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AMERICA'S PHYTONUTRIENT REPORT

BONE HEALTH BY COLOR

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Executive Summary

Recent data from *America's Phytonutrient Report: Quantifying the Gap* indicate that based on the five color groupings of phytonutrients, on average, 8 out of 10 Americans (76%) have a "phytonutrient gap." The "phytonutrient gap" referred to in the report was defined as the percentage of the population with phytonutrient intakes less than the median intake ("prudent intake" or PI) by adults who meet recommended daily intakes of fruits and vegetables based on established government guidelines. In other words, the "gap" represents the shortfall of phytonutrient intakes based on a typical level of phytonutrient intake consistent with a diet that is considered to have a prudent amount of fruits and vegetables.

More specifically, based on *America's Phytonutrient Report: Quantifying the Gap*, Americans are falling short in virtually every color category of phytonutrients:

- 69% fall short in green
- 74% fall short in red
- 83% fall short in white
- 76% fall short in purple/blue
- 80% fall short in yellow/orange

This extension report entitled *America's Phytonutrient Report: Bone Health by Color* explores the emerging research on the relationship between phytonutrients and bone health. The analysis includes a look at whether individuals meet fruit and vegetable intake recommendations ("meeters"), and who were found to have relatively higher phytonutrient intakes, also consume higher levels of calcium and vitamin D. In addition, data on top food sources for the phytonutrients with the strongest links to bone health among "meeters" and "non-meeters" are presented.

Key findings from the present analyses include:

- Emerging research in 4 of the 5 color categories suggests phytonutrients may offer benefits specific to bone health
- "Meeters" not only have the benefits of higher intakes of phytonutrients, they also have higher mean intakes of calcium and vitamin D
  - The mean intake of calcium among "meeters" was 1110 mg/day compared to 880 mg/day among "non-meeters"
  - Approximately 50% of "meeters" have average calcium intakes of 1000 mg/day or more, versus only about 25% of "non-meeters"
  - For vitamin D, the intake was 244 IU/day among "meeters" compared to 184 IU/day among "non-meeters"
  - Approximately 50% of "meeters" have intakes of vitamin D of 200 IU/day or more, versus just slightly more than 25% of "non-meeters"
- Top food sources for the phytonutrients of interest for bone are primarily the same between "meeters" and "non-meeters", suggesting that "meeters" and "non-meeters" tend to consume the same types of foods, though "meeters" eat more of these foods

Overall, consuming a wide variety of the most phytonutrient-rich whole fruits and vegetables is the primary dietary goal. Beyond this, a plant-based dietary supplement is an option for those individuals wishing to fill their "phytonutrient gap" in order to better protect their bones.

Nutrilite's *America's Phytonutrient Report: Bone Health by Color* was developed from analyses of dietary recall and health examination data from the National Health and Nutrition Examination Survey (NHANES), ongoing surveys designed to assess the health and nutritional status of the U.S. population, and supplemental nutrient concentration data from the United States Department of Agriculture (USDA) and the published literature. The analyses were completed by Exponent for Nutrilite during February and March 2010.

Introduction

Phytonutrients are natural components of plants thought to offer multiple health benefits. When it comes to bone health and nutrients, most people think of calcium and vitamin D. And while these two nutrients are important to building and maintaining bone density combined with smart lifestyle choices like regular physical activity, there is emerging evidence that phytonutrients which occur naturally in plant-based foods are also important to bone health.

According to the Surgeon General's report on bone health, an estimated 10 million Americans over age 50 have osteoporosis, while another 34 million Americans are at risk.[1] A healthy skeletal system is essential to overall health and quality of life. Bone health begins at an early age as peak bone density occurs in the first three decades of life. During mid-life, the best defense against thinning bones is avoiding premature bone loss. Therefore, bone health must be a life-long commitment.

There are several ways adults of all ages can intervene to protect their bones, including avoiding smoking, limiting alcohol intake and engaging in activities like jogging or weight lifting which cause muscles and bones to work against gravity. Next to regular physical activity, nutrition is equally important to building and maintaining strong bones throughout life.

Mounting research on plant-based diets suggests that phytonutrients, which are plant-derived nutrients that go beyond the basic known vitamins and minerals, may be beneficial to bone health.[2] Population-based research looking at six different dietary patterns shows that a diet high in fruit and vegetable intake may protect bone mineral density (BMD), thereby keeping bones from becoming weak or brittle.[3] A subtle shift away from animal-based proteins towards plant-based proteins, which lowers dietary acid load, may also help promote better bone health.[4]

Unfortunately, recent data from *America's Phytonutrient Report: Quantifying the Gap*[5] indicate that based on the five color groupings of phytonutrients, on average, 8 out of 10 Americans have a "phytonutrient gap" – that is, they fall short in consuming key phytonutrients from foods that could benefit their health.

The "Phytonutrient Gap" Defined

America's Phytonutrient Report: Quantifying the Gap looked at 14 select phytonutrients including carotenoids (alpha-carotene, beta-carotene, beta-cryptoxanthin, lutein/zeaxanthin, lycopene), flavonoids (anthocyanidins, epigallocatechin 3-gallate = EGCG, hesperitin, quercetin), phenolics (ellagic acid, resveratrol), isothiocyanates, isoflavones and allicin in order to determine gaps in consumption. Estimated phytonutrient intakes were developed from food consumption recall data collected in the National Health and Nutrition Examination Survey (NHANES) 2003-2006[6,7] and from nutrient concentration data from the United States Department of Agriculture (USDA) and the published literature. Phytonutrient intakes among U.S. adults meeting ("meeters") and not meeting ("non-meeters") their MyPyramid fruit and vegetable intake recommendations were estimated.

Because phytonutrients are not considered "essential" to human health, there are no corresponding Dietary Reference Intakes (DRIs), like there are for the macro and micronutrients. To be clear, this report is not designed to determine the ideal or even adequate intake level of any phytonutrient. Rather, this report identifies the median dietary intake of phytonutrients by the subpopulation of adults who meet their fruit and vegetable intake recommendations. This median is referred to as the "prudent intake" or PI. Therefore, the "phytonutrient gap" referred to in this report is defined as the percent of the total population with phytonutrient intakes less than the "prudent intake" or PI for the select phytonutrients of interest. In other words, this "gap" represents the shortfall of phytonutrient intakes based on a reference level of phytonutrient intake consistent with a "prudent diet" which is high in fruits and vegetables. It is important to point out that a "prudent diet" may still fall short of desirable or optimal levels of some or even most phytonutrients found in fruits, vegetables, and other plant sources such as teas and beans.

The "phytonutrient gaps" by color based on the original report are listed in Table 1.

Table 1: "Phytonutrient Gaps" by Color Category

COLOR CATEGORY	PHYTONUTRIENT	PERCENT OF AMERICANS WITH A PHYTONUTRIENT GAP
GREEN	EGCG	69
	Isothiocyanate	
	Lutein/zeaxanthin	
	Isoflavones	
RED	Lycopene	74
	Ellagic Acid	
WHITE	Allicin	83
	Quercetin	
PURPLE/ BLUE	Anthocyanidins	76
	Resveratrol	
YELLOW/ ORANGE	Alpha-carotene	80
	Beta-carotene	
	Hesperitin	
	Beta-cryptoxanthin	

The "Phytonutrient Gap" for Bones

Calcium and vitamin D continue to be important nutritional contributors to bone health. Emerging research outlined in this report suggests that the phytonutrients of interest for better bones span virtually all phytonutrient color categories:

Table 2: Bone-Healthy Phytonutrients

GREEN	EGCG, Lutein/zeaxanthin, Isoflavones
RED	Lycopene
WHITE	Quercetin
YELLOW/ORANGE	Beta-carotene, Hesperitin, Beta-cryptoxanthin

Bone is an active tissue in the body. The balance of building and breaking down bone is known as bone metabolism, or bone remodeling. The maintenance of bone mass is regulated by the dual actions of bone-forming cells called osteoblasts which build bone density, and cells which breakdown bone called osteoclasts. This breakdown is referred to as bone resorption. If there is an imbalance of bone remodeling with an excess of resorption, then bone diseases such as osteoporosis ("thinning of the bones") can occur.

Methodology & Data Sourcing

As previously stated, these analyses utilize publicly available data from NHANES and USDA. A total of 8072 adults age 19 years and older in the survey period 2003-2006 provided two complete days of dietary recalls. USDA's Food and Nutrient Database for Dietary Studies 3.0 (FNDDS 3)[8] and its Vitamin D Addendum[9] were the primary source of beta-carotene, beta-cryptoxanthin, lutein/zeaxanthin, lycopene, calcium and vitamin D concentration data for each food reported in NHANES; values from FNDDS 2 were used for foods consumed only in the period 2003-2004.[10] The USDA flavonoid database was used to identify concentrations of EGCG, hesperitin and quercetin,[11] and USDA's isoflavone database was used to identify concentrations of total isoflavones in each food as reported.[12] Estimates of intake of all of the phytonutrients were limited to the food forms (e.g., raw, cooked, canned) for which the phytonutrient concentration data were determined to be applicable. The analyses in this report utilize two-day average intakes from dietary recalls, and are not necessarily indicative of long-term intakes. An additional limitation of this study is the small sample size. Further research is needed in this area of fruit and vegetable consumption and bone health, particularly with respect to dietary patterns, which offer concentrated food sources of the most potent phytonutrients found in foods. Additional discovery research on currently unidentified phytonutrients is equally important to the evolution of this area of investigation.

THE GREEN GROUP

For the green category, the phytonutrients of interest include EGCG, lutein/zeaxanthin and isoflavones.

EGCG

Research: Epidemiological research on EGCG has shown that postmenopausal women who regularly consume tea have stronger bones.[13] Recently, there have been a number of mechanistic studies to further demonstrate how EGCG affects BMD. For example, in cell studies, EGCG has been shown to increase the expression of bone-building genes that stimulate bone mineralization.[14] EGCG has also been shown to help in the differentiation of bone-building cells,[15] which is important for bone density. In addition, because of its anti-inflammatory properties, EGCG has been shown to reduce the formation of osteoclasts, which results in less bone resorption[16] and decreased bone destruction.[17] These positive effects demonstrate the potential importance of EGCG for use in treatment of osteoporosis, as well as in helping ease arthritic symptoms.[16,18]

Prudent Intake (PI): The PI for EGCG was found to be 0.6 mg/day. Among adults 19 years and older, 37% meet this PI, which means that 63% fall short.

Food Sources: EGCG is a plant-derived flavonoid known as a catechin. Green tea is a rich source of EGCG, while black tea has only a negligible amount. Among both "meeters" and "non-meeters" in these analyses, tea was nearly the exclusive source of EGCG, providing 98% and 100% of intake respectively. EGCG can be converted to gallocatechin gallate (GCG) when heated excessively. Therefore, for better nutrition, it is advised not to infuse green tea or its extracts with rapidly boiling hot water.[19]

Lutein/zeaxanthin

Research: Bone research on lutein/zeaxanthin has typically been framed in the context of total carotenoid intake, and more generally in association with total fruit and vegetable intake. Several studies have shown that the antioxidants in fruits and vegetables have a positive effect on bone mineral status,[20] and may help decrease the oxidative stress involved in the bone resorptive process.[21] Recent studies have examined the association between carotenoids and BMD. Results from a longitudinal study on elderly adults show a protective effect between higher intakes of lutein/zeaxanthin and lower incidence of bone loss in the hip joint among men after four years of follow-up.[22] These results help support the concept that carotenoids, including lutein/zeaxanthin in part, may be useful in the prevention of osteoporosis by helping to maintain bone integrity.

Prudent Intake (PI): The PI for lutein/zeaxanthin was found to be 2055 mcg/day. Among adults 19 years and older, 17% meet this PI, which means 83% fall short.

Food Sources: Lutein and zeaxanthin are carotenoids that offer a high level of antioxidant activity. Zeaxanthin is a carotenoid pigment that is derived from lutein. Both are found in green, leafy vegetables such as spinach, salad greens and kale. Lutein is used to fortify chicken feed in order to respond to consumer appeal for a darker yellow-colored yolk, and therefore eggs are also a dietary source. Among both "meeters" and "non-meeters" in these analyses, spinach was the top source of lutein/zeaxanthin in the diet. For "meeters", the other primary contributors were all plant-based and included salad greens, kale, and broccoli, while the second highest source for "non-meeters"' was eggs, followed by salad greens and collards. Lutein is susceptible to degradation when exposed to excessive amounts of light and heat, and is unstable in acidic environments.[23]

Isoflavones

Research: Isoflavones are a class of phytoestrogens, which are plant-derived compounds with estrogenic activity. Isoflavones have the potential for maintaining or even modestly improving bone density when consumed at "optimal" doses.[24] More specifically, research suggests genistein and daidzein are the two isoflavones which appear to show positive effects on bone health. The clinical effectiveness of isoflavones may partly depend on their ability to produce equol, a gut bacterial metabolite of daidzein that shows stronger estrogenic activity than either genistein or daidzein.[25] In animal models, genistein and equol have been shown to improve both the compression strength of vertebra and bone mineralization.[26] The studies that have been conducted in humans have demonstrated a relationship between soy isoflavone intake and increased bone cell growth, differentiation, and synthesis of collagen as well as inhibition of the bone cells that cause degradation of bone tissue.[27] Research has also shown a positive, dose-response relationship between BMD and genistein among premenopausal Japanese women.[28] The potential rationale for a more positive effect among Japanese women is related to their higher intake of soy isoflavones over the course of a lifetime. Other studies have shown that daily supplementation with 120 mg of soy isoflavones over a two-year period among post-menopausal women resulted in a smaller reduction in whole body BMD compared to the control group.[29]

Prudent Intake (PI): The PI for isoflavones was found to be 0.4 mg/day. Among adults 19 years and older, 52% meet this PI, which means that 48% fall short.

Food Sources: The richest sources of isoflavones in the human diet are soybeans and soy products. Among "meeters" in these analyses, soybeans and soy ingredients were the top source of isoflavones in the diet. In contrast, among "non-meeters", soy-containing meal replacements and supplements were the number one source. Isoflavones are bioactive substances and their bioavailability in the human diet depends on a number of factors. Bioavailability is increased by a rapid transit time through the gastrointestinal tract, and is decreased by a fiber-rich diet.[30]

THE RED GROUP

For the red category, the phytonutrient of interest is lycopene.

Lycopene

Research: Lycopene is a carotenoid that exhibits potent antioxidant activity. Laboratory studies have shown that lycopene inhibits the formation of the bone cells that break bone down (osteoclasts), which in turn lowers bone resorption. Lycopene has also been shown to stimulate the growth and differentiation of the bone cells utilized in bone formation (osteoblasts).[31,32] Research among both men and women suggests that lycopene protects against bone loss and helps maintain BMD at several sites across the body including the lumbar spine and hip joint,[33] even after taking into account variables such as smoking, alcohol intake, seasonality, physical activity level and estrogen use by women. Among older adults, higher lycopene intake has been associated with lower risk of hip fracture as well as lower risk of fracture at the shoulder, wrist, elbow, ankle and pelvis.[34]

Prudent Intake (PI): The PI for lycopene was found to be 6332 mcg/day. Among all adults 19 years and older 31% meet this PI, which means that 69% of Americans fall short.

Food Sources: Lycopene is found in tomatoes and tomato products, as well as in fruits such as watermelon and pink/red grapefruit. For "meeters" and "non-meeters" alike, tomatoes and tomato products were the number one food source. The bioavailability of lycopene is enhanced when tomatoes and tomato-based products are heated.[35] Therefore, cooked tomatoes and tomato products as well as raw tomatoes can contribute to better health.

THE WHITE GROUP

For the white category, the phytonutrient of interest is quercetin.

Quercetin

Research: Quercetin is a type of plant-derived flavonoid known as a flavonol, and is a phytoestrogen too. With respect to bone health, quercetin has been shown in both cell and animal models to enhance bone mineralization and to stimulate bone formation.[36] It has also been shown to be useful in repairing bone defects by increasing the chemical activity of the bone matrix.[37] It is thought that quercetin may inhibit bone loss by regulating both systemic and local factors including hormones and cytokines.[38]

Prudent Intake (PI): The PI for quercetin was found to be 17.9 mg/day. Among adults 19 years and older, 20% meet this PI, which means that 80% fall short.

Food Sources: Quercetin is found in concentrated amounts in onions and green tea, but is also present in apples and black tea in lesser amounts. Among "meeters" in these analyses, onions were the top source of quercetin in the diet. In contrast, among "non-meeters" tea was the number one source of quercetin in the diet, with onions ranking second. Increases in quercetin concentration of 7-25% can be achieved by baking and sautéing onions, while boiling produces an 18% reduction in concentration.[39] In terms of flavonoid content of onions, there is a gradient such that the outer layers of a raw onion remain the richest source of flavonoids (including quercetin) even after cooking.[40]

THE YELLOW/ORANGE GROUP

For the yellow/orange category, the phytonutrients of interest include beta-carotene, hesperitin, and beta-cryptoxanthin.

Beta-carotene

Research: Studies consistently show that higher intakes of fruits and vegetables are associated with positive effects on bone mineral status, suggesting phytonutrients may play a role in the prevention of osteoporosis. Potential mechanisms of action for the carotenoid group, including beta-carotene, include protection of the skeleton by reducing oxidative stress, which also inhibits bone resorption. Other mechanisms may include non-antioxidant biological activities of carotenoids and their metabolites such as retinoid-dependent signaling, stimulation of gap junction communications, impact on the regulation of cell growth, and induction of detoxifying enzymes.[41]

Prudent Intake (PI): The PI for beta-carotene was found to be 3787 mcg/day. Among all adults 19 years and older, 16% meet this PI, which means that 84% of Americans fall short.

Food Sources: Beta-carotene is found in many orange fruits and vegetables such as cantaloupe, carrots, and sweet potatoes. As a general rule, the greater the intensity of the orange color of the fruit or vegetable, the more beta-carotene it contains. For "meeters" and "non-meeters" alike, carrots were the number one food source of beta-carotene followed by spinach. Absorption of beta-carotene is enhanced in the presence of fat because beta-carotene is fat soluble. Absorption can also be increased by cooking, which allows the plant cell wall to split and release the colored pigment.

Hesperitin

Research: Hesperitin is among the naturally-occurring citrus flavonoids, which are effective antioxidants. In animal models, hesperitin has been shown to inhibit bone loss while lowering serum and hepatic cholesterol.[42] The bone mechanism of action of hesperitin (thru the HMG-CoA reductase pathway) is likely similar to that of statin drugs. Statins, which are cholesterol-lowering agents, have been shown to induce bone formation and inhibit bone resorption. In animal studies, hesperitin has also been associated with increased concentrations of calcium, phosphorus, and zinc in the femur as well as a decreased number of osteoclasts.[43]

Prudent Intake (PI): The PI for hesperitin was found to be 9.6 mg/day. Among all adults 19 years and older, 23% meet this PI, which means that 77% of Americans fall short.

Food Sources: Hesperidin is a flavanone glycoside consisting of the flavones hesperitin bound to the dissacharide rutinose. Because the USDA flavonoid database quantifies hesperitin (not hesperidin), this report uses hesperitin, which is mainly found in citrus fruits such as lemons and oranges. For "meeters" and "non-meeters" alike, oranges were the primary food source of hesperitin (96 and 93% of total intake, respectively), followed by lemons and limes.

Beta-cryptoxanthin

Research: Studies in the laboratory and in humans have suggested that beta-cryptoxanthin has a unique anabolic effect on bone calcification. Potential mechanisms of action include increases in calcium content, alkaline phosphatase activity and DNA content in bone.[44] Studies have also shown that beta-cryptoxanthin has a direct stimulatory effect on bone formation, and an inhibitory effect on bone resorption.[45] These effects were observed in a controlled human trial that reported that the intake of beta-cryptoxanthin-fortified juice caused a significant increase in osteocalcin concentrations along with a corresponding decrease in bone-specific alkaline phosphatase activity and decrease in bone resorption. Osteocalcin is secreted by osteoblasts, and is thought to play a positive role in bone mineralization and calcium balance.

Prudent Intake (PI): The PI for beta-cryptoxanthin was found to be 223 mcg/day. Among all adults 19 years and older, 20% meet this PI, which means that 80% fall short.

Food Sources: Beta-cryptoxanthin is found in orange and yellow vegetables such as pumpkin and corn, and in fruits like oranges and peaches. Among "meeters" and "non-meeters" alike, oranges and orange juice accounted for nearly two-thirds of total beta-cryptoxanthin in the diet, and therefore were the top food source of this phytonutrient. A recent study suggests that the bioavailability of beta-cryptoxanthin is higher than either beta-carotene or alpha-carotene.[46] This means beta-cryptoxanthin may be a better source of provitamin A than currently believed.

CALCIUM & VITAMIN D

Adequate intakes of calcium and vitamin D are considered mainstays of sound bone health and osteoporosis prevention. For calcium, the adequate intake levels established by the Institute of Medicine (IOM) are 1000 mg/day for adults up to 50 years old, and 1200 mg/day for adults over 50 years of age. While dairy products like yogurt, cheese and milk are good sources of calcium, plant-based sources such as tofu are also a smart dietary addition for calcium. Just one-half cup of firm tofu made with calcium sulfate offers 20% of the daily value of calcium.[47] Plus tofu is a lean protein source, and is very versatile in the kitchen.

For vitamin D, the adequate intake level for adults up to 50 years old is 200 IU, for 51 – 70 years old it is 400 IU and 600 IU for those over 70 years old. Vitamin D is naturally present in a limited number of foods. Key food sources of vitamin D include fatty fish like salmon and tuna, as well as fortified dairy products and some fortified cereals. Research shows over three out of four Americans fall short in healthy intakes of vitamin D,[48] with recent additional research showing that adults 71 years and older and teenage females have the greatest shortfall in vitamin D when it comes to meeting adequate intake levels.[49]

In 2008, scientists at the Agricultural Research Service teamed up with industry and created an excellent plant-based source of vitamin D in the form of mushrooms. Thanks to UV-B light, the kind found in sunshine, some brands of mushrooms are now grown in specific conditions that result in 100% of the recommended intake of vitamin D in one 3-ounce serving (about one half cup).[50] It should be noted that emerging research now points to potential benefits of daily intakes of vitamin D above the levels previously established by the Institute of Medicine (IOM). The reader is advised to keep a watch for an uptick in daily vitamin D intake recommendations. Based on these analyses, a dietary pattern of higher intakes of fruits and vegetables, which corresponds to higher intakes of phytonutrients, also appears to be associated with higher calcium and vitamin D intakes. Specifically, the mean intake of calcium among "meeters" was 1110 mg/day compared to 880 mg/day among "non-meeters." Approximately 50% of "meeters" have average calcium intakes of 1000 mg/day or more, versus only about 25% of "non-meeters." For vitamin D, the intake was 244 IU/day among "meeters" compared to 184 IU/day among "non-meeters." Approximately 50% of "meeters" have intakes of vitamin D of 200 IU/day or more, versus just slightly more than 25% of "non-meeters."

Table 3: 2-Day Average Intakes of Calcium and Vitamin D by "Meeter" and "Non-Meeter" Status

NUTRIENT	"MEETER"* (N=501)				"NON-MEETER" (N=7571)			
		PERCENTILE				PERCENTILE		
	MEAN	25TH	50TH	75TH	MEAN	25TH	50TH	75TH
Calcium (mg/day)	1110	717	1013	1407	880	538	773	1099
Vitamin D (IU/day)	244	104	204	340	184	68	136	240

** Meet recommended intakes of fruits and vegetables as defined by MyPyramid food guidance (www.mypyramid.gov).*

Key Dietary Sources of Phytonutrients by "Meeters" Versus "Non-Meeters"

In order to better understand the dietary choices of "meeters" compared to "non-meeters" with respect to phytonutrient intake, an investigation of contributions by food source was performed. As was outlined in part in the previous sections, the results show that for most phytonutrients, "meeters" and "non-meeters" had the same number one food source with just two exceptions. For isoflavones, the top food source for "meeters" was soybean and soy ingredients, while meal replacements and supplements with isoflavones were the top contributor among "non-meeters." In the case of quercetin, the top food source for "meeters" was onions, while "non-meeters" consumed a greater percentage of total quercetin from tea. For all of the other phytonutrients listed, the same food source was the top contributor among "meeters" and "non-meeters" to total intake of the phytonutrient.

Table 4: Food Source Comparisons between "Meeters" and "Non-Meeters"

PHYTONUTRIENT	HIGHLY CONCENTRATED FOOD SOURCE	TOP FOOD SOURCE IN THE DIET (% CONTRIBUTION TO TOTAL INTAKE OF PHYTONUTRIENT)	
		"MEETERS"	"NON-MEETERS"
EGCG	Green tea	Tea (98%)	Tea (100%)
Lutein/zeaxanthin	Kale	Spinach (31%)	Spinach (27%)
Isoflavones	Cooked soybeans	Soybean/ soy ingredients (40%)	Meal replacement/ supplement (54%)
Lycopene	Tomatoes/tomato products	Tomatoes/tomato products (70%)	Tomatoes/tomato products (83%)
Quercetin	Onions	Onions (26%)	Tea (30%)
Beta-carotene	Baked sweet potato	Carrots (33%)	Carrots (30%)
Hesperitin	Oranges/orange juice	Oranges (96%)	Oranges (93%)
Beta-cryptoxanthin	Cooked pumpkin	Oranges/orange juice (63%)	Oranges/orange juice (64%)

Closing the "Phytonutrient Gap"

Overall, consuming a wide variety of phytonutrient-rich whole fruits and vegetables is the primary dietary goal. Further steps to specifically improve bone status include avoiding smoking, limiting alcohol intake, and increasing regular exercise, especially weight-bearing activities such as jogging or weight lifting.

Given the mounting evidence on plant-based eating as a means to better health in general, including better bone health, it is advisable to eat a wide variety of fruits and vegetables on a daily basis. A simple, actionable goal is to eat two servings from each of the five color categories every day for a total of 10 servings.

Natural plant-based supplements which contain extracted and concentrated phytonutrients are also an option for those individuals wishing to fill their "phytonutrient gap."

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