CHAPTER 133

Usage of Tomato (*Lycopersicum esculentum* Mill.) Seeds in Health

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CHAPTER OUTLINE

LIST OF ABBREVIATIONS

DW, dry weight, composition based on a dry matter basis
FA, fatty acid
FW, fresh weight, composition based on a wet matter basis

INTRODUCTION

World tomato production is approximately 130 million tonnes (FAOSTAT, 2008), 30% of which is used to obtain derived products. Tomato paste manufacturing produces 70–75 kg of solid waste per tonne of fresh tomatoes. Seeds account for approximately 10% of the fruit and 60% of the total waste; the amount of seeds produced by the tomato-processing industries is estimated to be around 1.7 million tonnes worldwide.

It is vital that these seeds be reused, because they constitute an environmental problem. Tomato seeds contain nutrients and healthy phytochemical compounds; therefore, they could be used as sources of ingredients to fortify or functionalize food.

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BOTANICAL DESCRIPTION

The tomato, usually referred to as *Lycopersicum esculentum* Mill. (syn. *Solanum lycopersicum* L.), belongs to the Solanaceae family, Solanoideae subfamily, and Solaneae tribe. The correct taxonomic genus is still being debated, although recent studies suggest that Linnaeus was correct in attributing them to *Solanum*.

The *Lycopersicum* genus includes cultivated tomatoes and a small number of closely related wild species native to Central and South America, from Mexico to Peru. Rick (1976) divided the genus in two groups: the *esculentum* complex (six species that are easily crossed with commercial tomatoes), and the *peruvianum* complex (two species that are not easily crossed with *L. esculentum*).

Tomato is a short-lived perennial diploid dicotyledonous (2n=24), cultivated as an annual for its fruits, which are savory in flavor (and, accordingly, often considered to be a vegetable). Plants are herbaceous, usually sprawling, and have weak, woody stems (1–3 m long), with pinnate leaves (10–25 cm long) consisting of five to nine serrated leaflets; both stems and leaves are densely glandular-hairy. Inflorescences are cymes with 2–12 yellow flowers (1–2 cm across), having five pointed lobes on the corolla.

HISTORICAL CULTIVATION AND USAGE

The cherry tomato (*L. esculentum* cv. *cerasiforme*) is indigenous to the Peru–Ecuador area, and is most likely an ancestor of modern cultivated varieties. It reached its present status after a long domestication history, probably initiated in Central Mexico, where the Aztecs used it for cooking, calling it *tomatl* or *xtomatl*.

After the colonization of the Americas, the Spanish took the tomato to their colonies in the Caribbean and the Philippines (whence it moved to South-east Asia), and also introduced it to southern Europe in Spain and in Naples, where the plants grew easily. Tomato fruits were definitely used as food in this area of the Mediterranean by the mid-16th century. However, their acceptance in north-western Europe was relatively slow. Initially, fruits were used solely as tabletop decoration, because it was suspected that they could be poisonous (as members of the nightshade family); they were only widely consumed by the end of the 18th century. Throughout the 17th and 18th centuries Europeans took the tomato to Asia and the USA, where its production and consumption expanded rapidly in the 19th century.

PRESENT-DAY CULTIVATION AND USAGE

Tomatoes are one of the most important fruits in the human diet around the world. Global production has increased by about 30% in the past four decades. The leading producers are China and the USA, followed by Turkey, India, Italy, Iran, Egypt, Brazil, and Spain (FAOSTAT, 2008).

Tomatoes can be consumed as fresh fruit or in processed forms – as tomato preserves, dried tomatoes, and tomato-based foods.

Varieties of tomatoes used in processing have a determinate growth, dwarf habit, concentrated and uniform fruit set and ripening, and are harvested mechanically. Fresh market varieties are generally indeterminate, grown in greenhouses, and harvested by hand. There are a large number of cultivars, differing in size, form, color, flavor, taste, and shelf-life, as well as in the content of nutritional and bioactive compounds. Usually they are grouped into five major types: classic round tomatoes, cherry and cocktail tomatoes, plum tomatoes, beefsteak tomatoes, and vine or truss tomatoes.

The tomato-processing industry produces large amounts of bio-wastes: the seeds and skin of the fruit. Tomato by-products are widely used as animal feed (Persia *et al.*, 2003; da Silva *et al.*, 2009). Other attempts at the practical utilization of this fruit waste include the production of enzymes, bioactive compounds, or biomass to produce biofuels (Giannelos *et al.*, 2005) or to generate electricity. Tomato seeds are also used to give an edible oil, and as a protein source that can be employed in the production of food products such as mayonnaise, margarine, tomato paste, or bread.

APPLICATIONS TO HEALTH PROMOTION AND DISEASE PREVENTION

Applications for tomato seeds that promote health and prevent disease are based on the nutrients and phytochemical compounds that it contains. The seeds are rich in dietary fiber (35% DW), fat (20–30%) and polyunsaturated FAs, proteins (25–30% DW) and essential amino acids, and minerals (Persia *et al.*, 2003).

Tomato seeds are made up of about 27% neutral lipids and about 3.5% waxy materials and polar lipids (Al-Wandawi *et al.*, 1985). Linoleic acid is the predominant FA, followed by oleic acid and palmitic acid (Table 133.1). Other FAs present in lower concentrations are stearic and linolenic acid, among others (Giannelos *et al.*, 2005; USDA, 2009). The nutritional value and health benefits of ω-6 and ω-3 polyunsaturated FAs (linoleic and linolenic acid, respectively) are widely known, including the prevention of cardiovascular diseases. However, the ω-6 to ω-3 FA ratio (20 : 1) in tomato seed oil is relatively high. Moreover, consuming 25 g (two tablespoons) of tomato seed oil per day would be an important contribution to meeting the adult dietary reference intake for FAs (Table 133.2). The ω-6 and ω-3 FA contributions are 59–91% and 29–42% (depending on the sex or age of the reference population), respectively. A very small percentage of *trans* FAs has been quantified in tomato seed oil (0.11%), indicating that this oil is practically unaltered during industrial processing. Therefore, tomato seed oil has a very promising FA profile, although further studies should be conducted to establish its suitability for human consumption.

The crude protein (N × 6.25) in full-fat tomato seeds is 32%, and seed flake obtained after lipids extraction indicates a high protein content (around 40%) (Al-Wandawi *et al.*, 1985)

TABLE 133.1 Fatty Acid (FA) Profile of Tomato Seed Oil (% Total FAs)

Fatty Acids	Reference			
	Cámara *et al.*, 2001	Giannelos *et al.*, 2005	Lazos *et al.*, 1998	USDA, 2009
Total saturated	19	18	21	21
12:0 lauric	–	–	–	0
14:0 myristic	0.13	0.10	0.20	0.21
16:0 palmitic	14	12	14	16
17:0 heptadecanoic	0.12	0.10	0.30	–
18:0 stearic	5.2	5.2	6.0	4.6
20:0 eicosanoic	0.37	0.41	0.30	–
22:0 behenic	0.12	0.090	< 0.1	–
Total monounsaturated	22	23	23	24
16:1 palmitoleic	0.55	0.35	0.50	0.52
18:1 oleic	20	22	22	23
20:1 eicosenoic	–	0.12	0.10	0
22:1 erucic	0.043	–	–	0
Total polyunsaturated	59	59	56	55
18:2 linoleic	56	56	54	53
18:3 linolenic	2.5	2.8	2.0	2.4

TABLE 133.2 Fatty Acid (FAs, % Total Weight of the Oil) Profile of Different Edible Oils Compared to Tomato Seed Oil (USDA, 2009); Contribution of Consumption of 25 g of Tomato Seed Oil to Adult Daily Dietary Intake of FAs

Fatty Acids	Corn	Grapeseed	Sunflower[1]	Olive	Palm	Tomato Seed			DRI[a] (g/day)
						Content (%)	Intake (g/day)	% of DRI[a]	
Total saturated	13	9.6	9.9	14	49	20	4.0	–	–
12:0 lauric	0.024	0	0	0	0.10	0	0	–	–
14:0 myristic	0	0.10	0.057	0	1.0	0.20	0.04	–	–
16:0 palmitic	11	6.7	3.7	11	44	15	3.0	–	–
17:0 heptadecanoic	0.067	–	–	0.022	–	–	–	–	–
18:0 stearic	1.9	2.7	4.3	2.0	4.3	4.4	0.88	–	–
20:0 eicosanoic	0.43	–	–	0.41	–	–	–	–	–
22:0 behenic	0	–	1.0	0.13	–	–	–	–	–
Total monounsaturated	28	16	84	73	37	23	4.6	–	–
16:1 palmitoleic	0.11	0.30	0.095	1.3	0.30	0.50	0.10	–	–
18:1 oleic	27	16	83	71	37	22	4.4	–	–
20:1 eicosenoic	0.13	–	0.96	0.31	0.10	0	0	–	–
22:1 erucic	0	–	0	0	0	0	0	–	–
Total polyunsaturated	55	70	3.8	11	9.3	53	11	–	–
18:2 linoleic	54	70	3.6	9.8	9.1	51	10	71–59 (91–83)[b]	*14–17 (11–12)*[b]
18:3 linolenic	1.2	0.10	0.19	0.76	0.20	2.3	0.46	29 (42)[b]	*1.6 (1.1)*[b]

The nutritional value, based on the FA profile, of the tomato seed oil is comparable to other edible oils such as corn oil. Moreover, consuming 25 g of tomato seed oil per day would be an important contribution to meeting the adult dietary reference intake (DRI) for proteins and FAs.

[1]*Sunflower oil high in oleic;*

[a]*Based on adequate intakes (in italics); Source: National Academy of Sciences (2005);*

[b]*When the references are different for males and females, the values for females are indicated in parentheses.*

(Table 133.3). Assuming a daily consumption of 20 g (two tablespoons) of tomato seeds per day, for an adult, the contribution to the protein intake in humans is considerably (Table 133.3) higher than that of cereal grains or other seed kernels. With the exception of tryptophan, all essential amino acids are present in tomato seeds (Table 133.4). Glutamic acid and aspartic acid are the most predominant amino acids. The major essential amino acids in seeds are arginine, lysine, valine, and leucine (Persia *et al.*, 2003; da Silva *et al.*, 2009). However, the most limited amino acids in defatted tomato seed flour are methionine and cysteine. Moreover, the contribution to the daily intake of essential amino acids of a 20-g serving of tomato seed is very significant, representing between 10 and 30% (depending on the sex or age of the reference population). It is important to highlight the high content of lysine and threonine in tomato seeds, which could substantially improve the protein quality of cereal products. The functional properties of tomato seed meal and protein concentrates are comparable to other plant proteins. Proteins of de-oiled meal and alkali-extracted concentrate of tomato seeds are classified into albumin, globulin (the major protein), gliadin, and glutenin. The quality of tomato seed protein, evaluated by using biological studies, indicates that tomato seeds contain high-quality plant proteins that could be supplemented into various food products (Sogi *et al.*, 2005).

The mineral content of tomato seed flour is considerable (Table 133.5), being the levels of all elements higher in tomato seed when compared with those of cereal grains and more similar to those of seed kernels (Table 133.3). A 20-g serving of tomato seeds would be a significant contribution to the daily intake of minerals such as copper, iron, magnesium, manganese, and zinc in general, but especially beneficial in respect of copper and manganese. The contribution to the intake of iron and zinc would also be considerable (35–79% and 27–38% of the

TABLE 133.3 Amino Acid [g/100 g Dry Weight (DW)] Profile, Protein Content (g/100 g DW) and Mineral Content (mg/100 g DW) of Different Cereal Grains and Seed Kernels (USDA, 2009) Compared to Tomato Seed (Al-Wandawi *et al.*, 1985); Contribution of Consumption of 20 g of Tomato Seeds to the Adult Daily Dietary Intake of Amino Acids, Total Proteins, and Minerals

Nutrient	Barley[1]	Corn[2]	Rice[3]	Wheat[4]	Pumpkin	Sesame[5]	Sunflower[6]	Tomato seed			DRI[b] (g/day)[a]
								Content (%)	Intake (g/day)[a]	% of DRI[b]	
Amino acids											
Tryptophan	0.21	0.067	0.10	0.21	0.58	0.39	0.35	–	–	–	0.39 (0.32)[c]
Threonine	0.42	0.35	0.29	0.40	1.0	0.74	0.93	1.3	0.33	22 (28)[c]	1.5 (1.2)[c]
Isoleucine	0.46	0.34	0.34	0.51	1.3	0.76	1.1	0.78	0.20	14 (17)[c]	1.4 (1.2)[c]
Leucine	0.85	1.2	0.66	0.93	2.4	1.4	1.7	1.5	0.38	12 (15)[c]	3.1 (2.5)[c]
Lysine	0.47	0.27	0.30	0.38	1.2	0.57	0.94	1.7	0.43	15 (19)[c]	2.9 (2.3)[c]
Methionine	0.24	0.20	0.18	0.21	0.60	0.59	0.49	0.38	0.10	9.1 (11)[c]	Met + Cys 1.4 (1.2)[c]
Cystine	0.28	0.17	0.096	0.32	0.33	0.36	0.45	0.11	0.028		
Phenylalanine	0.70	0.46	0.41	0.65	1.7	0.94	1.2	0.99	0.25	25 (30)[c]	Phe + Tyr 2.6 (2.2)[c]
Tyrosine	0.36	0.38	0.30	0.40	1.1	0.74	0.67	1.6	0.40		
Valine	0.61	0.48	0.47	0.62	1.6	0.99	1.3	1.2	0.30	17 (20)[c]	1.8 (1.5)[c]
Histidine	0.28	0.29	0.20	0.32	0.78	0.52	0.63	0.52	0.13	13 (16)[c]	1.0 (0.83)[c]
Arginine	0.63	0.47	0.60	0.64	5.4	2.6	2.4	1.8	0.45	–	–
Alanine	0.49	0.71	0.46	0.49	1.5	0.93	1.1	1.0	0.25	–	–
Aspartic acid	0.78	0.66	0.74	0.70	3.0	1.6	2.4	2.4	0.60	–	–
Glutamic acid	3.3	1.8	1.6	4.3	6.2	4.0	5.6	5.1	1.3	–	–
Glycine	0.45	0.39	0.39	0.55	1.4	1.2	1.5	0.94	0.24	–	–
Proline	1.5	0.82	0.37	1.4	1.3	0.81	1.2	0.92	0.23	–	–
Serine	0.53	0.45	0.41	0.65	1.7	0.97	1.1	1.0	0.25	–	–

Continued

TABLE 133.3 Amino Acid [g/100 g Dry Weight (DW)] Profile, Protein Content (g/100 g DW) and Mineral Content (mg/100 g DW) of Different Cereal Grains and Seed Kernels (USDA, 2009 Al-Wandawi *et al.*, 1985

Nutrient	Barley[1]	Corn[2]	Rice[3]	Wheat[4]	Pumpkin	Sesame[5]	Sunflower[6]	Tomato seed			DRI[b] (g/day)[a]
								Content (%)	Intake (g/day)[a]	% of DRI[b]	
Total proteins	12	9.4	7.9	14	30	18	21	32	8.0	14 (17)[c]	56 (46)[c]
Minerals											
Calcium	33	7	23	34	46	975	78	153	38[a]	4–3	*1000–1200*[a]
Copper	0.50	0.31	0.28	0.43	1.3	4.1	1.8	5	1.3[a]	144	0.90[a]
Iron	3.6	2.7	1.5	5.4	8.8	15	5.3	25	6.3[a]	79 (79–35)[c]	8 (8–18)[a,c]
Magnesium	133	127	143	90	592	351	325	400	100[a]	25 (32)[c]	400–420 (310–320)[a,c]
Manganese	1.9	0.49	3.7	3.4	4.5	2.5	2.0	13	3.3[a]	143 (183)[c]	*2.3 (1.8)*[a,c]
Phosphorus	264	210	333	402	1233	629	660	–	–	–	700[a]
Potassium	452	287	223	435	809	468	645	650	163[a]	3	*4700*[a]
Sodium	12	35	7.0	2.0	7.0	11	9.0	200	50[a]	4–3	*1300–1500*[a]
Zinc	2.8	2.2	2.0	3.5	7.8	7.8	5.0	12	3.0[a]	27 (38)[c]	11 (8)[a,c]

Tomato seed protein, the essential amino acids scores and the mineral content are similar, or even better, than those of cereal grains and seed kernels. Their contribution to the protein, essential amino acid and mineral intake in humans is considerable.

[1]*Hulled;*
[2]*Yellow;*
[3]*Brown, long-grain, raw;*
[4]*Flour, wholegrain;*
[5]*Whole, dried;*
[6]*Dried;*
[a]*For minerals, the data correspond to mg/day;*
[b]*Dietary reference intake (DRI) based on recommended dietary or adequate intakes (in italics); Source: National Academy of Sciences. (2006);*
[c]*When the references are different for males and females, the values for females are indicated in parentheses.*

TABLE 133.4 Amino Acid (g/100 g Dry Weight) Profile of Tomato Seed

Amino Acids	Reference			
	Al-Wandawi *et al.*, 1985	da Silva *et al.*, 2009[1]	Knoblich *et al.*, 2005[1]	Persia *et al.*, 2003
Tryptophan	–	–	–	–
Threonine	1.3	0.75	0.45	0.82
Isoleucine	0.78	0.78	0.46	0.97
Leucine	1.5	1.3	0.78	1.5
Lysine	1.7	1.1	0.61	1.3
Methionine	0.38	0.33	0.19	0.39
Cystine	0.11	0.30	0.21	0.40
Phenylalanine	0.99	0.93	0.54	1.2
Tyrosine	1.6	–	–	0.90
Valine	1.2	0.90	0.56	1.1
Histidine	0.52	0.43	0.26	0.55
Arginine	1.8	1.6	0.76	2.1
Alanine	1.0	0.94	0.60	1.1
Aspartic acid	2.4	2.2	1.5	2.6
Glutamic acid	5.1	3.1	3.0	4.7
Glycine	0.94	1.1	0.72	–
Proline	0.92	1.1	0.53	1.4
Serine	1.0	0.99	0.56	1.2

With the exception of tryptophan, all essential amino acids are present in tomato seeds.
[1]*Tomato seeds and peels.*

TABLE 133.5 Mineral (mg/100 g Dry Weight) Content of Tomato Seed

Minerals	Reference			
	Alvarado et al., 2001[1]	Al-Wandawi *et al.*, 1985	da Silva *et al.*, 1999[1]	Knoblich *et al.*, 2005
Calcium	170	153	160	140
Copper	1.3	5.0	–	1.6
Chromium	–	< 1.0	0.13	–
Iron	25	25	49	24
Magnesium	240	400	–	210
Manganese	1.8	13	–	2.5
Nickel	–	0.90	–	–
Phosphorus	300	–	–	400
Potassium	1310	650	1153	1530
Rubidium	–	0.80	–	–
Sodium	–	200	16	280
Strontium	–	1.7	–	–
Sulfur	–	–	–	190
Zinc	17	12	–	3.7

Tomato seeds are rich in minerals such as potassium, magnesium, phosphorus, sodium and calcium and, to a lesser extent, manganese, iron, zinc and copper.
[1]*Tomato seeds and peels.*

recommended dietary intake, respectively). However, these minerals may be poorly provided by certain plant-based foods, because bioavailability of non-heme iron and dietary zinc is greatly influenced by both dietary inhibitors and enhancers that should be studied more deeply in tomato seeds. Finally, the consumption of tomato seeds contributes relatively little to the intake of calcium and potassium (Table 133.3).

Tomato seed is a good source of antioxidants because it is rich in phytochemical compounds. It is an important reservoir of phenolic compounds. There is growing recognition that many phenolic secondary metabolites present in seeds may be beneficial to human health to some degree, mediated via antioxidant actions. Toor and Savage (2005) evaluated that the hydrophilic phenolic content in the seeds of three commercially grown tomato cultivars (Excell, Tradiro, and Flavourine) is 22 ± 4 mg gallic acid equivalents/100 g FW. Lipophilic phenolics only represent 12–15% of the total phenolic compounds present in the seed fraction of tomatoes. Moreover, the total amount of phenolics (hydrophilic and lipophilic) and flavonoids (12 ± 1 mg rutin equivalents/100 g FW) in seeds of the three cultivars of tomato studied are higher than the mean phenolic content of their pulps. Flavonoids such as quercetin (6.2 ± 0.5 mg/100 g FW), kaempferol (7.1 ± 0.4 mg/100 g FW) and naringenin enantiomers were identified in tomato seeds by Torres *et al.* (2005). *S*-naringenin is the predominant glycosylated enantiomer. Therefore, *S*-naringenin (3.1 ± 0.3 mg/100 g FW) accounts for around 60% of total naringenin in tomato seeds. Moreover, *S*-naringenin has a longer biological half-life than *R*-naringenin, which could be important for bioavailability studies, because chirality may have a significant influence on physiological action and disposition. Peng *et al.* (2008) found that seeds of Anqi, Chunjiao, and Mava tomato cultivars contain naringenin (between 0 and 0.20 mg/100 g FW), rutin (between 0.18 and 1.5 mg/100 g FW), chlorogenic acid (between 2.8 and 3.7 mg/100 g FW), and myricetin (between 0 and 0.64 mg/100 g FW).

Furthermore, carotenoids and different xanthophylls have been identified in tomato seeds (Table 133.6). In general, the carotenoid composition of the seeds reflects the qualitative pattern of the whole fruit (Rymal & Nakayama, 1974). However, the total carotenoid concentration is much lower than in the whole fruit, and the lycopene content is particularly low. β-Carotene, having a comparatively high concentration, emerges as the major carotenoid in the seeds. Lutein is the major xantophyll pigment in the seeds. Lutein, β-carotene, and lycopene are the major pigments of the seeds from the Chico Grande and Rutgers (red fruits) cultivars, and lutein, β-carotene and ζ-carotene (all-*trans* forms) are the major pigments of Golden Jubilee (yellow fruits) seeds (Rymal & Nakayama, 1974). Therefore, β-carotene is more common than lycopene in seeds of red-fruited cultivars, and ζ-carotene in seeds of yellow-fruited cultivars. Evidence has been presented that individuals with low carotenoid intake

TABLE 133.6 Carotenoid Content of Tomato Seed

Carotenoid	Reference					
	Rymal & Nakayama, 1974	Rymal & Nakayama, 1974	Rymal & Nakayama, 1974	Knoblich *et al.*, 2005	Rodríguez *et al.*, 1975	Toor & Savage, 2005
	Content (mg/l oil)			Content (μg/100 g fresh weight)		
β-Carotene	129	11	289	176	1290	—
Lycopene	85	9.0	n.d.	1144	820	1600
α-Carotene	—	—	—	—	60	—
γ-Carotene	—	—	—	—	80	—
ζ-Carotene	—	—	—	—	n.d.	—
Phytofluene	—	—	—	—	40	—
β-Zeacarotene	—	—	—	—	30	—
Lutein	386	180	776	57	50	—
Zeaxanthin	—	—	—	8.8	—	—
Plant material	cv. Chico Grande	cv. Rutgers	cv. Golden Jubilee	By-product	cv. Cerasiforme	Several cultivars

Phytochemical compounds such as carotenoids (lycopene, β-carotene) and xanthophylls (lutein and zeaxanthin) have been identified in tomato seeds. n.d., not detected.

and/or low carotenoid blood levels have an increased risk of degenerative diseases. According to epidemiological studies, carotenoids play an important role in the prevention of cancer, cataracts, and cardiovascular disease.

The following compounds are among the constituents of tomato seed oil unsaponifiables (Lazos *et al.*, 1998; Malecka, 2002): α-, β- and δ-tocopherols, and sterols including β-sitosterol, campesterol, stigmasterol, and Δ-5-avenasterol. In addition, trace to minor amounts of 24-methylenecholesterol, brassicasterol, Δ(7)-campesterol, clerosterol, Δ(7),(24)-stigmastadienol, Δ(7)-stigmastanol, Δ(7)-avenasterol, erythrodiol, and citrostadienol have also been found. Some of these sterols, as well as tocopherols, contribute to the antioxidant properties of tomato seed unsaponifiables. Moreover, plant sterols are effective in lowering total plasma and low density lipoprotein cholesterol by inhibiting the absorption of cholesterol from the small intestine.

Tomato seed also contains other phytochemical compounds, such as ascorbic acid, with a content between 8.2 and 17 mg/100 g FW (Toor & Savage, 2005; Peng *et al.*, 2008).

The antioxidant activity in the hydrophilic extracts (114 ± 20 μM Trolox equivalent antioxidant capacity/100 g) of tomato seeds from Excell, Tradiro, and Flavourine tomato cultivars is the major contributor (91—93%) to their total antioxidant activity (hydrophilic and lipophilic) (Toor & Savage, 2005). Furthermore, the seeds are an important contributor to the major antioxidants (28 ± 7% of total phenolics, 25 ± 4% of total flavonoids, 11 ± 4% of lycopene, and 19 ± 1% of ascorbic acid) and overall antioxidant activity (23 ± 5%) of tomatoes. Removing seeds from tomatoes when cooking at home and processing results in a significant loss of all the major antioxidants of tomatoes. Therefore, it is important to consume tomatoes along with their seeds in order to obtain maximum health benefits.

ADVERSE EFFECTS AND REACTIONS (ALLERGIES AND TOXICITY)

No antinutritional factors or harmful constituents have been reported in tomato seeds (Rahma *et al.*, 1986), making them a better source of protein, lipids, or bioactive compounds than other non-conventional sources. Moreover, it is important to highlight that the contribution of a 20-g serving of tomato seeds to the tolerable upper intake level of sodium, defined as the highest level of daily nutrient intake that is likely to pose no risk of adverse health effects to almost all individuals in the general population, is very low (2.2%). This contribution must be considered, because it is known that increased sodium chloride intake increases blood pressure and is associated with an increased risk of cardiovascular disease.

SUMMARY POINTS

- Tomato seed oil is high in unsaturated fatty acids (80%), with a nutritional value comparable to other edible oils, such as corn oil.
- Tomato seed is also high in protein, more than double the amount found in most cereal grains.
- The essential amino acid scores of tomato seed are similar, or even better, than those of different cereal grains and seed kernels.
- Tomato seed is rich in minerals.
- Phytochemicals such as phenolic compounds, carotenoids and xanthophylls, tocopherols, and sterols have been identified in tomato seed.
- Tomato seeds contain a great deal of nutrients and potentially healthy bioactive compounds, could be used as sources of ingredients to fortify or functionalize food.

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