Nutrient Content of Tomatoes and Tomato Products

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Abstract. **During the last half-century, the fruit of the cultivated tomato (*Lycopersicon esculentum*), commonly considered a vegetable, has become a popular and highly consumed food in the United States. Production of tomatoes in the United States ranks second only to potatoes. As a consequence, tomatoes and tomato-based foods provide a convenient matrix by which nutrients and other health-related food components can be supplied to human beings. Tomatoes and tomato products are rich sources of folate, vitamin C, and potassium. Relative to phytonutrients, the most abundant in tomatoes are the carotenoids. Lycopene is the most prominent carotenoid followed by beta-carotene, gamma-carotene and phytoene as well as several minor carotenoids. The antioxidant activity of lycopene as well as several other carotenoids and their abundance in tomatoes makes these foods rich sources of antioxidant activity. The provitamin A activity of beta- and gamma-carotene, their modest levels in tomato products, and the high consumption of these foods results in a rich supply of vitamin A activity from tomato-based foods. Tomatoes also contain several other components that are beneficial to health, including vitamin E, trace elements, flavonoids, phytosterols, and several water-soluble vitamins.** [P.S.E.B.M. 1998, Vol 218]

Tomatoes constitutes a large agricultural industry and have become a dietary staple for humans in many parts of the world. The cultivated tomato (*Lycopersicon esculentum*) originated in the New World, probably Mexico, from wild species that are native to the Andean region of South America (1, 2). The tomato was taken to Europe in the 16th century and later disseminated to many areas of the world including the United States. As early as 1782, Thomas Jefferson wrote of tomato plantings in Virginia and later referred to the planting and culinary uses of "tomatas" at Monticello (2).

The early, remarkably slow development and acceptance of the fruit of the tomato plant as a food is probably due to its relationship with poisonous members of the nightshade family and fears of toxicity caused by the alkaloid, tomatine (3). Even though tomatine is concentrated in the foliage and the green fruit, is degraded to inert compounds as the fruit ripens, and is much less toxic than alkaloids of other nightshade species, these concerns and superstitions persisted well into the 20th century in northern Europe and North America. However, over the past 50 years, rapid progress has been made in tomato breeding and utilization. Examples of advances include increased yields, improved fruit quality, better handling and storage durability, improved pest resistance, technological developments in the mechanical handling of tomatoes, and the development of a plethora of new tomato-containing food products (1).

Today, Americans consume vast quantities of tomatoes and tomato products. Based on the production of vegetables and melons in the United States, the consumption of tomatoes and tomato products is second only to potatoes (Table I). Notwithstanding the ranking of number two in vegetable production, a net total of 13.3 million tons of tomatoes were available for consumption and processing in 1995. Nearly 85% of these tomatoes, about 11 million tons (Table I), were processed into such products as juice, paste, puree, and sauce, which were either consumed directly or served as ingredients for other processed foods. The remainder of the production, slightly more than two million tons, was consumed as fresh tomatoes. Production of sweet corn and carrots ranked a distant three and four, corresponding to 33% and 14%, respectively, of tomato production (Table I). The huge consumption of tomatoes and tomato products by Americans provides a convenient matrix by which nutrients and other health-related food components can be conveniently supplied to human beings.

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Table I. Production of Selected Vegetables in the United States[a]

Vegetable	Utilization	Production (million tons)
Potatoes	Fresh market	6.7
	Processing	13.1
Tomatoes	Fresh market	2.2
	Processing	11.1
Sweet Corn	Fresh market	1.1
	Processing	3.3
Carrots	Fresh market	1.3
	Processing	0.6

[a]Data from the U.S. Department of Agriculture (4). All production data have have been corrected for exports, imports, and nonhuman consumption uses.

Tomatoes have modest to high concentrations of several traditional nutrients (Table II). The folate content of tomatoes is similar to the concentrations found in carrots and potatoes, and about one-tenth the levels observed in spinach, one of the richest sources of this important vitamin. Tomatoes are also rich sources of potassium and vitamin C, compared to carrots, potatoes, or spinach (Table II). Vitamin A activity, in the form of beta-carotene, is substantially lower in tomatoes compared to carrots or spinach. However, when this modest level of vitamin A activity is combined with the high consumption of tomatoes and tomato juice, these foods are the number four contributor of vitamin A and provitamin A in the U.S. diet (6). Only liver, carrots, and eggs contribute more total vitamin A activity to the U.S. diet than these tomato products. Using similar calculations, tomatoes and tomato juice are the number three contributor of vitamin C, after orange juice and grapefruit/grapefruit juice, and the number nine contributor of potassium to the American diet.

The concentrations of the prominent carotenoids for several tomato products are tabulated in Table III. These data show that lycopene is the carotenoid in highest concentration in tomatoes and tomato products. Other commonly consumed foods that contain lycopene include watermelon and pink grapefruit; however, the concentration of lycopene is about one-half to one-fifth that observed in canned tomatoes (8). As a result, tomatoes and tomato products are the major contributors of lycopene to the diets of Americans (9). Other carotenoids that are easily quantifiable in these foods include phytoene, phytofluene, zeta-carotene, neurosporene, gamma-carotene and beta-carotene, but at much lower concentrations compared to lycopene (Table III). Nonetheless, several of these may have oxygen radical–quenching capability (e.g., beta-carotene) in addition to lycopene (10), which adds to the health benefit of tomatoes. Only very low levels of lutein (an oxygenated carotenoid) have been observed in tomatoes or in foods produced exclusively from tomatoes (7).

Table II. Nutrient Content of Tomatoes and Selected Other Vegetables[a]

Nutrient[c]	Vegetable[b]			
	Tomatoes	Carrots	Potatoes	Spinach
Folate (μg/100 g)	13	14	22	146
Potassium (mg/100 g)	279	227	573	466
Vitamin A (IU/100 g)	743	24,554	-0-	8,190
Vitamin C (mg/100 g)	23	2	14	10

[a] Data compiled from the U.S. Department of Agriculture (5).
[b] Nutrient values are for cooked vegetables. The corresponding USDA Nutrient Data Bank Numbers (NDB No.) are: tomatoes, 11530; carrots, 11125; potatoes, 11364; and spinach, 11458.
[c] Units for each nutrient are shown in parentheses following the nutrient name.

Table III. Carotenoid Content of Tomatoes and Selected Tomato Products

Carotenoid	Vitamin A activity[b]	Tomato Product[a]: Canned tomatoes	Tomato catsup	Tomato sauce
		mg/100 g		
Phytoene	–	1.9	3.4	3.0
Phytofluene	–	0.8	1.5	1.3
zeta-Carotene	–	0.2	0.3	0.8
Neurosporene	–	1.1	2.6	7.0
Lycopene	–	9.3	17.2	18.0
gamma-Carotene	+	1.5	3.0	3.2
beta-Carotene	++	0.2	0.6	0.5

[a] Data from Tonucci *et al* (7).
[b] Vitamin A activity based on similarity of chemical structure of part of carotenoid molecule to retinol.

The vitamin A activity of tomatoes and tomato products is derived from beta- and gamma-carotene (Table III). Until recently, beta-carotene was the only carotenoid in tomatoes thought to have vitamin A activity. However, advances in separations technology and interest in the complete spectrum of carotenoids in foods now permit the routine quantification of several carotenoids that previously went undetected. Among these is gamma-carotene, which is about 7-fold higher in concentration than beta-carotene in tomato products (Table III). The structure of gamma-carotene (one beta end group) suggests that it has about one-half the vitamin A activity of beta-carotene (12 μg gamma-carotene/retinol equivalent [RE] vs. 6 μg beta-carotene/RE [11]). As a result, inclusion of gamma-carotene in the calculation of vitamin A activity for tomato-containing foods substantially increases its value. For example the vitamin A activity of canned tomatoes, derived from beta-carotene only, is 33 RE (330 IU)/100 g (Table III), whereas the addition of the vitamin A activity of gamma-carotene (125 RE or 1250 IU) results in a total vitamin A activity of 158 RE (1580 IU)/100 g. These calculations show that inclusion of gamma-carotene increases vitamin A activity nearly 5-fold for this and similar food products. At this time, only the beta-carotene content of plant foods is used to calculate the vitamin A values for food labels (12), which may be an underestimation of the concentration of this important vitamin in tomatoes and tomato products.

The carotenoids in Table III are listed in order of their biosynthetic sequence (13). Each enzymatic step from phytoene to lycopene adds one double bond to the molecule resulting in lycopene, which is a symmetrical molecule containing 13 double bonds. The steps after lycopene involve enzymatic cyclization of the end groups that result in gamma-carotene (one beta ring) and beta-carotene (two beta rings). The concentration of each carotenoid in this sequence (Table III) provides some clues as to which enzymes may be rate-limiting in this cascade. The very high concentration of lycopene suggests that red tomatoes lack sufficient enzyme activity to convert lycopene to gamma-carotene (insufficient cyclase activity). Furthermore, the high ratio of the concentration of gamma-carotene to beta-carotene indicates that there also is a lack of sufficient enzyme activity to cyclize the second beta ring of gamma-carotene to form beta-carotene. Mechanisms that control these rate-limiting enzymes currently are an active area of research in tomato breeding and production.

Tomatoes contain several additional nutrients and phytonutrients that have been shown to have positive health effects. These include vitamin E (0.32 mg/100 g) and quercetin (0.80 mg/100 g), one of the flavonoids that has very high antioxidant activity relative to alpha-tocopherol (5, 14). A search of one of the phytochemical databases available on the worldwide web (15) indicates that tomatoes also contain several trace elements, phenypropanoids (phenolic acids), phytosterols, and water-soluble vitamins as well as naringenin (Flavonoid). Unfortunately, quantitative values are not associated with entries in this database, therefore, it is difficult to assess the importance that tomatoes and tomato products might have in supplying these components to consumers.

In summary, during the last half-century, the fruit of the cultivated tomato (*Lycopersicon esculentum*) has become a very popular and highly consumed vegetable in the United States. Production of tomatoes in the United States ranks second only to potatoes and is three times greater than sweet corn, the next most highly produced vegetable. Tomatoes provide substantial amounts of several nutrients, including folate, potassium, and vitamins A and C to the diets of American. Currently, tomato-based foods are best known for their rich source of lycopene, a nonvitamin A–active carotenoid that has high oxygen radical scavenging and quenching capacity. In addition, these foods supply several other carotenoids, nutrients, and phytonutrients that may be beneficial to human health.

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