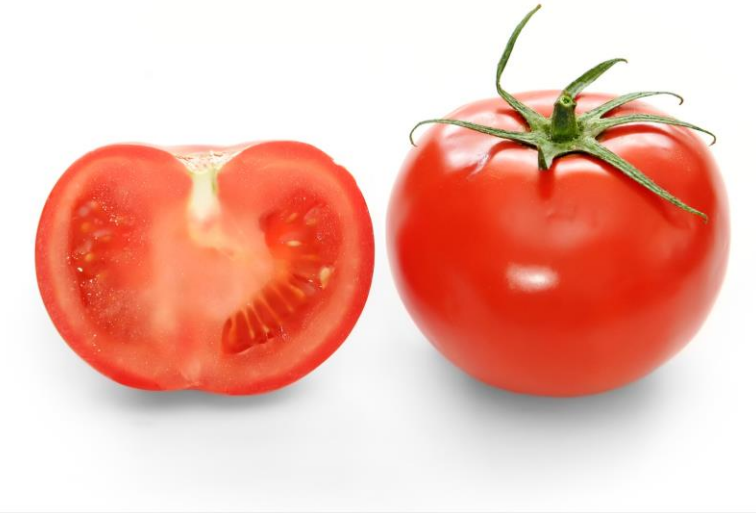
SOLANUM LYCOPERSICUM



A MONOGRAPH

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Introduction

Solanum lycopersicum, popularly known as tomato, originated in South America and now is used and cultivated in various parts of the world. This product is cultivated in warm climate regions, but can also be planted inside a greenhouse during winter. Tomatoes are full of vitamins and antioxidants essential to a healthy body. Since the tomato doesn't need a lot of tending, it's an easy plant to grow. Tomatoes can be consumed in several ways from salads up to sauces and easily harvested, making it the second most consumed vegetable of the American diet and has China being the main country that producer tomatoes in 31% of the total produce in the world.

Chapter 1: Ecology

1.1 Distribution

1.1.1.Affinities

- Kingdom: Plantae
- Division: magnoliophyta
- Class: magnoliopsida
- Order: solanales
- Family: solanaceace
- Genus: solanum
- Species: s. lycopersicum

1.1.2 Origin

The tomato originated in the Andean region of South America and in Central America. The tomatoes are believed to have originated in the coastal trip of western South America, from the equator to about 30° latitude south.

Figure 1. Western South America map

Figure 2. Central America map

1.1.3 Present Distribution

Up to 2014, the tomato's production quantity is mostly in Asia with a 51.2% followed by the Americas with a 19% (FAOSTAT, 2014). In 2015, the tomato exports by country summed US$8.4 billion with Mexico being the country that exported the highest dollar value worth of tomatoes that year with a value of US$1.8 billion – the 21.6% of total tomato exports (Workman, 2016).

1.2 Environmental Factors

1.2.1 Climate and temperature regime

The climate should be a temperate one ranging from 26° to 32° C for seed germination and 17° to 27° C for cultivation, with a higher temperature the blossoms can drop off. The crops can't be exposed to dry wind because this can cause failure of fruit set since it creates drying of stigmatic acid. Tomatoes have to

grow in a long, hot, growing season, if not they can grow inside a greenhouse during wintertime since hail and frost can impede them from growing. A warm weather helps for accurate ripening, color, quality and high yield. (My Agriculture Information Bank, n.d.)

1.2.2 Rainfall and water requirements

Excessive irrigation on the crops during the flowering period can increase the flower drop and reduce fruit set while and irrigation deficit during this period can limit plant growth and reduce yields. The irrigation should not be heavy or irregular but controlled. Some methods for irrigation can include surface irrigation and with a sprinkler which can cause the fruit set to be reduced and having an increase in fruit rotting. (Crop Water Information: Tomato, n.d.)

1.2.3 Geology and Soils

The soil where the tomato grows can't be too sandy, have too many rocks, to clayey, have a low pH making it too acidic, or have too much alkaline which make it have a high level of pH. The pH levels of the soil have to be 6.0 to 7.0. To help prevent disease such as verticillium wilt, the soil can be solarized by covering the entire plot with plastic for the whole season and plowing the land four to five times should level the soil. (My Agriculture Information Bank, n.d.)

1.3 Vegetation Components

1.3.1 Pests and diseases

Some of the pests that tomatoes can have are aphids, cutworms, flea beetles, hornworms, nematodes, and whiteflies. These pests can feed on the tomato foliage and roots, interfere with the plant's ability to take up nutrients and to perform photosynthesis, and create mold. The diseases that affect tomato plants can include

damping off, fusarium wilt, mosaic virus, and verticillium wilt. (Planet Natural RSS, n.d.)

Chapter 2: Biology

2.1 Chromosome Complement

The chromosome complement is the number of chromosomes that a species possesses in the somatic cells. The tomato has a chromosome number of 2n=2x=24 and a genome size of 950 Mb/haploid genome (Pavan, Heusden, & Bai, 2009).

2.2 Life cycle and phenology

2.2.1 Life cycle and longevity

The tomato is a perennial plant, which means they can live for several years, and they are grown as an annual (5-6 months). The first stage of the life cycle is the seed stage where there is a dormant seed and where germination starts, this takes 5 to 10 days. The vegetative state starts (from emergence until the first flower) which takes about 10-12 weeks. The reproductive stage is next; this is where the flowering period happens. The flowering period is “a period between floral initiation and production of mature flower” ("*Solanum lycopersicum*, tomato", 2013) where the number of carpels and the shape of the fruit is determined, this takes about 2 weeks. The next stage is fruit development where the fruit set takes place. “At fruit set, flower petals and anthers senesce and fall away and a pea-sized green fruit appears; from this point it takes typically 40-50 days for fruits to be harvestable” ("*Solanum lycopersicum*, tomato", 2013). During the developing of the fruit it has a light green color and is very firm but the fruit growth is very slow, this takes 2-3 weeks. When the fruit is still green; “its growth accelerated by cell expansion rather than the cell division; cells enlarge up to 20-fold; this period takes about 3-5 weeks; fruit almost reached its final size and is changing colors” ("*Solanum lycopersicum*, tomato",

2013). During the breaker stage of the fruit development, there are chemical and structural changes, which are responsible to determine the characteristics of the tomato such as the aroma, color, texture, etc. In the turning stage, the 10-30% surface of the fruit can turn tannish-yellow, pink, or red. The next stages are the pink, light red and ripe where the surface of the fruit gradually turns red or orange.

2.2.2 Flowering and fruiting seasonality and frequency

Table 2.1: Fruit developmental landmarks
(Timing of the fruit landmarks in *S. pimpinellifolium* LA1589) ("*Solanum lycopersicum*, tomato", 2013)

Fruit Development Landmarks	Days post anthesis (flowering period of the plant)	Fruit growth (Gillaspy et al 1993)	Embryo/seed development
(1) Anthesis	0	Mature ovary, phase I.	Mature gametes. Pollen is shed, which will land on the stigma and germinate. Pollen tubes growth through the style.
(2) Fertilization	1 - 2	End of phase I, beginning of phase II.	Fusion of sperm and egg nuclei.
(3) 4–16 Cell Stage Embryo	3 - 6	Phase II and III, cell division and elongation stage.	First embryo divisions.
(4) Globular Stage Embryo	6 - 10	Phase III, cell expansion stage.	Globular embryo.
(5) Heart Stage Embryo	10 - 12	Phase III, cell expansion stage.	Heart Stage embryo lasts approximately one day and occurs 10–12 dpa.
(6) Torpedo Stage Embryo	13 - 16	Phase III, continued fruit enlargement.	Torpedo Stage embryo lasts approximately one day and occurs 13–16 dpa.
(7) Coiled Stage Embryo	20	Phase III, continued fruit enlargement.	Cotyledon expansion and curl as they elongate. Embryo appears physically mature, but the seed is not yet viable.
	20 - 28		Seed maturation period.
(8) Seed germination	29 - 31	The fruit has reached the mature green stage. Fruit becomes sensitive to ethylene.	Seeds are becoming viable for germination.
(9) Fruit ripening	33 - 40	Ripening starts at the onset of the breaker stage. Changes in	After ripening of seed.

Fruit Development Landmarks	Days post anthesis (flowering period of the plant)	Fruit growth (Gillaspy et al 1993)	Embryo/seed development
		pigmentation are visible.	
(10) Ripe Fruit	40	Red ripe stage of tomato.	

Table 2.2:Flower Development Landmarks

(The timing of the landmarks described by Buzgo et al (2004) in *S. pimpinellifolium* accession LA1589) ("*Solanum lycopersicum*, tomato", 2013)

Flower Development Landmarks	Days after flower initiation in tomato	Perianth (outer part of the flower) organs	Ovary and ovule (the part of the ovary of plants that have the female germ cell)	Stamen (pollen-producing part of the flower) and pollen
(1) Inflorescence formation and flower initiation	1	Flattened inflorescence apex becomes dome-shaped.		
(2) Initiation of outermost perianth organs	2	Emergence of sepal primordia in a helical pattern.		
(3) Initiation of inner perianth organs.	4	Simultaneous emergence of petal primordia in alternating positions to the sepals. Sepals overlay the floral meristem		
(4) Stamen initiation	5	Sepals and petals elongate.		Simultaneous initiation of stamen primordia.
(5) Carpel initiation	6	Petals start curling over the stamens.	Carpel primordia arise.	
	7		Central column that will form the locular cavities arise.	Central column that will form the locular cavities arise.

Flower Development Landmarks	**Days after flower initiation in tomato**	**Perianth (outer part of the flower) organs**	**Ovary and ovule (the part of the ovary of plants that have the female germ cell)**	**Stamen (pollen-producing part of the flower) and pollen**
6) Microsporangia initiation	8		Central column continues to elongate. Carpels fuse at the apex of the ovary. Style initiation. Initiation of placental development.	Primary pariety cells develop into endothecium, middle layers and tapetum. Sporogenous layers visible.
(7) Ovule initiation	9		Ovule primordia begin to emerge from the placenta.	The two lobes of the anther and the locule are distinguishable, microsporocyte and tapetal cells are distinguishable. Binucleate tapetal cells.
(8) Male meiosis	10			Microsporogenesis. Microsporocytes or microspore mother cells undergo meiosis I and II and forming tetrads.
(9) Female meiosis	11		Megasporogenesis. Megaspore mother cell (meiocyte or megasporocyte) is visible. Meiosis I. The nucellus is small resulting in a tenui-nucellate ovule.	
	12	Petals grow to the top of sepals.	The single integument begins to grow over the nucellus resulting in unitegmic ovules.	Callose wall surrounding the tetrads degrades releasing the microspores. Tapetum starts degenerating.
	13	Petals emerge from the sepals.	Petals emerge from the sepals.	Free microspores are being incased in a thick polysaccharide wall; tapetum degenerated.
	14	Onset of sepal opening.	Megagametogenesis and development of the embryo sac.	Microspores come vacuolated, and begins asymmetric mitosis.
	15			Bi-cellular pollen grain.

Flower Development Landmarks	Days after flower initiation in tomato	Perianth (outer part of the flower) organs	Ovary and ovule (the part of the ovary of plants that have the female germ cell)	Stamen (pollen-producing part of the flower) and pollen
	16		Bi-cellular pollen grain.	The vegetative cell and generative cell are well distinguishable.
(10) Anthesis	19	Petal opening.		

2.2.4 Deciduousness

Not applicable

2.3 Reproductive biology

2.3.1 Pollen

"Pollen is a fine to coarse powdery substance comprising pollen grains, which are male microgametophytes of seed plants, which produce male gametes" (sperm cells) ("Pollen"). Tomatoes have open pollination and are self-pollinated, which makes them produce seeds that can carry the genetic material of the parent plant. Tomatoes can be crossed pollinated to create hybrids that have the traits of the two parent plants. By being a hybrid, the tomatoes will be tastier, more resistant to diseases, and much more productive. (Pence). Although, the plant's exposure to raised temperatures can reduce crop yield and quality because of the sensitivity of developing pollen grains. "Ethylene plays a significant role in tomato pollen thermotolerance. Interfering with the ethylene signaling pathway or reducing ethylene levels increased tomato pollen sensitivity to heat stress, whereas increasing ethylene levels prior to heat-stress exposure increased pollen quality" (Firon N, Pressman E, Meir S, Khoury R, & Altahan L, 2012)

2.3.2 Anthesis

The anthesis is the period or act of expansion in flowers, the maturing of the stamens (the male organ of the flower)

Table 2.3: The size of the tomato floral organ at the days before anthesis (Zhao, Zhao, Sheng, Li, & Peng, 2011)

	Bud form bud anther style the days before anthesis					
	Length (mm)	width (mm)	Length (mm)	width (mm)	length (mm)	day
A			10.17	2.79	13.00	0
B	12.76	4.89				2
C	11.48	4.05				3
D	10.09	3.41				4
E	8.22	3.04				5
F	6.83	2.48				6
G	6.04	2.45				7
H	5.6	2.28				Buddies
I	4.81	2.25				Buddies

2.3.4 Fruit and seed dispersal

Solanum lycopersicum is able to produce a new plant because it has all the necessary genetic material, but the seed have to be distributed near the parent plant. The seeds can be dispersed by wind, water, by sticking to the fur of animals that have passed by them, or can be eaten by animals to later be passed undigested. Tomatoes can be eaten by an animal and still be intact since they have a biological process called endozoochory that gives them a gelatinous coat that protects the seed. (Pence)

2.4 Ecophysiology

Ecophysiology is the adaptation of an organism's physiology to environmental conditions. In a study, the tomato plants were exposed to gas change and chlorophyll a fluorescence and the visible symptoms were studied to see the ecophysiology of the plant. After one month, the vessel colonization and all leaves

over the end point of colonization appeared as healthy although they had a reduction in photosynthetic activity attributable to a severe drop in stomatal conductance. (Nali, C., Lorenzini, G., & Guidi, L., 2011)

Chapter 3: Propagation and Management

3.1 Natural regeneration

Natural regeneration is the growth of young trees from seed, suckers, etc., produced by those already established (Natural Regeneration, n.d). This can be used to produce genetically identical clones and it is an essential part of genetic transformation techniques (Ashakiran, Sivankalyani, Jayanthi, Govindasamy, & Girija, 2011). With tomatoes, "plant regeneration is accomplished through organogenesis and it is affected by several factors such as genotype, explant characteristics (type, size, age, and orientation), media composition (growth regulators, carbon source, minerals, and vitamins), and environmental conditions (irradiation, photoperiod, and temperature)" (Cruz, et al., 2011).

3.2 Nursery Propagation

3.2.1 Propagation from seed

3.2.1.1 Pre-preparation and implications for germination

In order to start planting tomatoes, first decide on the type of tomato you want (cherry, slicers, or tomatoes for sauce). Then consider the size of the mature plants and get a container filled with soil and some support for the plant such as tomato ladders or tomato cages. Next, look for disease-resistance since tomatoes are prone to a number of diseases such as verticilium and fusarium. The pots should be placed in a warm place and have water, the soil has to be moist but not soaking wet (DeJohn, n.d).

3.2.1.2 Sowing and the germination process

A tomato should be sown 6-8 weeks before the last frost date,

which is near March/April. Sprinkle the seeds in a soft layer on the surface of quality compost. The seed has to be covered with about 1.5mm (1/16in) of compost and has to be watered lightly with a fine-rose watering can. The seeds can start to germinate in 7 to 14 days in a temperature of about 21°C (70°F). The compost must be kept moist, but if it is over-watered it can encourage *"damping off disease and other moulds and diseases"* (Sanderson, n.d).

3.2.1.3 Storage

For unripe green tomatoes, they should be placed stem side down inside a paper bag or in a cardboard box without mounting more on top, and in a cool area until they turn red in color. Perfectly ripe tomatoes should be located at room temperature without contact to direct sunlight. They can't be stacked, touching one another, and stem side up. They should be eaten in a couple of days. Overripe tomatoes that are soft to touch should be kept in the fridge. *"The cold air will keep the tomatoes from ripening more, and they should last for another three days. Before eating refrigerated tomatoes, take them out of the fridge and let them come to room temperature. This will allow the fruit to develop some of the flavor it has lost due to refrigeration."* (Sweeney, 2016).

3.2.2 Vegetative propagation

3.2.2.1 Grafting

Grafting is to insert scions from one plant into another ("Graft"). By grafting tomatoes, you get both excellent production

and disease resistance. In order to graft, you take the top scion of a tomato plant and attach it to a “specialized hybrid rootstock grown specifically for its vigor and disease resistance”. This rootstock protects the plant from tomato mosaic virus, nematodes, verticillium wilt, and other diseases. Grafting helps you grow in big amounts. Putting the plant against a bamboo skewer or a toothpick and, to add a more humid environment, put a plastic bag over your container garden, can support the plant. In order to allow the plant to have more energy to produce fruit and quicker, don’t bury the graft below the soil and remember to actively prune the plant. (Grisak, 2016)

3.2.2.2 Cuttings

A piece, as a root, stem, or leaf, cut from a plant and used for propagation. ("Cutting"). In order to root a tomato cutting, first you’ll have to cut out a part from another tomato plant that has the best yields since your cutting will have all its characteristics, it’ll be a clone. Cut about 6-8 inches from the plant and then clip off any flowers or buds and the bottom leaves. With this you then have to place it inside a bottle filled with soil, but if you place it in water to then transplant it to soil then the cutting will start rooting after one week, although their roots grow stronger in soil. The cuttings can be indoors or outdoors but always in a warm shaded area. They should be in a moist area in the shade for a week and then gradually expose them to sunlight until they get sun for the most part of the day (Grant, 2017).

3.3 Planting

(refer to chapter 2.3)

3.4 Management

3.4.1 Tending

Since tomatoes are easy to grow they don't really need a lot of tending. Make sure air circulates beneath and through the plant since the air circulation can help prevent disease, just as does removing lower branches that when it rains or when watering the garden, can be splashed by the soil. In order to successfully prune your plant, you should mulch the tomato plant and the plant should be watered at the bottom of the stem (Pilarchik, 2011).

3.4.2 Fruiting

(refer to chapter 2.2.2)

3.4.3 Pest and diseases

(refer to chapter 1.3.1)

Chapter 4: Emerging Products

4.1 Market Trends

Tomatoes are a popular ingredient in the typical American diet, they are the second most consumed vegetable in United States; it can be consumed in sauces, drinks, and recipes. In 2014, the consumption of tomatoes from fresh markets and processed were of 20.6 pounds and 67,2 pounds per capita. Canned tomatoes, pastes and sauces compose the tomato processing industry in the United States, unattached from the fresh market industry. In the fresh market industry, the tomatoes are hand-picked and sold on the open market. The fresh market tomatoes are produced in every state and Florida is the largest producer with California behind it since the production has dropped in the last few years due to the droughts. These two sates cover over two-thirds of the total production of fresh tomatoes in the United Sates. The total tomato production in the processed industry has dropped 10% since 2007 while the fresh market production went up by 20%, according to the USDA 2012 Census of Agriculture. The largest growth in production was evidenced in farms that were smaller than 5 acres of land because of the increase in the number of small-scale vegetable farms producing for the local fresh market. 27.3 million CWT of fresh market tomatoes were gathered from 97,600 acres with a total value of $1.14 billion dollars in 2014, while only 14.6 million tons of processed tomatoes were harvested on 277,000 acres with a value of $1.325 billion, that year (Naeve, 2015). In the processed tomato industry, the tomatoes are harvested mechanically and sold under contract and just 1% of their produce goes into the open market. The commercial-scale production is only in 20 states. Over 150 countries grow and harvest tomatoes, 80% of the tomatoes are consumed fresh and the other 20% are used in the tomato processing industry. The processing industry uses

the tomatoes as a flavoring ingredient for fast foods, hotels, restaurant and residences. Some products from the processing industry can include peeled tomato, partially dehydrated tomato, diced tomato, tomato snacks, tomato paste, ketchup, soup, juice, sauce, powder and concentrate. This tomato processing began in 1847 with manually canned tomatoes and now it is a highly organized industry with sales worth billions of dollars.

In 2016, the worldwide tomato processing industry produced around 34 million tonnes, according to IMARC Group. Factors like the changing food habits, rising incomes, urbanization, emerging markets, growing consumption of fast foods, and more are currently controlling the growth of this market. Presently, sauces are almost third of the total processed tomato consumption, followed by pastes, canned tomatoes, ketchups and juices. With more than third of the total global tomatoes processed, United States is the world's biggest tomato processor, flowed by other countries like Italy, China, Turkey, Iran, Spain and Brazil. *"Some of the key players currently operating in this market include - Morning Star, Tunhe, Chalkis, Ingomar Packing and JG Boswell"* (Market Business Insider.com, 2017)

Figure 4.1 : US fresh tomato production, consumption, imports and exports in 1990-2014 (Cook, 2015)

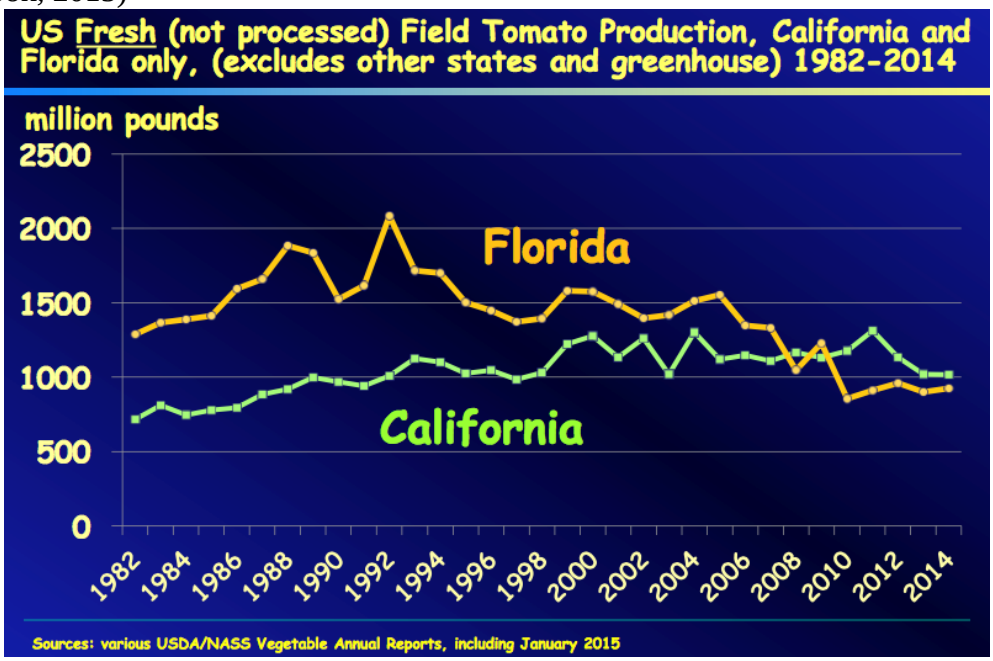
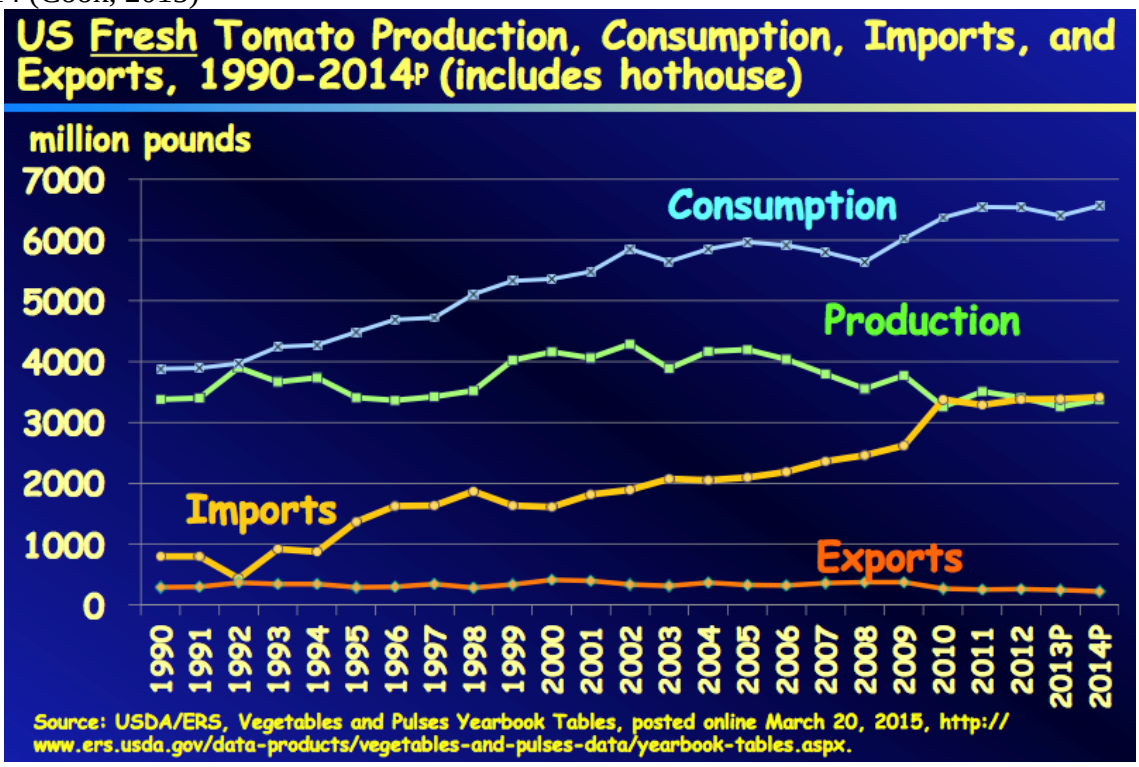


Figure 4.2: US fresh tomato production, consumption, imports, and exports in 1990-2014 (Cook, 2015)



Rank	Country	Production millions of tonnes[39][42]
1	China	52.6
2	India	18.7
3	United States	14.5
4	Turkey	11.9
5	Egypt	8.3
6	Iran	6.0
7	Italy	5.6
8	Spain	4.9
	World	**170.8**

Table 4.1: Amount of production in millions of tones of tomatoes in the world, by countries (FAOSTAT, 2013)

In 2014, the productions of tomatoes in the world was of 170.8 million tones, with China being the number one country tomato producer with 31% of the total, India being the second with 18.7 tones, and then United Sates with 14.5 tones. (n.d.)

4.2 Production Development

Because of the rise of greenhouses, the tomato production has changed in the United State's fresh market industry. With the use of greenhouses, producers can now grow fresh tomatoes inside structures where they use methods of climate control and alternative soils. Some advantages the greenhouses production brings include the uniform appearance and quality, consistency in production, increased harvest per acre and enhanced grower capability to sustain year-round production (Naeve, 2015).

4.3 Tomato Uses

4.3.1 Medicinal

Nutrient	**Benefit**
Vitamin A	-The presence of its high quantities has shown to reduce the effects of carcinogens and can protect from lung cancer -Improves vision -Prevents night-blindness and macular degeneration -Powerful antioxidant
Vitamin K	-Essential in blood clotting -Controls bleeding
Vitamin C	-About 40% of the daily requirement -Natural antioxidant (prevents cancer-causing free radicals)
Potassium	-Maintains nerve health -Reduces the risk of developing hypertension or high blood pressure -It is a vasodilator so it reduces the tension in blood vessels and arteries and so it increases circulation and lowers the stress on the heart by eliminating hypertension
Iron	-Maintains blood health
Lycopene	-Antioxidant: very effective when fighting cancer since they cause free radicals, it can even be obtained from products from the processed industry and not only from the fresh market. Effective when fighting prostate, cervical, stomach, rectum, breast, mouth, pharynx, and esophageal cancer according to studies published by the Harvard School of Public Health -Prevents serum lipid oxidation and deposition of fats in the blood vessels, so it protects the body from cardiovascular diseases -Decreases the levels of LDL cholesterol and triglycerides in the blood

Coumaric and chlorogenic acid	-Fights against nitrosamines that are produced in the body, they are the main carcinogens found in cigarettes
Fiber	-Keep the digestive system healthy -Prevents constipation, jaundice and diarrhea -Effectively removes toxins from the body -Stimulates peristaltic motion in the smooth digestive muscles which can help regulate bowel movements and so improving your overall digestive health and helps avoid conditions like colorectal cancer
High water content	-Reduces the incidence of urinary tract infections -Prevents bladder cancer -Stimulates urination -Eliminates the toxins from the body, excess water, salts, uric acid, and some fat

Table 4: Benefits of tomato's nutrients (Organic Facts, 2017).

4.3.2 Side Effects

The tomato leaf in large amounts can be unsafe since it can cause poisoning. The symptoms of poisoning can include severe mouth and throat irritation, vomiting, diarrhea, dizziness, headache, mild spasms, and death in severe cases (WebMD, n.d.).

4.3.3 Food Products

The tomato paste and ketchup are used as sauces (2012)

Since tomatoes are considered culinary vegetables, they are also used in different types of recipes such as salads, sandwiches or soups, either sun dried or normal tomatoes (Mooth, 2013)

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Chapter 4

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