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From the Farm to the Kitchen Table: A Review of the Nutrient Losses in Foods

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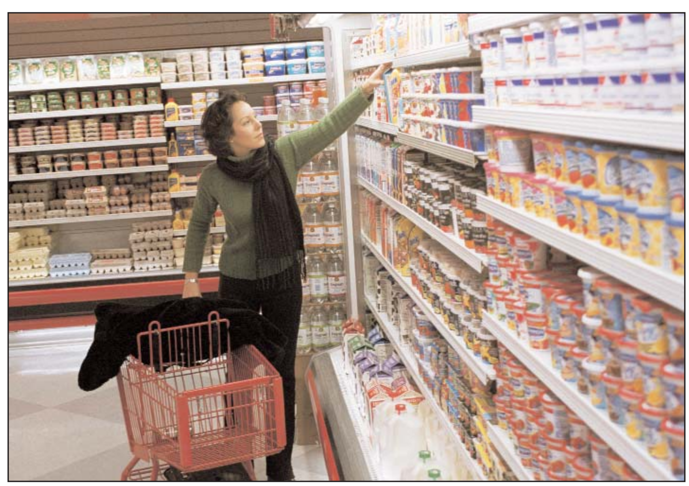
ABSTRACT

Fresh foods are commonly regarded as being the most nutrient-rich. From an extensive review of the nutrition literature, we report that there are significant losses of many nutrients in foods during all stages of food production. Two studies have reported that, compared with data collected as little as 30 years ago, some fresh fruits and vegetables contain lower levels of some vitamins and minerals. Given the documented importance of vitamins, minerals and other phytonutrients in supporting good health, we conclude that fresh fruits and vegetables should be the cornerstone of a healthful diet. Considering the difficulties of accessing fresh, nutrient-rich, unprocessed foods on a daily basis, nutritional supplementation is appropriate for most people. *GlycoScience & Nutrition (Official Publication of Glyco-Science.com: The Nutrition Science Site) 2002;3(5):1-12.*



INTRODUCTION

"Eat your vegetables!" and "Clean your plate!" are refrains that most of us remember from our childhoods. Now, nutritionists have taken our mother's place, reminding us to eat 5-9 servings of fruits and vegetables (along with a healthy balance of dairy products, lean meats, and whole grains). What's so special about fruits and vegetables? Nutritionists have long known that they are valuable sources of health-promoting vitamins, minerals, and fiber. But, these nutrients are only the "tip of the iceberg." As nutrition science becomes more sophisticated we are learning about additional phytonutrients (e.g., nutrients founds in plants) that support good health. The *Food Composition and Nutrition Tables* by Souci et al.,[1] an impressive compendium of the nutrient content of many foods, has reflected this trend. As new nutritional components have become recognized, these authors have continued to add new groups of nutrients to their analyses, recently including data on additional carbohydrates (saccharides), flavonoids, and phytosterols. The total number of phytonutrients may never be known. In 1994, one author estimated that 600 food factors in vegetables were considered to influence human health.[2]

We recently reviewed the health benefits of saccharide and fiber consumption.[3] The importance of adequate flavonoid consumption has been underscored by growing evidence of protection from heart disease, stroke, and some cancers. In response, the USDA is currently compiling a flavonoid database of foods, which should be available online by the end of this year. Souci et al. also provide comprehensive raw food data on dietary phytosterols (i.e., beta-sitosterol, campesterol, and stigmasterol) that cannot be found elsewhere. The benefits of sufficient phytosterol consumption include protection from certain cancers and hyperlipidemia.[4,5,6,7,8]

Based on ongoing developments in nutrition science, the modern view of what levels of specific nutrients we need is also constantly changing.[9,10,11] Assessing the foods of our hunter-gatherer ancestors can offer clues. We are virtually identical genetically to these ancestors, so we know that our nutrient needs should be similar (even when adjustments are included for our reduced caloric requirements). We also know that our ancestors were as tall as we are today,[12] and they did not suffer from diseases now known to be caused by the modern Western diet, such as heart disease, high blood pressure, diabetes, and some cancers.[13] Our ancestors ate a diet that included a limited amount of meat and an abundance of a wide variety of freshly collected unprocessed plant foods — foods that we now know contain a diverse array of phytonutrients.[12,13] Even if we try today to eat a preponderance of fresh, unprocessed foods, these foods are typically grown on a large scale, picked at varying degrees of ripeness (dictated by storage and transportation issues), and then stored before they appear in the produce section of our grocery store. Moreover, many more of our foods today are processed (boiled, microwaved, canned, frozen, refined, pasteurized, protected with preservatives, etc). Thus, it is certainly legitimate to question whether the nutrients that our ancestors obtained from their foods are also present in our foods today.

LEVELS OF NUTRIENTS CAN BE VARIABLE IN FRESH FOODS

Plant species and variety, soil mineral conditions, growing season, time of harvest, and the use of herbicides or plant regulators affect the nutrient content of many fresh foods.[14,15,16]

- The levels of vitamin A, vitamin D, vitamin E and carotenoids in milk increase if a cow is feeding on green grass, as opposed to hay.[17]
- Carotenoid levels generally increase in fruits as they ripen.[18]
- Vine-ripened tomatoes contain higher levels of lycopene, beta-carotene, and soluble fiber than tomatoes ripened off the vine under otherwise identical environmental conditions.[19]

Two recent studies reported that our fresh fruits and vegetables are lower in certain vitamins and minerals today than they were as little as 30 years ago. One analysis compared levels of 7 vitamins and minerals found in 25 common fruits and vegetables between 1951 and 1999. Overall, nutrient losses far exceeded nutrient gains.[20] Of particular concern were losses in foods that are reported to be good sources of a particular nutrient. These include broccoli (calcium, riboflavin, vitamin A, and vitamin C), spinach (riboflavin and vitamin A), and potatoes, cauliflower, strawberries, tomatoes, and green peppers (vitamin C). Whereas one serving of broccoli would have supplied more than the current RDA of vitamin A for adult males in 1951, one would have to eat more than two servings today to obtain the same amount of vitamin A. Two peaches would have supplied the current RDA of vitamin A for adult women in 1951. Today, a woman would have to eat almost 53 peaches to meet her daily requirements! Another study compared data collected in 1930 and 1980 for 8 minerals in 40 fruits and vegetables. The author reported significant losses of calcium, magnesium, copper and sodium in vegetables, and magnesium, iron, copper and potassium in fruits. The foods were also significantly higher in water and lower in dry matter (e.g., fiber) content.[21]

Why are these nutrient losses occurring? The author of the second study speculated that numerous factors could be involved, including plant breeding practices that select for post-harvest handling qualities and cosmetic appeal (rather than nutrient content), changed storage and ripening systems, and reliance on chemical fertilizers that have contributed to soil nutrient losses.[21] Our investigations of the food science literature lend support to this author's opinion. In a random sampling of the Table of Contents in 3 issues of the *Journal of Food Science*, a journal devoted to "the basic and applied aspects of the preparation, nutrition, and safety of the food supply," we found that only about 7% of the articles in this journal were actually devoted to nutrition. The remaining approximately 93% were devoted to technological developments in food processing, particularly those that improve sensory and physical qualities of foods and lengthen shelf-life. In a book chapter devoted to the technological aspects of freezing fish and seafood, the authors stated that the nutrients in frozen fish are not well-known because attention has been focused on the sensory attributes of frozen fish.[22] In another text, the chapter on frozen vegetables began by discussing the importance of using good raw materials. Nutrient content was never included as an important consideration; rather, the author emphasized such features as color, texture, and simultaneous and uniform maturity.[23] Taken as a whole, it appears that food science has focused on technical issues associated with mass production, visual and palatability issues that influence consumer choice, and physical features that are suitable for processing.

Even if we eat the freshest possible fruits and vegetables, they may not be as nutrient-rich as the foods our ancestors enjoyed.

So, even if we eat the freshest possible fruits and vegetables, they may not be as nutrient-rich as the foods our ancestors enjoyed. Now let us consider post-harvest practices that affect our foods before they reach our table — that is, the effects of storage, food preparation (washing and chopping), boiling, microwaving, freezing, canning, pasteurization, milling and refining, and the use of food additives and preservatives. But before we begin, keep in mind that nutritionists have not measured the quantity of many nutrients in foods that have been cooked or processed because nutrient analyses are difficult and expensive. Instead, they have chosen to largely focus on those nutrients for which deficiencies are already widely recognized and/or are thought to be vulnerable to losses. For these reasons, vitamin C and thiamine (vitamin B_1) have been scrutinized at length. It is believed that if these vitamins are depleted, other important nutrients may also be at risk. Other vitamins, such as vitamin D and niacin, are regarded as being stable to food processing and storage and have received limited attention.[24] The data that we compiled from Souci et al.[1] (see below) suggest that such assumptions, however, may not be warranted. Vitamin C and thiamine are thought to be vulnerable partially because they are water-soluble and thus prone to losses when foods are chopped, washed, or cooked in water. The amounts of vitamin C and thiamine in raw, boiled and canned fruits or vegetables are provided in Figures A and B.

We found almost no data reporting the effects of food storage and processing on the other important phytonutrients, such as flavonoids, saccharides, and sterols. Souci et al.[1] have to date only compiled data on these nutrients in raw foods. As their nutritional importance gains acceptance, we expect that such analyses will be performed. Until then, we can only speculate about the fate of these nutrients based on the nutrient data that are currently available.

STORAGE OF FRESH FOODS

Considering the fact that the average fruit or vegetable travels 1,500 to 2,500 miles from the farm to your plate, the impact of storage on nutrients is a worthwhile concern. There is, however, relatively little published information available on this topic.

- Most stored fresh vegetables steadily lose ascorbic acid.[25]
- Green beans refrigerated after harvest lost more than 90% ascorbic acid following 16 days of refrigeration; broccoli lost about 50% of both ascorbic acid and beta-carotene following 5 days of storage.[25]
- Following cold storage for 8 days in the light, spinach lost 22% lutein; in 8 days of dark cold, spinach lost 18% beta-carotene. Carrot carotenoids were stable under both conditions.[26]
- Storage of whole heads of lettuce or endive in the cold dark for 7 days resulted in total flavanol glycoside losses from 7-46%.[27]
- Storage partially depletes milk of vitamin C.[17]
- There are significant losses of vitamin C in orange juice stored in polyethylene or wax paper containers; retention is better in glass containers.[14]
- Ready-to-drink orange juice should be purchased 3-4 weeks before the expiration date and consumed within 1 week of opening.[28]
- Tomato juice retains vitamin C better in cans than glass containers.[14]

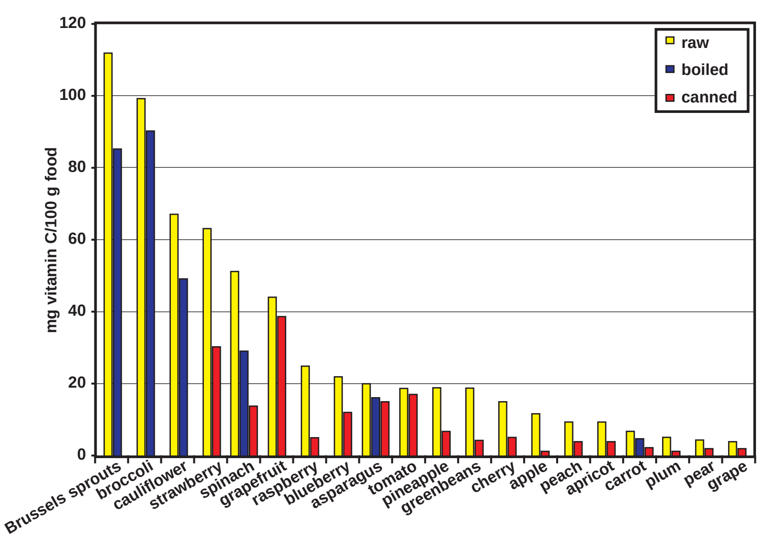
The substantial losses of water-soluble nutrients (flavonoids, vitamin C) and some losses of a fat-soluble nutrient (beta-carotene) suggest that similar losses of the water-soluble saccharides and fat-soluble sterols may also occur during fresh food storage.

STORAGE OF PROCESSED FOODS

Atmospheric oxygen is responsible for most losses of vitamin C during storage.[14] In acidic foods, vitamin C and thiamine

Figure A

Amount of Vitamin C in Raw, Boiled and Canned Fruits and Vegetables*

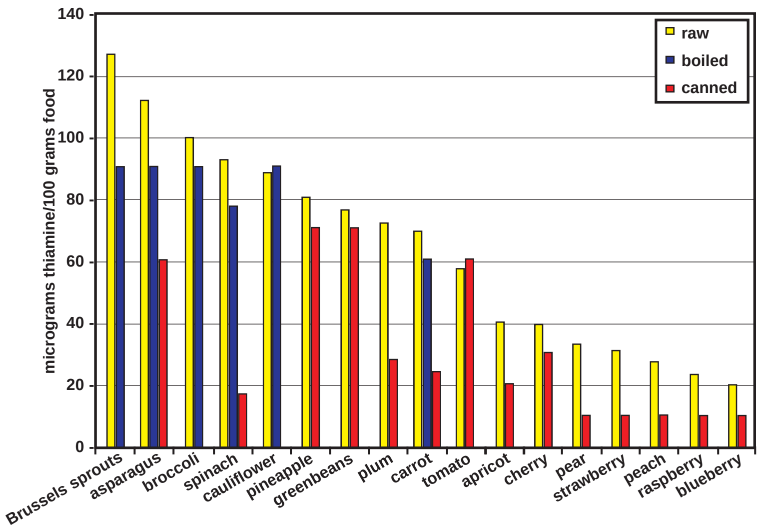


*No data is available if no value is shown.

Souci et al. *Food Composition and Nutrition Tables*. 6th Edition. Boca Raton, Fla.:CRC Press, 2000.

Figure B

Amount of Thiamine in Raw, Boiled and Canned Fruits and Vegetables*



*No data is availabel if no value is shown.

Souci et al. *Food Composition and Nutrition Tables.* 6th Edition. Boca Raton, Fla.:CRC Press, 2000.

are stable.[24]

Plant oils are a major source of vitamins E and K. Losses of vitamin E are high in the presence of oxygen and are accelerated by light, heat, alkaline pH, and the presence of metals (iron and copper).[24] Vitamin K, which is stable to oxidation and most food processing and preparation procedures, is unstable to light (daylight and fluorescent) and alkaline pH. There were extensive losses of vitamin K_1 in plant oils following 2 days of exposure to fluorescent light.[24]

The exposure of foods to light can significantly lower levels of vitamin B_6.[24] Riboflavin (and other flavins) are also light-sensitive.

- Documentation of riboflavin losses from milk stored in glass bottles was one of the first scientific studies demonstrating nutrient losses during food storage.[24]
- Losses may be high even under dim light; enriched pastas lost up to 80% riboflavin within 12 weeks when stored under fluorescent light.[24]

WASHING FOODS

All of the water-soluble vitamins, particularly thiamine, vitamin C, and folate, are vulnerable to losses during washing.[18] Although there are no available data, it is reasonable to speculate that the water-soluble flavonoids and saccharides would also be vulnerable to losses when fruits and vegetables are washed.

CHOPPING FOODS

Losses of antioxidants appear to be rapid and significant when plant foods are chopped, shredded or pureed. It is believed that this is caused by physical release of oxidase enzymes.[29]

- Thiaminase reactions are initiated by bruising, blending, homogenization, or other processes that break tissue structure, leading to breakdown of thiamine.[24]
- Carotenoids become unstable if the food matrix is disrupted.[24]
- Peeling carrots may increase carotenoid loss due to oxidation.[30]
- Shredding of lettuce followed by exposure to light can produce significant losses (0-94%) of flavonoids, depending on the variety (green oak leaf lost 94% and iceberg lost 36%).[27]
- Shredding of endive resulted in 8-32% losses of flavonoids.[27]
- Slicing vegetables can cause loss of sugars.[23]

There are no available data on losses of sterols when fruits or vegetables are chopped.

COOKING OVERVIEW

Minerals are not heat-sensitive, but are vulnerable to leaching into the cooking water.[18] The water-soluble vitamins (particularly thiamine, vitamin C and folate) are the most sensitive to heat.[18]

Cooking losses of vitamin C depend on the degree of heating, the amount that leaches into the cooking water, the surface area exposed to water and oxygen, the acidity of the food, the presence of certain metals, and other factors that facilitate its oxidation and conversion to non-biologically active forms.[24] The presence of vitamin C in food can improve folate retention during heating; the presence of metals can increase loss.[24]

Interconversion of forms of vitamin B_6 (there are many) occurs during heating of foods; this dramatically changes the relative concentrations of these forms, thus also significantly affecting bioavailability.[24] Vitamin B_6 in animal products is more sensitive to heat degradation.[24] Processing losses of vitamin B_6 in vegetables can be large and variable because of physical loss from leaching.[24]

Retinoids and carotenoids are thought to be generally unstable. Typical thermal processing and home cooking reduce vitamin A activity (e.g., the conversion from trans to cis isomers of beta-carotene) by 15-35%.[23] Cis isomers are less biologically active.[24] This occurs particularly at higher temperatures, and when foods are supplemented with iron and copper.[24] A recent study challenged this, stating that the nutritionally important carotenes (particularly beta-carotene and lutein) are heat-*stable* during mild cooking (e.g., steaming or microwaving). It's the minor forms that are more fragile.[31]

While flavonoids are heat-stable, they are highly sensitive to degradation in the presence of light. They are also susceptible to leaching into cooking water and are less stable if the pH is alkaline.[24] Very little information is available about the specific effects of cooking and processing on flavonoids.[32]

The specific amounts of sterols and the nutritionally important saccharides in foods that have been cooked are not yet available. Considering the consistent losses of many nutrients when foods are cooked in water, we expect that there would also be similar losses of these phytonutrients.

BOILING

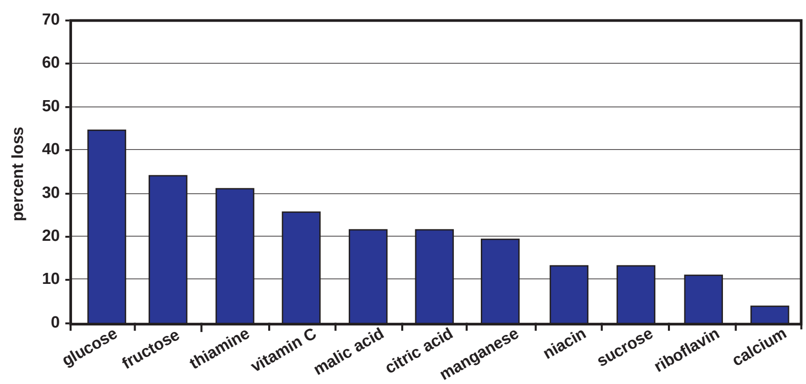
Nutrient losses can be large when foods are heated in the presence of water. While Souci et al.[1] have provided extensive nutrient information for raw fruits and vegetables, many of the nutrients in boiled vegetables have not yet been measured. We have selected two vegetables assessed by Souci et al. and plotted the nutrient data that are available. For both Brussels sprouts (Figure C) and carrots (Figure D), the percent loss is high for many nutrients.

The significant losses of fruit acids (malic acid and citric acid) and common sugars (i.e., glucose, fructose and sucrose), suggest that other water-soluble nutrients would be at risk, including the less common but nutritionally important sugars and the flavonoids (all water-soluble).

When vegetables are boiled, many of the minerals are retained in the cooking water.[16] Steaming and pressure cooking are significantly better than boiling at retaining minerals.[16,33] The most nutritious ways to cook potatoes are to bake them or boil them, unpeeled.[34]

Figure C

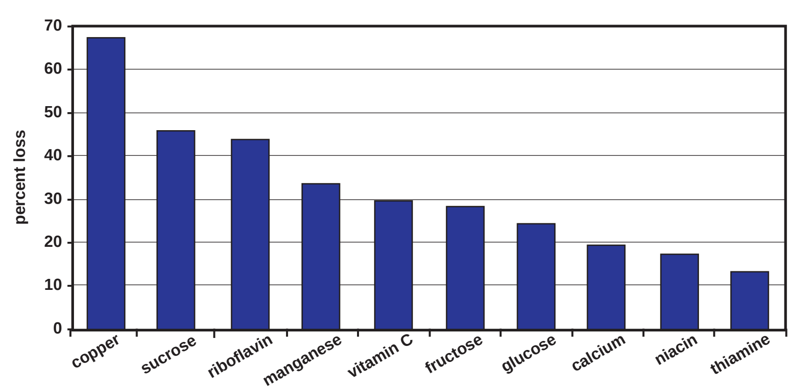
Percent Loss of Reported Nutrients when Brussels Sprouts are Boiled



Souci et al. *Food Composition and Nutrition Tables*. 6th Edition. Boca Raton, Fla.:CRC Press, 2000.

Figure D

Percent Loss of Reported Nutrients when Carrots are Boiled



Souci et al. *Food Composition and Nutrition Tables*. 6th Edition. Boca Raton, Fla.:CRC Press, 2000.

MICROWAVE COOKING

Overall, when foods are microwave-cooked at low power, nutrient retention is equal to or better than that of the same food prepared by conventional methods or held hot in food service operations.[35,36,37,38,39] Vitamin retention improves if small amounts of water are used.[35] We could find no information reporting the effects of microwave cooking on the flavonoids, sterols, and saccharides.

MICROWAVE REHEATING

Low power techniques show equal or better retention of thiamine, riboflavin, vitamin B6, folate, and ascorbic acid when compared with foods that are conventionally reheated.[37]

HEATED-REHEATED FOODS IN FOOD SERVICE OPERATIONS (E.G., CAFETERIA, HOSPITAL FOOD)

Foods that are heated and then reheated, particularly if they are held for long periods over heat, suffer high losses of vitamin C, folate, and vitamin B6. Vitamin A, thiamine, riboflavin, and niacin appear to be relatively stable.[40] It's generally preferable to use a microwave to reheat foods than to hold them over heat for long periods of time.[36,37]

FROZEN FOODS

Overall, fruits retain more nutrients if they are frozen rapidly, stored in airtight packaging, and thawed rapidly.[18] Damage during storage is more common than damage during actual freezing or thawing.[23]

Even though blanching (brief boiling) causes some losses of vitamins, minerals, and saccharides, overall nutrient retention is higher (sometimes twice as high) if vegetables are first blanched before they are frozen.[23]

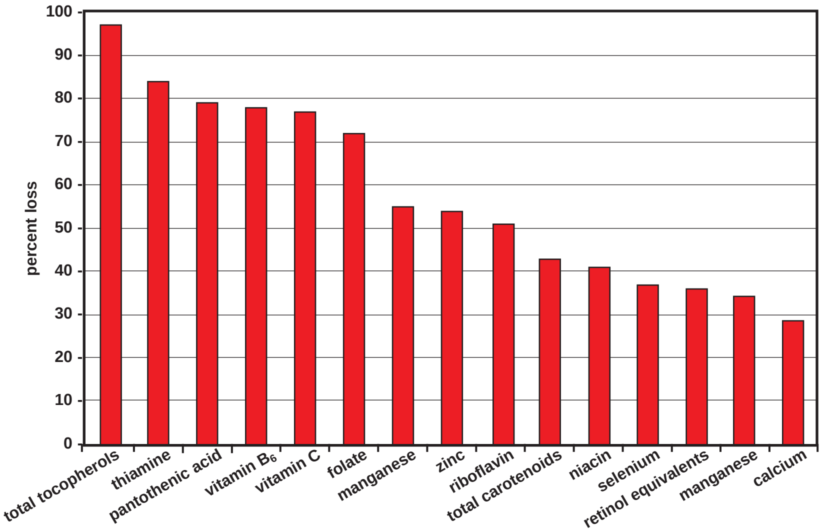
- Up to 45% of vitamin C is lost when vegetables are blanched; unblanched frozen green beans lose more than 75% of their original vitamin C after one year of freezing.[23]
- Fruits and meats are less vulnerable to vitamin C losses.[41]
- Minerals are generally stable to blanching.[23]

Here are some points to keep in mind when buying and storing frozen foods:

- Freezer temperature should be -18° C (or 0° F) or lower. If a constant temperature of -22° C is maintained, many foods will only lose 25% vitamin C in 1 year.[23]
- Buy foods that are well-frozen and then hurry home; temperature fluctuations can cause significant nutrient losses.[23]

Figure E

Average Percent Loss of Reported Vitamins and Minerals when Fruits and Vegetables are Canned



Souci et al. *Food Composition and Nutrition Tables*. 6th Edition. Boca Raton, Fla.:CRC Press, 2000.

- Strawberries frozen with added sugar retain more vitamin C than unsweetened strawberries.[18]
- Thawing fruits in the dark can protect vitamin C.[42]
- When thawing frozen fruits, save the liquid because it contains vitamins and minerals.[42]
- Avoid vegetables that have been frozen a long time; vitamin C and beta-carotene deteriorate steadily over time.[18,23]
- Citrus juice concentrates retain high levels of vitamin C;[41] many other fruits or lime juice suffer significant losses.[42]
- Freezing whole tomatoes or tomato puree for 12 weeks results in significant losses of vitamin C.[42]
- Most losses of B vitamins in meats are due to prolonged storage and thawing.[41]
- Beef, pork and oysters lose substantial amounts of vitamin B_6.[41]
- Pork loses substantial amounts of riboflavin.[41]
- When frozen meats are cooked, they can lose substantial amounts of thiamine, riboflavin, niacin, pantothenic acid, and vitamin B_{12}. These nutrients are retained in the cooking water.[22]

CANNING

When compared with frozen vegetables, canned vegetables can lose about twice as much vitamin C, niacin, and riboflavin and over 3 times as much thiamine. Vitamin A losses are comparable (about 10%).[25] There are significant losses of beta-carotene when sweet potatoes or carrots are canned.[25,43] Canning liquid can contain a significant proportion of the folate originally in the raw product.

Souci et al.[1] have provided more extensive data on the nutrient content of canned fruits and vegetables. We have used these data to calculate the average percent loss of individual nutrients from an average of 13 fruits and vegetables. We report surprisingly high losses of fat soluble nutrients (96% tocopherols, 42% total carotenoids, 35% vitamin A [retinol equivalents]). As expected, losses of thiamine were also high (83%). Similar losses were reported for other B vitamins, including pantothenic acid (78%), vitamin B_6 (77%), folate (71%) and riboflavin (50%) (Figure E).

It is not surprising that Souci et al.[1] reported a 13% loss of pentoses and 16% loss of hexoses when fresh asparagus was canned. Considering the consistency of losses of nutrients when fruits and vegetables are cooked or processed, it is reasonable to speculate that similar losses of other saccharides, flavonoids and sterols also occur when other fruits and vegetables are canned.

PASTEURIZATION OF BEVERAGES AND REMOVAL OF FAT FROM DAIRY PRODUCTS

Pasteurized ready-to-drink orange juice contains 25% less vitamin C per serving compared with frozen concentrates.[28]

In low-fat dairy products, all fat-soluble vitamins are lower or removed, including vitamin A, vitamin D, vitamin E, and vitamin K. Vitamin D that is then added to low-fat milks is stable to pasteurization, boiling, and sterilization.[17] Biotin is stable in whole, pasteurized, 3.5% and 1.5% fat milks, and depleted by half in skim milk.[1]

MILLING AND REFINING

Grains

Consumption of grains (largely refined) has dramatically increased in the past 30 years in the U.S. Rice has almost doubled, pasta has doubled and breakfast cereal consumption has increased by 50%.[44,45] Most vitamins and minerals are in the germ and bran portion of grains. Milling of grains results in major losses (in descending order) of thiamine, biotin, vitamin B_6, folic acid, riboflavin, niacin, and pantothenic acid; there are also substantial losses of calcium, iron, and magnesium. A staggering 70-80% of the original vitamins are lost when grains are milled. The larger the portion of the grain removed, the greater nutrient losses.[41]

- When wheat is milled into wheat flour, there is an approximate 70% loss of vitamins and minerals (range 25-90%) and fiber, 25% loss of protein, 90% loss of manganese, 85% loss of zinc and linoleic acid, and 80% loss of magnesium, potassium, copper, and vitamin B_6.[41]
- The milling of white rice from brown rice results in losses of certain vitamins and minerals, particularly zinc, iron, niacin, and biotin.[41]
- When corn is degermed, the majority of the germ and bran is removed. Degermed corn can be used to manu facture degermed cornmeal, a product that is lower in fat and has an increased shelf-life. Degerming of corn reduces minerals by 70% and significantly reduces fiber, lysine and tryptophan.[41]

- Production of refined cornmeal significantly reduces levels of calcium, zinc, iron, niacin, and biotin.[41]
- Milling of barley reduces minerals by 60% and also causes significant loss of protein and lysine.[41]
- Milling of sorghum and rye causes high mineral losses.[41]

Oils

Refining, bleaching, deacidifying, deodorizing and hydrogenating vegetable oils decrease their levels of vitamin E.[46] Peanut and olive oils are rich in phytosterols. Unrefined peanut oil has 43% more phytosterols than extra virgin olive oil. Refined peanut oil contains 8% less phytosterols; refined olive oil contains 19% less phytosterols. Deodorizing peanut oil causes a 26% loss of phytosterols.[4]

FOOD ADDITIVES AND PRESERVATIVES

Common food additives (such as sodium nitrate) cause folate destruction.[24] Use of sulfite as a food processing aid to inhibit browning reactions can lead to extensive losses of thiamine.[24] Consumption of processed foods containing antimicrobial preservatives[8,47] may also deleteriously affect the bacterial population of our colons, which can in turn affect the bioavailability of nutrients (see below).

NUTRIFIED FOODS

As we have learned, nutritionists have recognized that losses of some nutrients are common when foods are cooked or otherwise processed. We have compiled for the first time data that confirm additional losses of saccharides, fibers, flavonoids, and sterols. Nutritionists have also recognized that nutrient deficiencies in developed countries throughout the world are common, particularly among the elderly, athletes, females, alcoholics, individuals on reduced calorie diets, and, of course, individuals eating many processed foods.[48,49] Food scientists have attempted to deal with this problem by adding nutrients back, thereby creating "nutrified” or “enriched” foods. Products derived from grains have been a popular choice for a number of reasons: they are an economical food source (so that people who need it will get it), they are foods that have suffered major depletion of nutrients, and their taste and texture aren’t significantly altered by the added nutrients.[44]

However, enriched flour, from which most breads are made, is not a whole grain. The processor is simply adding back the niacin, thiamine, and riboflavin that were lost when the flour was refined. But, nothing replaces the lost vitamin E, B_6, pantothenic acid, magnesium, manganese, zinc, potassium, copper, and other phytochemicals.[45] Moreover, most of us are already eating too many refined grain products, so dependence on enriched grains for missing nutrients would certainly be unwise.

Enriched grains also experience nutrient losses during storage and processing:

- Enriched rice can lose significant amounts of vitamin A when stored for 6 months.[44]
- Room temperature storage of enriched breakfast cereals can cause significant depletion of nutrients.[44]
  - 3 months: 25% vitamin A
  - 6 months: 35% vitamin A, 10% vitamin C, 6% riboflavin, 4% vitamin B_{12}
  - 12 months: 50% vitamin A, 41% vitamin C, 23% riboflavin, 19% folate, 17% vitamin B_{12}
- Baking or toasting can deplete nutrients.[44]
- Enriched flour used to make chocolate cake can lose 90% thiamine.
- Cookie baking causes 80% loss of thiamine and 15% loss of folate.
- Commercially baked white bread from enriched flour can lose 36% lysine, 32% vitamin A, 16-23% thiamine, and up to 15% vitamin B_6.
- Baking enriched corn bread can result in 15-91% losses of thiamine, depending on the pH of the batter.
- Toasting white enriched bread can deplete 0-24% thiamine; toasting whole wheat bread can deplete 0-12% thiamine.

Fruits and vegetables also commonly lose nutrients when they are used to make juices.[1] Important variables affecting nutrient content are temperature, pH, exposure to air or light, type of storage container, and presence of antioxidants or preservatives.[14]

- When vitamin C is added to juices, about 40% loss is expected by the end of the normal shelf-life.
- Vitamin C is most stable in pineapple juice and less stable in apple juices blended with other fruits, tomato/vegetable juice blends, and carbonated fruit beverages.
- Vitamin A is quite stable when added to juices and other beverages, but least stable in pineapple juice and pineapple juice drinks.
- Carotenoids are very stable in juices.
- B vitamins are stable in frozen beverages.
- There are significant losses of B vitamins (particularly thiamine and B_{12}) when liquid soy protein is stored at room temperature.

A WORD ABOUT BIOAVAILABILITY

Before we can conclude that we should only consume fresh, unprocessed foods, we must consider the issue of bioavailability, “the fraction of an ingested nutrient that is available to the body for utilization in normal physiological functions or for storage.” The argument can certainly be made that while there are significant nutrient losses when many foods are processed, if they are more bioavailable in the cooked form, perhaps we should cook our foods anyway. Factors that are thought to affect bioavailability are: specific form of nutrient, molecular linkage, amount consumed in a meal, food matrix of nutrient, presence of effectors of absorption and bioconversion, nutrient status of the host, genetic factors, host factors, and other interactions.[50] In other words, bioavailability is very difficult to assess![24,51]

Our knowledge of the bioavailability of carotenoids, folate, and vitamin C is limited.[52,53,54] The bioavailability of fat-soluble nutrients is particularly hard to assess.[51] Plasma measures of nutrients may not accurately measure bioavailability because their metabolites formed in body tissues or by colonic bacteria may not be known.[55] Because vitamin C, beta-carotene and flavonoids have been extensively studied, we will briefly look at the bioavailability of these nutrients.

We have demonstrated that there are extensive losses of many important nutrients during all stages of food production — from the farm to the kitchen table.

Vitamin C[54]

- Iron doesn't seem to affect bioavailability.
- Bioavailability of vitamin C from baked potatoes, raw cabbage, canned tomato juice, orange juice, oranges, raspberries, papayas, guavas, and cooked broccoli is about the same.
- The bioavailability of vitamin C may be 20% lower in raw broccoli when compared with cooked broccoli.

Beta-carotene

The bioavailability of beta-carotene is a complex issue. Heating converts trans-beta-carotene to cis-beta-carotene (which is reportedly less bioavailable). However, the conversion back to trans-beta-carotene can occur in the gut.[56] Bioavailability studies suggest that cooking or fine grinding of some foods may increase the bioavailability by disrupting or softening plant cell walls and disrupting carotenoid-protein complexes,[50] but the data are mixed and the issue is certainly not resolved.[50,52,56]

Flavonoids

The bioavailability of flavonoids varies depending on form. For example, quercetin can be bound to sugars (quercetin glycoside) or occur in the pure form (aglycone).

- Human absorption of quercetin glycosides from onions was 52%, compared with 24% from the aglycone.[57]
- When equal amounts of quercetin from wine, black tea, apples, and fried onions were consumed, the quercetin in onions was the most bioavailable (the onion form is a glucoside; red wine, apples, and black tea are rutinosides).[58,59]

An important point that is often ignored is the fact that the bioavailability of nutrients is influenced by one's habitual diet. Why? The foods that we eat profoundly affect the microflora in our gut. The activities of these colonic bacteria can markedly affect levels of nutrients and their metabolites in the human body.[55,60] For example, there is considerable variation of isoflavone metabolite excretion (particularly a gut bacterial metabolite of diadzein [equol]) between individuals. This variability is strongly influenced by the population of gut microflora, which is influenced by one's habitual diet.[60] Populations most susceptible to vitamin A deficiencies are believed to be less able to absorb carotenoids from foods because of gut problems.[56]

DISCUSSION

We have demonstrated that there are extensive losses of many important nutrients during all stages of food production — from the farm to the kitchen table. Why is the extent of nutrient losses in many foods not more commonly known? There is a striking contradiction between much of the nutrient data compiled by Souci et al.[1] and the USDA's *Table of Nutrient Retention Factors, Release 4* (Table 1 next page).[61]

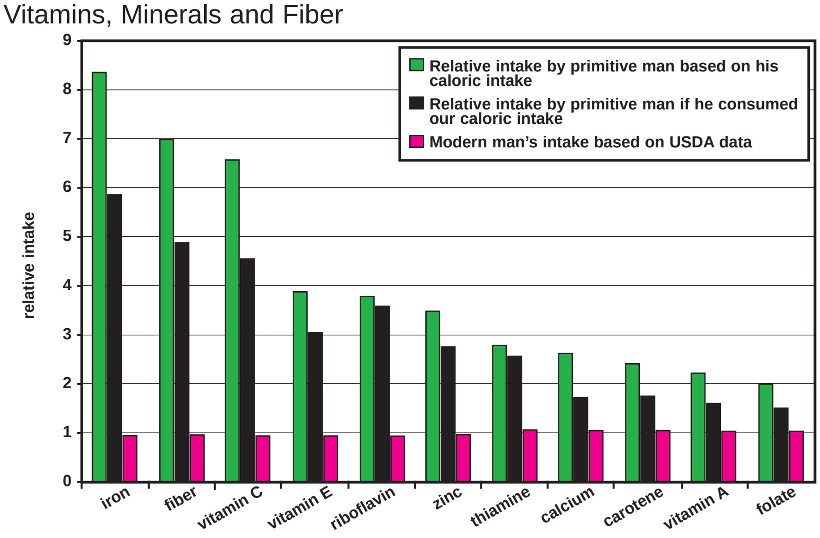
The explanation for these inconsistencies may be found in the introduction to the USDA report, which states: "Nutrient data are frequently lacking for cooked foods. The nutrient composition of a cooked food may be calculated from the uncooked food by applying nutrient retention factors. Most public and private sector databases use these retention factors to calculate nutrient values where analytical data for cooked foods are not available." We propose that for many foods the data are now provided by Souci et al.[1] and these data are preferred over values which are based on assumptions.

These nutrients that are depleted today were consumed in abundance by our hunter-gatherer ancestors. Even if we accept the data provided by the USDA, we consume considerably less vitamins, minerals, and fiber today when compared with our ancestors, even if adjustments are made for needs based on caloric intakes (figure F).[12] We can see from this figure that our ancestors consumed over 8X the amount of iron and 6X the amount of vitamin C that we consume today. The data that we have assembled on saccharides, fiber, flavonoids and sterols suggest that our ancestors probably consumed much higher levels of these food components as well.

Again, considering the nutrient losses presented in the data by Souci et al., these discrepancies may be even larger. There is very little scientific information available about the effects of eating a diet composed entirely of fresh unprocessed foods. In a small study, subjects eating a "living food" diet (berries, fruits, vegetables, roots, nuts)

Figure F

Comparison Between Primitive and Modern Man's Intake of Some Vitamins, Minerals and Fiber



Eaton et al. *Eur J Clin. Nutr.* 1997; 51(4):207-216

Table 1

Nutrient Losses When Fruits and Vegetables are Canned: A Comparison of USDA Nutrient Retention Factors (estimates) vs Actual Food Nutrient Analysis (data)

Nutrient	Percent loss estimates from USDA's Table*	Percent loss calculated from Souci et al. data**
calcium	5%	28%
magnesium	0%	34%
zinc	0%	53%
vitamin C	50%	76%
thiamine	20%	83%
riboflavin	10%	50%
niacin	10%	40%
vitamin B_6	10%	77%
folate	50%	71%
vitamin A (retinol equivalents)	25%	35%
carotenoids	25%	42%

*canned fruit
**canned fruits and vegetables

Souci et al. *Food Composition and Nutrition Tables.* 6th Edition. Boca Raton, Fla.:CRC Press, 2000.
USDA *Table of Nutrient Retention Factors, Release 4* (1998).

exhibited higher blood levels of carotenoids, vitamin C, vitamin E, and flavonoids when compared with a control group eating a mixed diet.[63] Health-promoting Lactobacilli were increased by an order of magnitude in the colons of "living food" subjects. In addition, the "living food" subjects with rheumatoid arthritis and fibromyalgia experienced less joint stiffness and an improved overall feeling of well-being. The increases in gut microflora were correlated with reduced symptoms of rheumatoid arthritis. In a population-based study, the authors reported a decreased risk of pancreatic cancer in individuals who consumed raw foods, foods with no preservatives or additives, or foods prepared by high-pressure cooking, electricity, or microwave.[64]

The health benefits of appropriate vitamin and mineral intake have been exhaustively reviewed.[49] We recently discussed the health benefits of adequate saccharide and fiber consumption.[3] In a study of over 10,000 men and women, people with higher intake of various flavonoids showed protection from ischemic heart disease, cerebrovascular disease, lung cancer, prostate cancer, and asthma.[65] The Western diet contains about 80 mg/day of phytosterols. Asians and vegetarians consume 345-400 mg/day, and both of these groups have a lower incidence of colon, breast, and prostate cancers.[4] The adequacy of all of these nutrients in our diets is questionable when we consider our modern consumption of limited amounts of fresh fruits and vegetables and the abundance of cooked and processed foods that we now know may be deficient.

CONCLUSIONS

We have concluded that mother (as always!) knows best. While the value of cleaning our plates is certainly debatable, there is no question that we should eat our vegetables! However, we have shown that because of the nutrient losses in many of our foods today (including fruits and vegetables), our modern diets may be deficient. What can we do? We can plant a garden every summer and try to take the time to visit our local farmers' market. Farmers' markets can be a great source of fresh, locally grown, vine-ripened produce. These markets can also be a source of heirloom vegetables that have not been genetically selected for marketing purposes and may therefore contain more nutrients. If we are obliged to rely primarily on grocery store produce, we can strive to purchase the freshest foods possible (preferably locally grown), check expiration dates, boil vegetables the minimum amount of time in a small amount of water, save this water to use for soup stocks, keep frozen foods cold enough, and try to eliminate our dependence on processed foods. Whole foods are always the best choice because they contain a veritable cornucopia of nutrients. These are worthwhile efforts! Small increases in fruit and vegetable consumption have been shown to significantly influence health outcomes.[66,67] Nevertheless, because our lifestyles dictate that we rely on many foods that have been cooked or otherwise processed, dietary supplementation makes sense for most people.

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