial effect on lipid levels. The addition of raisins to the a daily diet has been shown to lower total and LDL cholesterol levels, reduce markers of inflammation, increase plasma antioxidant capacity and lower circulating levels of oxidized LDL, a marker of coronary heart disease risk.

Table 12. Plasma total cholesterol (TC), LDL cholesterol (LDL-C), HDL cholesterol (HDL-C) and triglycerides (TG) of subjects consuming raisins (RAISIN), increasing walking (WALK) or both (RAISIN + WALK).[1 2]

Variable	TC (mmol/L)	LDL-C (mmol/L)	HDL-C (mmol/L)	TG (mmol/L)
Raisin (n = 12)				
Baseline	5.21 ± 0.98	3.21 ± 0.84	1.56 ± 0.36	0.94 ± 0.47
6 Weeks	4.82 ± 0.93	2.90 ± 0.76	1.53 ± 0.31	0.90 ± 0.35
Walk (n = 12)				
Baseline	5.47 ± 1.37	3.16 ± 1.16	1.56 ± 0.50	1.49 ± 0.99
6 Weeks	4.68 ± 1.12	2.48 ± 0.69	1.58 ± 0.41	1.20 ± 0.73
Raisin + Walk (n = 10)				
Baseline	5.25 ± 0.96	3.01 ± 1.11	1.71 ± 0.50	1.17 ± 0.53
6 Weeks	4.96 ± 0.79	2.74 ± 0.71	1.66 ± 0.55	1.24 ± 1.54
Time effect	$P < 0.01$	$P < 0.01$	ns	ns
Group effect	ns	ns	ns	$P < 0.05$
Interaction	ns	ns	ns	ns

[1]Values are means ± standard deviation for the number of subjects indicated in parenthesis. Data were analyzed using repeated measures ANOVA. [2] Puglisi *et al.* Lipids in Health and Disease 2008 7:14.

iii. Raisins and Cancer Prevention

Cancer causes over 550,000 deaths each year, making it the second leading cause of death in the United States, after heart disease. Lung cancer accounts for the majority of these mortalities, while prostate cancer and breast cancer rank second among men and women, respectively, before colorectal cancer.[123] While these statistics are sobering, cancer is in part a preventable disease: it is estimated that nearly one-third of all cancer deaths in the United States could be avoided through appropriate dietary modifications. Raisins are fruits with unique nutrient value that offer a convenient step towards healthier eating.

Epidemiological studies have consistently shown that diets rich in fruits and vegetables help prevent many types of cancer. The inverse association between fruit and vegetable consumption and cancer incidence is strikingly consistent, and has led organizations around the world to recommend that populations increase their daily intake of these foods. Many components found in fruits and vegetables have been proposed as candidates for the observed protective effects, such as soluble and insoluble fiber and, more recently, polyphenolic compounds, particularly flavonoids. ***Raisins are an important dietary source of both of these cancer-protective compounds.*** Health benefits of fiber in raisins, including its potential cancer protective effect, are discussed in section VII, iii.

Although it is not well understood exactly how flavonoids work in the body to prevent cancer, they appear to affect the various stages of carcinogenesis: cancer initiation, promotion and progression. Flavonoids are potent antioxidants *in vitro* and are able to scavenge a wide variety of reactive molecules that can harm cell constituents. They have been shown to repair DNA damage; modulate nuclear receptors and gene expression; stimulate or inhibit enzymes that detoxify or activate carcinogens,[124] and influence the cell cycle, signaling pathways[125] and angiogenesis.[126] A number of reviews have described the above mechanisms in detail.[127] [128] [129]

The main flavonoids present in raisins are the flavonols quercetin and kaempferol. Quercetin inhibits carcinogen-induced cancer in many animal models*.[130 131 132] In cell culture studies, quercetin suppresses the growth of ovarian, prostate and breast cancer cells and inhibits proliferation of ovarian and lung tumor cell lines. The exact molecular pathways that explain these effects are yet to be established, but may involve stimulating the production of the anti-proliferative transforming growth factor β1; inhibiting cell growth and inducing apoptosis (programmed cell death) in damaged cells.[133]

Despite considerable experimental evidence supporting the notion that certain flavonoids have anti-carcinogenic activity, data from human population studies are still limited. Reviews on epidemiological studies[134 135] conclude that, while there is only modest evidence that total flavonoid intake is inversely associated with cancer risk; the evidence is stronger for an association between the intake of quercetin and the risk for lung and colorectal cancers. Recent studies are consistent with this assessment. A population-based, case-controlled study in California showed that intake of certain flavonoids including catechins; epicatechins, quercetin and kaempferol were inversely associated with lung cancer risk among tobacco smokers, but not among non-smokers.[136] A large prospective, case-controlled study in Scotland found a 27% reduction in colorectal cancer risk in people with the highest quartile of flavonol intake when compared to those with the lowest intakes. The reduction in risk was 32% when comparing quercetin intakes.[137] A series of multi-center, case-control studies conducted in Italy between 1991 and 2005 analyzing the relationship between intake of the six main classes of flavonoids (isoflavones, anthocyanins, flavan-3-ols, flavanones, flavones and flavonols) and the risk of different types of cancers further supports a protective effect for flavonols. Investigators found a reduced risk of developing ovarian cancer,[138] breast cancer,[139] oral and pharyngeal cancers,[140] and colorectal cancer[141] with higher intakes of selected flavonoids including flavonols. No association was found for prostate cancer risk.[142] Investigators evaluating prospectively the

* AOM-induced colon cancer in mice; DMBA-induced skin cancer in mice, in rats and in hamster buccal pouch; DMBA-induced breast cancer in rats; DEN-induced lung cancer in mice; 4-NQO-induced tongue carcinoma.

association between intake of flavonoids and colorectal cancer in 71,976 women from the Nurse's Health Study and 35,425 men from the Health Professionals Follow-Up Study found no significant association with intakes of flavonols, including quercetin and kaempferol.[143] The Multiethnic Cohort Study in Hawaii and California looked at the association between intake of three flavonols (quercetin, kaempferol and myricetin) and the incidence of pancreatic cancer among 183,518 participants.[144] While intake of total flavonols was associated with a significantly lower cancer risk, kaempferol showed the greatest preventive effect. It is noteworthy that in a prospective study of fatal pancreatic cancer among 34,000 California Seventh-day Adventists, the higher levels of dried fruit consumption (raisins, dates and other) were associated with a highly significant protective effect on pancreatic cancer risk (< 1 times per month = 1.0; 1-2 times per month 0.47; ≥ 3 times per week 0.35, trend $p = 0.009$).[145] These data provide support for the limited but growing epidemiologic evidence that certain flavonoids are associated with a lower risk of cancer. Therefore, foods rich in flavonoids may be important determinants of cancer risk in the population.

Only one animal study has investigated the anti-cancer effect of raisin-containing diets.[146] Dannenberg fed cancer-susceptible mice[*] diets made to contain 1% and 10% raisins for 70 days. Mice on the raisin diets had about one third less tumors ($p < 0.047$) than mice on the control diets. There was no dose response since both concentrations caused similar tumor inhibition. The apparent effectiveness in preventing intestinal cancer could be due to their relatively high fiber content in addition to their flavonoid content.

Diets high in fruits and vegetables have been associated with a lower risk of developing cancer and other chronic diseases. Over the years, many phytochemicals, bioactive compounds that contribute to these benefits, have been identified and studied. Scientists believe that it is the additive and synergistic effect of phytochemicals in fruits and vegetables that are responsible for their anticancer activity.[147 148] The benefit of a diet rich in fruits and vegetables is a result of the complex mixture of phytochemicals present in them. Raisins, with

[*] The Min/+ mouse develops multiple intestinal adenomas spontaneously.

their unique combination of nutrients, polyphenols and fiber are an important ingredient of a dietary strategy for optimal health.

iv. Raisins in Diabetes Management

Diabetes is the 7th leading cause of death in the United States. An estimated 20.8 million people in the US – 7% of the population – have diabetes, a serious, life-long condition. Overall, the risk of death among people with diabetes is about twice that of people without diabetes of similar age. Diabetes also increases the risk of heart disease and complications include damage to the retina, kidneys and peripheral nerves.[149] Controlling blood sugar levels and keeping these closer to normal values will lower the risk of disease and death from complications. Since dietary carbohydrates have the most direct impact on blood sugar levels, controlling the amount of carbohydrate consumed per meal is the focus of diabetes nutrition management.

Raisins, like all commonly consumed fruits, provide carbohydrates as the only caloric macronutrient; many questions arise as to when and how much fruit should be consumed. The American Diabetes Association recommends following a dietary pattern, which includes carbohydrates from fruits, vegetables, whole grains, legumes and low-fat milk, as well as monitoring dietary carbohydrates, whether by carbohydrate counting, exchanges (Table 13) or experience-based estimates, to achieve glycemic control.[150] The use of the Glycemic Index in addition to the consideration of total carbohydrate may provide an added benefit. Of course, frequent blood glucose monitoring is strongly recommended, as it indicates which foods, physical activities and/or meal times elevate blood glucose levels. Individuals diagnosed with diabetes should work with a registered dietician to create a meal plan that accommodates the patient's weight, medication, carbohydrate needs and lifestyle.

Table 13. Exchange List for Dried Fruits †

Dried Fruit	Serving Size
Raisins	2 Tablespoons
Apples	4 Rings
Blueberries, cranberries, cherries	2 Tablespoons
Apricots	8 Halves
Figs	1 1/2
Prunes	3

† One serving (exchange) of fruit contains about 15 grams of carbohydrate, no protein or fat, and about 60 calories. Fruits in the amounts listed equal one exchange.

As with the general population, people with diabetes are encouraged to consume a variety of fiber-containing foods. The nutritional guidelines proposed by the general public's healthy-lifestyle recommendations are also appropriate for those with type 2 diabetes. They are therefore encouraged to consume fruits, including raisins. It is no surprise then that raisins feature prominently in recipes promoted by the American Diabetic Association.[151]

v. Glycemic Index (GI) of Raisins

In addition to their high antioxidant activity and dietary fiber content, raisins have a low to moderate Glycemic Index – a measure of how a food affects blood sugar levels. These three factors are important tools in diabetes management.

Raisins could be useful for both athletes and people with impaired glucose tolerance because they provide energy to fuel physical activity without causing excessive increases in the postprandial blood glucose or insulin response. The GI* is a measure of how a food affects blood sugar levels. The GI of raisins was first assessed at 64 ± 11 (glucose =100)[152] in a study involving 6 healthy, non-diabetic individuals. A more recent study measured raisin GI and Insulin Index† in 10 sedentary adults, 10 pre-diabetic individuals, and 11 endurance athletes.[153] The GIs, using glucose as the reference food, were 49.4 ± 7.4, 49.6 ± 4.8 and 62.3 ± 4.8, respectively (Figure 6). The Insulin Index was 47.3 ± 9.4, 54.4 ± 8.9 and 51.9 ± 6.5 for these groups (Figure 7). This is important because high fasting and/or postprandial insulin levels can increase cholesterol synthesis and impair fat mobilization from adipose tissue. Kern *et al* calculated a raisin GI of 62‡ in 8 endurance-trained cyclists, a value which is consistent with those above.

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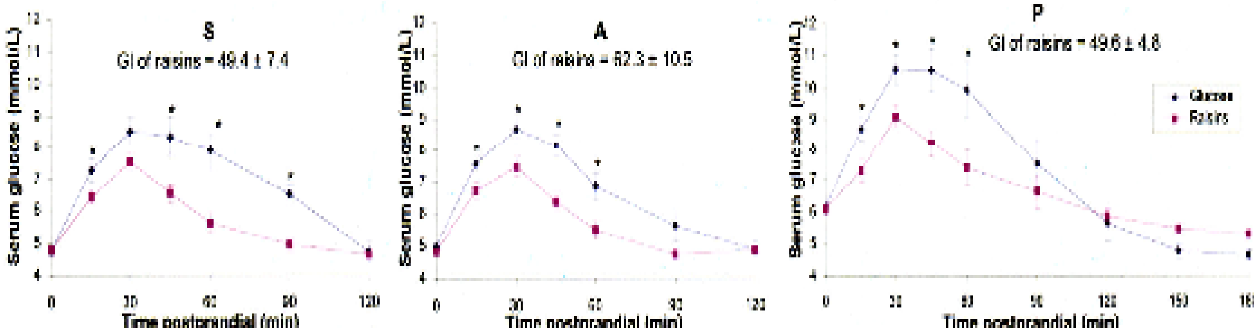
* The GI is determined by measuring the postprandial (2-3 hours) increase in blood glucose resulting from ingesting a portion of food containing 50 grams of available carbohydrate. The incremental area under the curve (AUC) is calculated for the test food and divided by the incremental AUC achieved from ingestion of 50 grams of carbohydrate from a reference food (i.e. white bread, glucose solution) and expressed as a percentage.

$$GI = \frac{\text{Blood glucose AUC from test food}}{\text{Blood glucose AUC from reference food}} \times 100$$

† The Insulin Index is calculated in a similar way, though sometimes energy, rather than the carbohydrate content of the meal, is used to standardize the equation.

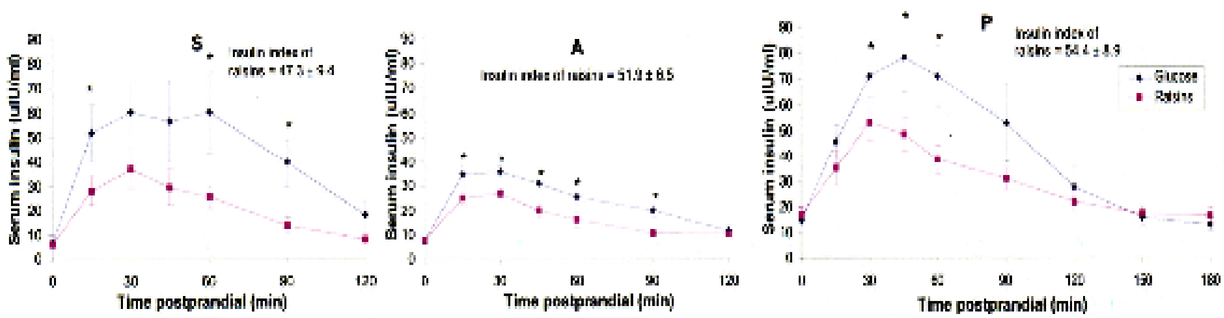
‡ The actual raisin GI value was 88, obtained using white bread as a standard.

Figure 6. Serum Glucose Responses to Raisins and Glucose in Sedentary Individuals, Athletes and Pre-diabetics



* Data points are means ± SEM; Significant differences between glucose and raisins *($p < 0.05$)*

Figure 7. Serum Insulin Response to Raisins and Glucose in Sedentary Individuals, Athletes and Pre-diabetics



* Data points are means ± SEM; Significant differences between glucose and raisins *($p < 0.05$)*

Foods with high fiber content generally have a low GI. However, other factors also contribute to a food's glycemic response, such as the type of carbohydrate or sugar present, the physical characteristic of the food matrix and the presence of organic acids. For example, one study found considerable differences in blood glucose response between processed snack meals (chocolate-coated candy bar or a cola drink with crisps) and whole-food snack meals (raisins and peanuts or bananas and peanuts),[154] which were designed to provide equal amounts of fat and energy. Peak glucose concentrations tended to be higher after the candy bar snack and the cola drink snack than after either of the peanut snacks. Plasma insulin levels were significantly lower after the raisin-peanut snack than after the candy bar and cola drink snack. The area under the insulin curve (Table 14) was 68%, 75% and 52% lower after the raisin-peanut snack than after the candy bar, the cola drink and the banana-peanut snacks, respectively. The comparison between the raisin-peanut snack and the banana-peanut snack is particularly interesting, since both meals had similar total carbohydrate, sugar, fat and protein content. Factors thought to contribute to raisins' lower glycemic response were the viscous texture of its food matrix when chewed; the presence of tartaric acid and the type of sugar present (about 50% fructose).

In conclusion, all studies assessing raisin GI show that raisins are a low to moderate GI food and that the insulin response is proportional to their GI.

Table 14. Areas under the plasma glucose and insulin curves after different snack meals † ‡

Snack Meal	Glucose	Insulin
Candy bar, tea	730 ± 26	3518 ± 406
Cola drink, crisps	731 ± 27	3670 ± 275
Raisins, peanut, tea	745 ± 26	2093 ± 284*
Bananas, peanuts, tea	716 ± 26	3194 ± 202

† Mean ± SEM; ‡ Adapted from Oettle, *et al.*

*Significantly different than the other meals

vi. Raisins, Polyphenols and Incidence of Diabetes

Given the potential for flavonoids to protect the body against free radicals and other oxidative compounds, it is biologically plausible that consumption of flavonoids or flavonoid-rich foods such as raisins may reduce the risk of diabetes.

Several small dietary intervention trials have shown that eating flavonoid-rich foods is associated with a significant increase in flavonoid levels in the blood of diabetic patients. Flavonoids are potent antioxidants because they function as free radical scavengers and metal chelators. It has been hypothesized that free radicals may contribute to autoimmune destruction of pancreatic β-cells, leading to diabetes and impaired insulin action. Flavonoids may preserve β-cell function by reducing oxidative stress-induced tissue damage and so protect against the progression of insulin resistance to type 2 diabetes.

Three large epidemiological studies have investigated the relationship between dietary flavonoids and development of type 2 diabetes. Knekt[155] examined the association between flavonoid intake and the incidence of a variety of chronic diseases, including diabetes, using data from the Finnish Mobile Health Examination Survey.[*] A lower risk of type 2 diabetes tended to be associated with higher quercetin and myricetin intakes. Adjustments for cardiovascular disease risk factors or dietary sources did not alter the results. However, the Women's Health Survey, a large prospective study of American middle-aged and older women, found no association between risk of type 2 diabetes and intake of either total or individual flavonoids as well as of most flavonoid-rich foods.[156] In a subset of 344 non-diabetic women, total flavonoid intake was not significantly related to plasma insulin levels. Results from this study are consistent with those from the Iowa Health Study of postmenopausal, predominantly white women where investigators found no association between flavonoid intake and the incidence of diabetes.[157] A possible limitation of these studies is the small variation in the participants' intake of flavonoids and flavonoid-rich foods. Also, flavonoids consist of more

[*] The Finnish Mobile Clinic Health Examination Survey conducted multiphasic screening examinations of 62,440 people, 40 years and older, in different regions of Finland during 1966 – 1972. Food consumption questionnaires were obtained from a random 10,054 participants, in addition to data on disease symptoms, medicine use and smoking habits. Flavonoid intakes were estimated from a database on flavonoid concentrations in Finnish foods.

than 4,000 different compounds, but quantitative information is only available on a handful of them in food composition databases. Further research is evidently needed before firm conclusions can be drawn regarding the role of dietary flavonoids in the development of type 2 diabetes.

vii. Raisins, the Perfect Snack

Snacks are an important part of a child's diet. Young children need more frequent meals than adults and need snacks between meals to support growth and development. However, the snack's nutritional value should take precedence over its caloric content. Overweight and obesity in children have become the most prevalent nutritional problem in the US. Since the 1980s, the rates have doubled for children and tripled for adolescents. More than 15% of all 6 to 19 year olds are overweight. Childhood obesity is often referred to as an epidemic in both the medical and nutrition community settings.

A mid-morning and a mid-afternoon snack should be an opportunity to increase a child's intake of dairy, fruits and vegetables. A healthy snack will also cut down on the feeling of hunger and overeating at meal times. ***The American Dietetic Association*[158] *lists raisins among "The Perfect Snack," foods that provide energy and also help meet nutritional needs. The Committee on Nutrition Standards in Schools, in their recommendations for snacks, foods and beverages offered in schools, has designated raisins as a Tier 1 Food. Tier 1 Foods "provide important health benefits that warrant encouraging consumption by school-age children, and do not exceed levels of certain nutrients and compounds that may be unhealthful for school-age children when consumed in excess."*** [159]

Healthy snacks should be promoted among children participating in sport activities. Too often children are provided with high sugar snacks and drinks, with little nutrient value beyond energy, that override the benefits of exercising. ***Raisins either alone*[160] *or with nuts*[161] *have***

been shown to maintain steady glucose levels and support the demand for energy during sports activities in young soccer players.

viii. Raisins in Sports Nutrition

Carbohydrate-rich foods enhance endurance and performance when eaten either before or during exercise. They help promote carbohydrate availability and maintain blood glucose levels. Although not all studies agree, research suggests that pre-exercise carbohydrate snacks of low to moderate glycemic index (GI) are more effective in enhancing performance than high GI ones.[162] ***Raisins, an excellent source of carbohydrates and a moderate GI food, are the ideal pre-exercise snack to provide sustained energy and ensure optimal athletic performance***.

A recent study[163] compared raisins to a commercial, sucrose-based, high GI sports gel to see if one offered cyclists a performance advantage. Researchers fed endurance-trained cyclists the equivalent of either 3 one-ounce gel packs or 2 small boxes of raisins, 45 minutes before exercising. Both snacks supplied about the same amount of carbohydrates (1 gram of carbohydrate per kilogram of body weight), to supply the readily available fuel needed for strength and endurance. Despite the differences in GI, both snacks elicited similar metabolic responses after 45 minutes of exercise. There was no difference in performance during a subsequent 15-minute exercise bout. The researchers concluded that raisins, being less expensive than sports gels and a source of naturally occurring nutrients, offer an advantage to those athletes desiring a “food first” approach to nourishment. Furthermore, they commented, the benefits of raisin-nut based trail mixes should be studied because research suggests that adding protein in post-exercise feedings may be useful during recovery.[164]

Research shows that carbohydrate-rich foods fed prior to exercise enhance endurance performance. Raisins are a nutritious, cost-effective source of carbohydrate, an excellent choice to prepare an athlete for the upcoming activity.

ix. Triterpenes, Raisins and Dental Health

Raisins may promote healthy teeth and gums. Contrary to longstanding popular perception that raisins promote cavities, recent studies indicate that raisins may benefit oral health. Phytochemicals found in raisins may benefit oral health by fighting bacteria that cause cavities and gum disease.[165] Oleanolic acid, oleanolic aldehyde and 5-(hydroxymethyl)-2-furfural have been shown to inhibit the growth of two species of oral bacteria: Streptococcus mutans, which cause cavities, and Porphyromonas gingivitis, which causes periodontal disease. These compounds were found to be effective at concentrations ranging from about 200mcg to 1,000mcg per ml. Two other compounds isolated from raisins, betulin and betulinic acid, also exhibit antimicrobial activity, but much higher concentrations are needed to achieve similar effects. At concentrations of 31mcg per ml, oleanolic acid also blocks the adherence of S. mutans to experimental surfaces. This quality is significant because adherence is bacteria's first step in forming dental plaque, the film that accumulates on teeth.

Raisins have been thought of as cariogenic foods because they are sweet and sticky. However, recent research has shown that perceived "stickiness" bears little relationship to the actual retention of food particles on tooth surfaces (or objective measures of tooth retention) and the clearance of food-derived sugars from saliva.[166] In these studies, ***raisins have been shown to exhibit rapid clearing rates, placing them among the least retentive foods within a sample of 21 commercially available snack foods.***

Finally, ***the predominant sugars in raisins are fructose and glucose, with minimal amounts of sucrose***. Studies comparing the cariogenicity of different sugars (sucrose, maltose, lactose, fructose and glucose) invariably demonstrate that sucrose, more than any other type of sugar, induces the most smooth-surface-type and fissure-type caries.[167]

X. References

[1] Block G, Patterson B and Subar A. Fruit, vegetables and cancer prevention: A review of the epidemiological evidence. Nutr Cancer 1992; 18:1-9

[2] World Health Organization. Cancer preventive effects. In*: IARC Handbook of Cancer Prevention: Fruit and Vegetables*. IARC Press, Lyon, France. 2008; 8:53-62

[3] Steinmetz KA and Potter JD. Vegetables, fruit and cancer prevention: A review. J Am Diet Assoc 1996; 10:1027-1039

[4] Hung H, Joshipura KJ, Jiang R, *et al.* Fruit and vegetable intake and risk of major chronic disease. J Nat Cancer Inst. 2004; 96(21):1577-1584

[5] Hu B. Vegetarian diets and risk of selected chronic diseases: Plant based foods and prevention of cardiovascular disease: An overview. Am J Clin Nutr 2003;78:544-551

[6] Ness AR and Powles JW. Fruit and vegetables, and cardiovascular disease: A review. Int J Epidemiol 1997; 269(1):1-12

[7] Edwards T. Inflammation, pain and chronic disease: An integrative approach to treatment and prevention. Althern Ther Health Med 2005; 11(6):20-7

[8] Schroeder H. Protective mechanisms of the Mediterranean diet in obesity and type 2 diabetes. J Nutr Biochem 2007; 18(3): 149-60

[9] Feldeisen SE and Tucker KL. Nutritional strategies in the prevention and treatment of metabolic syndrome. Appl Physiol Nutr Metab 2007; 32(1):46-60

[10] Joseph JA, Shukitt-Hale B and Lau FC. Fruit polyphenol and their effects on neuronal signaling and behaviour senescence. Ann N Y Acad Sci. 2007; 1100:470-85.

[11] Lau FC, Shukitt-Hale B and Joseph JA. The beneficial effects of fruit polyphenols on brain aging. Neurobiol Aging 2005; 26(51):128-32

[12] Cho E, Seddon JM, Rosner B, *et al.* Prospective study of intake of fruits and vegetables and carotenoids and risk of age related maculopathy. Arch Opthalmol 2004; 122(6):883-92

[13] Laham-New SA. Fruits and vegetables: the unexpected natural answer to the question of osteoporosis. Am J Clin Nutr 2006: 83(6):1254-5

[14] Maynard M, Cunnell D, Emmett P, *et al.* Fruit, vegetables and antioxidants in childhood and risk of adult cancer. J Epidemiol Comm Health 2003; 57:218-225

[15] Ness AR, Maynard M, Frankel S, *et al.* Diet in childhood and adult cardiovascular and all cause mortality: The Boyd Orr cohort. Heart 2005; 91:894-8

[16] Bal DG and Forester SB. Changing the American diet. Cancer 1991; 67:2671-80

[17] National Academy of Science – National Research Council. Committee on Diet, Nutrition and Cancer. *Diet, Nutrition and Cancer*. National Academy Press, Washington DC. 1982

[18] National Academy of Science – National Research Council. Commission on Life Sciences. *Diet and Health: Implications for Reducing Chronic Disease*, National Academy Press, Washington DC. 1989

[19] Subar A, Heimendiger J, Krebs-Smith SM, *et al. 5 A Day for Better Health: A Baseline Study of American Fruit and Vegetable Consumption*. Rockville MD, National Cancer Institute, 1992

[20] United States Department of Agriculture, United States Department of Health and Human Services. Dietary Guidelines for Americans 2005. http://www.health.gov/dietaryguidelines/dga2005/document/pdf/DGA2005.pdf (accessed December 2007)

[21] Produce for Better Health Foundation 2007. http://www.fruitsandveggiesmorematters.org (accessed January 2007)

[22] Casagrande SS, Wang Y, Anderson C and Gary TL. Have Americans increased their fruit and vegetable intake? The trends between 1988 and 2002. Am J Prev Med. 2007; 32(4):257-63

[23] Patterson BH, Block G, Rosenberger WF, *et al.* Fruit and vegetables in the American diet: Data from the NHANES II survey. Am J Public Health 1990; 80(12):1443-9

[24] Kranz S, Siega-Riz AM, and Herring AH. Changes of dietary quality in American pre-schoolers between 1977 and 1998. Am J Public Health 2004; 94(91): 1525-30

[25] Cavadini C, Siega-Riz AM and Popkin BM. US Adolescent food intake trends from 1965-1996. Arch Dis Child 83; 18(1):18-24.

[26] Krebs-Smith SM, Cook A, Subar AF, *et al.* Fruit and vegetable intakes 1989-1991: A revised baseline for the healthy people 2000 objectives. Am J Public Health 1995; 85(12):1623-9

[27] Wikipedia.org: Raisin. http://en.wikipedia.org/wiki/Raisin (accessed Jan 2008)

[28] Dewell A: Healthy Raisins: History. In: *Healthy Raisins and Other Dried Fruits*. (Spiller G, Marcus MJ, eds.) Sphera Foundation, Los Altos, In press, p. 14
[29] Sun-Maid Growers of California History of Raisins and Dried Fruit http://www.sunmaid.com/en/healthyliving/history_of_raisins_and_dried_fruit.html (accessed Jan 2008)
[30] Trager J: *The Food Chronology: a food lover's compendium of events and anecdotes, from prehistory to the present.* Henry Holt and Company Inc, New York, NY. 1995
[31] George Mateljan Foundation: The World's Healthiest Foods: Raisins. http://www.whfoods.com/genpage.php?tname=foodspice&dbid=33 (accessed Jan 2008).
[32] Petrucci VE: Overview of World Dried Grape Production. In: *A Treatise on Raisin Production, Processing and Marketing*. (Petrucci VE, Clary CD, eds.) Malcolm Media Press, Clovis, CA. 2001
[33] Brothwell D and Brothwell P. *Food in Antiquity: A Survey of the Diet of Early Peoples*. John Hopkins University Press, Baltimore, MD. 1998
[34] Raisin Administrative Committee: Raisins Are Part of History. http://www.raisins.org/history.html (accessed Jan 2008).
[35] Quaschnick L. The history of California raisin industry. In: *A Treatise on Raisin Production, Processing and Marketing*. (Petrucci VE, Clary CD, eds.) Malcolm Media Press, Clovis, CA. 2001
[36] Too Many Grapevines. The Science News-Letter Oct 1997; 12, No. 339:233
[37] Christensen, LP. Raisin Grape Varieties. In: *Raisin Production Manual*. University of California, Agricultural and Natural Resources Publication 3393, Oakland, CA. 2000; pp: 38-47
[38] U.S. Department of Agriculture, Agricultural Research Service. USDA Nutrient Database for Standard Reference, Release 13. Nutrient Laboratory Homepage, http://www.nal.usda.gov/fnic/foodcomp (accessed Dec 2007**)**
[39] Rainey CJ, Nyquist LA, Christensen RE *et al*. Daily boron intake from the American diet. J Am Diet Assoc 1999; 99:335-40
[40] World Health Organization. Boron. In: *Trace Elements in Human Nutrition and Health: Report of the WHO Expert Committee on Trace Elements in Human Nutrition*. Geneva, Switzerland. 1996; pp 175-179
[41] Hunt CD and Stoeker BJ. Deliberations and evaluations of the approaches, endpoints and paradigms for boron, chromium and fluoride dietary recommendations. J Nutr. 1996; 126:S2441- S2451
[42] Hunt CD. Biochemical effects of physiological amounts of dietary boron. J Trace Elem Exp Med 1996; 9:185-213
[43] Devirian TA and Volpe SL. The physiological effects of dietary boron. Crit Rev Food Sci Nutr 2003; 43(2):219-31
[44] Nielsen FH. Boron in human and animal nutrition. Plant Soil. 1997; 193:199-208
[45] Nielsen FH. Evidence for the essentiality of Boron. Environ Health Perspect 1994; 102 7:S59-S63
[46] Naghii MR and Samman S. Role of boron in nutrition and metabolism. Prog Food Nutr Sci. 1993; 17(4):331-49
[47] Gaby AR. Natural treatments for osteoarthritis. Altern Med Rev. 1999; 4(5):330-41
[48] Hunt CD and Idso J. Boron as a regulator of the normal inflammatory response: a review and current progress. J Trace Elem Exp Med 1999; 12: 221-233
[49] Institute of Medicine. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*. The National Academies Press, Washington, DC. 2002
[50] U.S. Department of Health and Human Services and U.S. Department of Agriculture. *Chapter 7: Carbohydrates. Dietary Guidelines for Americans, 2005*. Sixth Edition. Washington, DC: U.S. Government Printing Office, Jan 2005
[51] Camire ME and Dougherty MP. Raisin dietary fiber composition and *in vitro* bile acid binding. J Agric Food Chem 2003; 51:834-837
[52] Burkitt DP, Spiller GA. Dietary fiber: from early hunter-gatherers to the 1990s. In: *Handbook of Dietary Fiber in Human Nutrition*. (Spiller GA, ed.). CRC Press, Boca Raton, FL; 1992; pp 3-6
[53] Niba LL and Niba SN. Role of non-digestible carbohydrates in colon cancer protection. Nutr Food Sci 2003; 33(1):28-33
[54] Ferguson LR and Haris PJ. The dietary fiber debate: More food for thought – commentary. Lancet 2003; 361:1487-88
[55] Spiller GA and Spiller M. Correlation of transit time to a critical fecal weight (CFW) and to substances associated with dietary fiber. In: *Handbook of Dietary Fiber in Human Nutrition*. (Spiller GA, ed.). CRC Press, Boca Raton, Florida 1992; pp 253-256
[56] Spiller, GA, Story JA, Furumoto EJ *et al*. Effect of tartaric acids and dietary fiber from sun-dried raisins on colonic function and on bile acid and volatile fatty acid excretion in healthy adults. British J Nutr 2003; 90:803-7
[57] Scheppach W, Bartram HP and Richter F. Role of short term fatty acids in the prevention of colorectal cancer. Sur J Cancer 1995; 31A(7/8):1077-80
[58] Poole-Zobel B. Insulin-type fructans and reduction in colon cancer risk: a review of experimental and human data. British J Nutr 2005; 93:S73-S90

[59] Beyer-Sehlmeyer G, Glei H, Hartmann F, *et al.* Butyrate is only one of several growth inhibitors produced during gut-flora mediated fermentation of dietary fiber sources. Br J Nutr 2003; 90:1057-1070
[60] Spiller GA, Story JA, Lodics TA, *et al.* Effect of sun-dried raisins on bile acid excretion, intestinal transit time and fecal weight: a dose response study. J Am Coll Nutr 2000; 19(5):703 (Abstract # 113)
[61] Gibson GR and Roberfroid MB. Dietary modulation of the human colonic microbiota. Introducing the concept of prebiotics. J Nutr 1995;125:1401-12
[62] Muir JG, Shepherd SJ, Rosella O, *et al*. Fructan and free fructose content of common Australian vegetables and fruit. J Agric Food Chem 2007; 55:6619-27
[63] Langlands SJ, Hopkins MJ Coleman N, and Cummings JH. Prebiotic carbohydrates modify the mucosa-associated microflora of the human large bowel. Gut 2004; 53:1610-16
[64] Reddy BS, Hamid R and Rao CV. Effect of dietary oligofructose and inulin on colonic preneoplastic aberrant crypt foci inhibition. Carcinogenesis 1997; 18(7):1371-4
[65] Poulsen M, Molck A-M and Jacobsen BL. Different effects of short and long chained fructans on large intestinal physiology and carcinogen-induced aberrant crypt foci in rats. Nutr Cancer 2002; 42(2):194-205
[66] Reddy BS. Possible mechanisms by which pro- and prebiotics influence colon carcinogenesis and tumor growth. J Nutr 1999; 129:S1478-S1482
[67] Brighenti F. Dietary fructans and serum triglycerols: a meta-analysis of randomized controlled trials. J Nutr 2007, 137:2552S-2556S
[68] Fiordaliso M, Kok N, Desager JP, Goethals F, *et al*. Dietary oligofructose lower triglycerides, phospholipids and cholesterol in serum and very low density lipoproteins of rats. 2007; 30(2):163-7
[69] Beylot M. Effects of inulin-type fructans on lipid metabolism in man and animal models. British J Nutr 2005; 93:S163-S168
[70] Abrams SA, Griffin IJ, Hawthorne KM, *et al*. A combination of prebiotic short and long chain inulin type fructans enhances calcium absorption and bone mineralization in young adolescents. Am J Clinic Nutr 2005; 82:471-6
[71] Van den Heuvel PM, Muijs T, Van Dokkum W*, et al.* Lactulose stimulates calcium absorption in postmenopausal women. J Bone Mineral Research 1999; 14:1211-6
[72] Macfarlane S, Macfarlane GT and Cummings JH. Prebiotics in the gastrointestinal tract. Aliment Pharmacol Ther 2006; 24:701-14
[73] Scholz-Ahrens KE, Ade P, Marten B, *et al.* Prebiotics, probiotics, and synbiotics affect mineral absorption, bone mineral content, and bone structure. J Nutr 2007; 137:S838-S846
[74] Scholz-Ahrens KE, Shrezenmeir J. Inulin and oligofructose and mineral metabolism: the evidence from animal trials. J Nutr 2007; 137:S2513- S2523
[75] Salovaara S, Sandberg AS, Andlid T. Combined impact of PH and organic acids on iron uptake by Caco-2 cells. J Agric Food Chem. 2003; 51:7820-4
[76] Salovaara S, Sandberg AS, Andlid T. Organic acids influence iron uptake in the human epithelial cell line Caco-2. J Agric Chem 2002;50(21):6233-8
[77] Shiowatana J, Purawatt S, Sottimai U, *et al*. Enhancement effect study of some organic acids on the calcium availability of vegetables: application of the dynamic *in vitro* simulated gastrointestinal digestion method with continuous-flow dialysis. J Agric Food Chem 2006; 54(24):9010-16
[78] Govindaraj T, Krishna Rau L and Prakash J. *In vitro* bioavailability of iron and sensory qualities of iron-fortified wheat biscuits. Food Nutr Bull 2007; 28(3):299-306
[79] Wu X, Beecher GR, Holden JM, *et al.* Lipophilic and hydrophilic antioxidant capacities of common foods in the United States. J Agric Food Chem 2004 52, 4026-4037
[80] Karadeniz F, Durst RW & Wrolstad RE. Polyphenolic composition of raisins. J Agric Food Chem 2000: 48:5343-50
[81] Parker TL, Wang XH, Pazmino J and Engeseth NJ. Antioxidant capacity and phenolic content of grapes, sun-dried raisins & golden raisins & their effect on *ex vivo* serum antioxidant capacity. J Agric Food Chem 2007, 55, 8472-8477
[82] USDA Database for the flavonoids content of selected foods, (release 2.1, 2007). http://www.nal.usda.gov/fnic/foodcomp/DATA/flav/flav02-1.pdf
[83] Harnly JM, Doherty R, Beecher GR *et al.* Flavonoid content of U.S. fruits, vegetables and nuts. J Agric Food Chem 2006 (submitted)
[84] Liggins J, Bluck LJC and Runswick S. Daidzein and genistein content of fruits and nuts. J Biochem 2000; 11(6):326-31
[85] Reinli K and Block G. Phytoestrogen content of foods–a compendium. Nutr Cancer 1996; 26:123–148
[86] Ames BN and Gould LG. Endogenous mutagens and the causes of aging and cancer. Mutat Res 1995; 250(1-2):3-16

[87] Awika JM, Roomey LW, Prior RL, *et al.* Screening methods to measure antioxidant activity of sorghum and sorghum products. J Agric Food Chem. 2003; 51:6657-62
[88] Wolfe KL and Liu RH. Cellular antioxidant activity (CAA) assay for assessing antioxidants, foods and dietary supplements. J Agric Food Chem 2007; 55:8896-907
[89] Pellegrini N, Serafini M Salvatore S, *et al.* Total antioxidant capacity of spices, dried fruits, nuts, pulses, cereals and sweets consumed in Italy assessed by three different *in vitro* assays. Mol Nutr Food Res 2006, 50, 1030-38
[90] Halvorsen BE, Carlsen MH, Phillips KM, *et al.* Content of redox active compounds (ie, antioxidants) in foods consumed in the United States. Am J Clin Nutr 2006, 84:95-135
[91] Fang N, Yu S and Prior RL. LC/MS/MS characterization of phenolic constituents in dried plums. J Agri Chem 2002; 50:3579-85
[92] Vinson JA, Zubik L, Bose P, *et al.* Dried fruits: excellent *in vivo* and *in vitro* antioxidants. J Am Coll Nutr 2005; 24(1):44-50
[93] Vinson JA, Su X and Bose P. Phenol antioxidant quantity and quality in foods: fruits. J Agri Food Chem 2001; 49(11):5315-21
[94] Cao G, Russell RM, Lischener N and Prior RL. Serum antioxidant capacity is increased by consumption of strawberries, spinach, red wine or vitamin C in elderly women. J Nutr 1998; 128:2383-90
[95] Cao G, Booth SL, Sadowski JA, *et al.* Increases in human plasma antioxidant capacity after consumption of controlled diets high in fruits and vegetables. Am J Clin Nutr 1998; 68:1081-7
[96] Keen CL and Schram DD. The effect of raisins on antioxidant capacity and cholesterol concentration in human subjects. (Unpublished data)
[97] Spiller GA and Miller AF. Effect of sun-dried raisins on the plasma antioxidant status of healthy adults. J Am Coll Nutr 200; 19(5):684 (Abstract 43)
[98] Prior RL, Gu L, Wu X, *et al.* Plasma antioxidant capacity changes following a meal as a measure of the ability of a food to alter *in vivo* antioxidant status. J Am Coll Nutr. 2007; 26(2):170-81
[99] Rankin JW, Andreae MC, Chen O and O'Keefe SF. Effect of raisin consumption on oxidative stress and inflammation in obesity. Diabetes Obes Metabol. March 18, 2008 E-publication ahead of print.
[100] Halliwell B. Effect of diet on cancer development: Is oxidative DNA damage a biomarker? Free Radic Biol Med 2002; 32(10):968-74
[101] Perez DD, Sobel P, Foncea R, *et al*. Wine, diet, antioxidant defenses and oxidative damage. Ann NY Acad Sci. 2002; 957:136-45
[102] Huan HY, Helzlsouer KJ and Appel LJ. The effect of vitamin C and vitamin E on oxidative DNA damage: results from a randomized controlled trial. Cancer Epidemiol Biomarkers Prev 200; 9(7):647-52
[103] Verhagen H, Poulsen HE, Lofts S, *et al*. Reduction of oxidative DNA damage in humans by Brussels sprouts. Carcinogenesis 1995; 16:969-70
[104] Kim HY, Kim OH and Sung MK. Effect of phenol-depleted and phenol-rich diets on blood markers of oxidative stress and urinary excretion of quercetin and kaempferol in healthy volunteers. J Am Coll Nutr 2003; 22(3):217-223
[105] Poulsen HE, Loft S and Vistisen K. Extreme exercise and oxidative DNA modification. J Sports Sci. 1996;14(4):343-6
[106] Urso ML, Clarkson PM. Oxidative stress, exercise and antioxidant supplementation. Toxicol 2003; 189(1-2):41-54
[107] Spiller GA, Schultz L, Spiller M and Ou B. Sun-dried raisins help prevent oxidative DNA damage during intense athletic activity. J Am Coll Nutr 2002; 21(5): 487
[108] Stein J, Keevil JG, Weibe DA, *et al.* Purple grape juice improves endothelial function and reduces LDL cholesterol to oxidation in patients with coronary artery disease. Circulation 1991; 100:1050-1055
[109] American Heart Association, Heart Disease and Stroke Statistics: 2005 Update. Dallas, TX 2005
[110] Wolk A, Manson JE, Stampfer JE, *et al.* Long-term intake of dietary fiber and decreased risk of coronary heart disease among women. JAMA 1999; 281:1998-2004
[111] Todd S, Woodward M, Tunstall-Pedoe H and Bolton-Smith C. Dietary antioxidants and fiber in the etiology of cardiovascular disease and all-cause mortality: results from the Scottish Heart Health Study. Am J Epidemiol 1999; 150:1073-80
[112] Jalili T, Medeiros DM and Wildman REC. Dietary fiber and coronary heart disease. In: *Handbook of Nutraceuticals and Functional Foods*. (Wildman REC ed.) CRC Press, Boca Raton, FL. 2001; pp 131-44
[113] Salas-Salvado J, Bullo M, Perez-Heras A and Ros E. Dietary fibre, nuts and cardiovascular disease. Br J Nutr 2006; 96(2):S46-51

[114] Graf BA, Milbury PE and Blumberg JB. Flavonols, flavones, flavanones and human health: Epidemiological evidence. J Med Food 2005; 8(3) 281-90
[115] Erdman JW, Balentine D and Arab L. Flavonoids and heart health: Proceedings of the ILSI North America flavonoids workshop. J Nutr 2007: 137:718S-37S
[116] Dubick MA and Omaye ST. Grape wine and tea polyphenols in the modulation of atherosclerosis and heart disease. In: *Handbook of Nutraceuticals and Functional Foods*. (Wildman REC ed.), CRC Press, Boca Raton, FL 2001 pp 101-130
[117] Spiller GA, Bruce B and Farquar JW. Lipid-lowering effect of a Mediterranean-type diet, high in total and soluble fiber and monounsaturated fat. Circulation 1996 93(3) Abstract P36
[118] Bruce B, Spiller GA and Farquhar JW. Effects of a plant-based diet rich in whole grains, sun-dried raisins and nuts on serum lipoproteins. Veg Nutrit: Int J 1997; 1(2):58-63
[119] Bruce D, Spiller GA, Klevey LM, *et al.* A diet high in whole and unrefined foods favorably alter lipids, antioxidant defenses and colon function. J Am Coll Nutr 2000; 19(1):61-7
[120] Gardner CD, Coulston A, Chatterjee L, *et al*. The effect of a plant-based diet on plasma lipids in hypercholesterolemic adults. Ann Inter Med 2005; 142:725-33
[121] Puglisi MJ, Mutumgi G and Vaishnav U. Raisins and additional walking have distinct effects of plasma lipids and inflammatory cytokines. Lipids in Health and Disease 2008; 7:14
[122] Spiller GA and Bruce B. Regular consumption of a high fiber carbohydrate foods such as sun-dried raisins and whole wheat bread does not raise serum triglycerides. FASEB J 1998; 93:S163-8
[123]Jemal A, Siegel R, Ward E, *et al.* CA Cancer J Clin 2007; 57(1):43-66
[124] Hodek P, Trefil P and Stiborova M. Flavonoids-potent and versatile biologically active compounds interacting with cytochrome P450. Chem Biol Interact 2002; 139(1):1-21
[125] Ramos S. Cancer chemoprevention and chemotherapy: dietary polyphenols and signaling pathways. Mol Nutr Food Res 2008; 54(5):507-26
[126] Moizis J, Varinska L and Moizisova G. Antiangiogenic effects of flavonoids and chalcones. Pharmacol Res 2008; 57(4):259-65
[127] Lambert J, Hong J and Yang G. Inhibition of carcinogenesis by polyphenols: evidence from laboratory investigations. Am J Clin Nutr 2005;81(suppl.):284S-91S
[128] Kale A, Gawande S and Kotwal S. Cancer phytotherapeutics: role for flavonoids at the cellular level. Phytother Res 2008; 22(5):567-77
[129] Kandaswami C, Lee LT and Lee PP. The antitumor activities of flavonoids *In Vivo* 2005;19(5):895-909
[130] Deschner EE, Ruperto J, Wong G and Newmark HL. Quercetin and rutin as inhibitors of azoxymethane-induced colonic neoplasia. Carcinogenesis 1991; 12:1193-6
[131] Hertog GL and Katan MB. Quercetin in foods, cardiovascular disease and cancer. In: *Flavonoids in health and disease*. Rice-Evans C and Packer L. *Eds* Marcel Dekker, New York 1998; pp 447-67
[132] Verma AK, Johnson JA, Gould MN and Tanner MA. Inhibition of 7,12-dimethyl benz[a]anthracene and N-nitrosomethylkurea-induced rat mammary cancer by dietary flavonol quercetin. Cancer Res 1988; 48:5754-5758
[133] Boots AW, Haenen GR and Bast A. Health effects of quercetin: from antioxidant to nutraceutical. Eur J Pharmacol 2008; 585:325-37
[134] Arts ICW and Hollman PCH. Polyphenols and disease risk in epidemiological studies. Am J Clin Nutr 2005;81(suppl.):317S-25S
[135] Neuhouser ML. Dietary flavonoids and cancer risk: evidence from human population studies. Nutr Cancer 2004;50:1-7
[136] Cui Y, Morgenstern H, Greenland S, *et al*. Dietary flavonoid intake and lung cancer – a population-based case-control study. Cancer 2008; 1122(10):2241-8
[137] Theodoratou E, Kyle J, Cetnarskyj R, e*t al*. Dietary flavonoids and the risk of colorectal cancer. Cancer Epidemiol Biomarkers Prev 2007; 16(4):684-93
[138] Rossi M, Negri E, Lagiou P, *et al*. Flavonoids and ovarian cancer risk: A case control study in Italy. Epidemiology 2008; 123(4):895-8
[139] Bosetti C, Spertini L, Parpinel M, *et al.* Flavonoids and breast cancer risk in Italy. Cancer Epidemiol Biomarkers Prev 2005; 14(4):805-8
[140] Rossi M, Garavello W, Talamini R, *et al*. Flavonoids and the risk of oral and pharyngeal cancer: A case control study in Italy. Cancer Epidmiol Biomarkers Prev 2007; 16(8):1621-5

[141] Rossi M, Garavello W, Talamini R, *et al*. Flavonoids and colorectal cancer in Italy. Cancer Epidemiol Biomarkers Prev 2006; 15(8):1555-8

[142] Bosetti C, Bravi F, Talamini R, *et al*. Flavonoids and prostate cancer risk: A study in Italy. Nutr Cancer 2006; 56(2):123-7

[143] Ling J, Zhang SM, Wu K, *et al.* Flavonoid intake and colorectal cancer risk in men and women. J Epidemiol 2006; 164(7):644-51

[144] Nothlings U, Murphy SP, Wilkens LR, *et al*. Flavonols and pancreatic cancer risk: the multiethnic cohort study. Am J Epidmiol 2007; 166(8):924-31

[145] Mills PK, Beeson L, Abbey DE, *et al*. Dietary habits and past medical history as related to fatal pancreas cancer risk among Adventists. Cancer 1988; 61:2578-85

[146] Dannenberg A. Raisins and catechins inhibit the formation of tumors in the Min/+ mouse, a murine model of intestinal tumorigenesis. Report to the California Raisin Marketing Board, December 1998 (unpublished)

[147] Liu RH. Potential synergy of phytochemicals in cancer prevention: Mechanism of action. J Nutr 2004; 134(suppl.):3479S-485S

[148] deKok TM, vanBreda SG and Manson MM. Mechanisms of combined action of different chemopreventive dietary compounds: a review. Eur J Nutr 2008; 47(suppl.)51-9

[149] National Diabetes Information Clearinghouse. National Diabetes Statistics. http://www.diabetes.niddk.nih.gov/dm/pubs/statistics/#deaths (accessed July 2008)

[150] American Diabetes Association. Nutrition recommendations and interventions for diabetes: A position statement of the American Diabetes Association. Diabetes Care 2008; 31(S1):S61-71

[151] American Diabetes Association. Recipes. http://www.vgs.diabetes.org/recipe/index.jsp (accessed July 2008)

[152] Jenkins JA, Wolever TM, Taylor RH, *et al.* Glycemic index of foods: a physiological basis for carbohydrate exchange. Am J Clin Nutr 1981; 34:362-366

[153] Kim Y, Hertzler RS, Byrne HK and Mattern CO. Determination of the glycemic and insulenemic indexes of raisins in three populations. Presented at Experimental Biology Meeting 2006, Abstract No. 391.6

[154] Oettle GJ, Emmet PM and Heaton KW. Glucose and insulin responses to manufactured and whole-food snacks. Am J Clin Nutr 1987; 45:86-91

[155] Knekt P, Kumpulainen J, Jarvinen R, *et al.* Flavonoid intake and risk of chronic disease. Am J Clin Nutr 2002; 76(3):560-8

[156] Song Y, Manson JE, Buring J, *et al*. Association of dietary flavonoids with risk of type 2 diabetes and markers of insulin resistance in women: a propective and cross sectional analysis. J Am Coll Nutr. 2005; 24(3):376-84

[157] Nettleton JA, Hanack LJ, Scrafford CG, *et al*. Dietary flavonoids and flavonoid-rich foods are not associated with risk of type 2 diabetes in postmenopausal women. J Nutr. 2006; 136(12): 3039-45

[158] American Dietetic Organization. *The Perfect Snack* http://www.eatright.org/cps/rde/xchg/ada/hs.xsl/home_14380_ENU_HTML.htm (accessed September 2008)

[159] Committee on Nutrition Standards for Foods in Schools, Food and Nutrition Board, Institute of Medicine. *Nutrition Standard in Schools: Leading the Way Towards Healthier Youth.* National Academy Press, Washington, DC. 2007; pp 120-122

[160] Spiller GA, Bruce B and Butterfield G. Sun-dried raisins as an energy source in adolescents during soccer. Proceedings of the 16th International Congress of Nutrition, Montreal, Canada, July-Aug 1997

[161] Haskel W, Spiller GA, Bolen K, *et al.* The effects of two pre-event snacks in young soccer players playing soccer match. Med Sci Sports Exercise 2002; 34:5234

[162] Burke LM, Collier GR and Hargreaves M. Glycemic index – A new tool in sports nutrition? Int. J. Sports Nutr 1998; 8:401-15

[163] Kern M, Heslin CJ and Rezende RS. Metabolic and performance effects of raisins versus sports gel as pre-exercise feedings in cyclists. J Strength Conditioning Res 2007; 21(4):1204-7

[164] Zawabszki KM and Yasperlkis BB. Carbohydrate-protein complex increases the rate of muscle glycogen storage after exercise. J Appl Physiol 1992; 72:1854-9

[165]Wu CD, Rivero-Cruz JF, Zhu M, *et al*. Antimicrobial Phytochemicals in Thompson Seedless Raisins (*Vitis vinifera L*) Inhibit dental Plaque Bacteria. Am Society for Microbiology Meeting. 2005 Atlanta, June 5-9

[166] Kahket S, Van Houte LR and Stocks S. Lack of correlation between food retention on the human dentition and consumer perception of food stickiness. J Dent Res 1991; 70(10):1314-9

[167] Newbrun E. Dental effects of sugars and sweeteners in *Sugars and Sweeteners*. (Kretchmer N and Hollenbeck, eds.) CRC Press, Boca Raton, FL. 1991