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Post harvest technology and value addition of tomatoes

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INTRODUCTION

The word "tomato" may refer to the plant (*Solanum lycopersicum*) or the edible, typically red, fruit that it bears. Originating in South America, the tomato was spread around the world following the Spanish colonization of the Americas, and its many varieties are now widely grown. The tomato belongs to the nightshade family. The plants typically grow to 1–3 meters (3–10 ft) in height and have a weak stem that often sprawls over the ground and vines over other plants. It is a perennial in its native habitat, although often grown outdoors in temperate climates as an annual. The tomato is now grown worldwide for its edible fruits, with thousands of cultivars having been selected with varying fruit types and for optimum growth in differing growing conditions. Cultivated tomatoes vary in size, from tom berries, about 5 mm in diameter, through cherry tomatoes, about the same 1–2 centimeters (0.4–0.8 in) size as the wild tomato, up to beefsteak tomatoes 10 centimeters (4 in) or more in diameter. The most widely grown commercial tomatoes tend to be in the 5–6 centimeters (2.0–2.4 in) diameter range. Most cultivars produce red fruit, but a number of cultivars with yellow, orange, pink, purple, green, black, or white fruit are also available. Multicolored and striped fruit can also be quite striking. Tomatoes grown for canning and sauces are often elongated, 7–9 centimeters (3–4 in) long and 4–5 centimeters (1.6–2.0 in) diameter; they are known as plum tomatoes, and have lower water content. Roma-type tomatoes are important cultivars in the Sacramento Valley (Allen, 2008).

Tomatoes are one of the world's most consumed vegetable crops. According to statistics from the Food and Agriculture Organization (FAO), around 340 billion pounds (170 million tons) of fresh and processed tomatoes were produced globally in 2014 (FAO, 2017). The harvested area covered 12.4 million acres (5 million hectares) of farmland. The world production of tomatoes has consistently increased since 2000, growing more than 54 per cent from 2000 to 2014 (FAO, 2017). China is the largest producer of tomatoes, followed by the United States and India. Other major players in the tomato market are the European Union and Turkey. Together, these top five tomato producers supply around 70 per cent of the global production. Mexico is the largest exporter of tomatoes in the world, followed by the Netherlands and Spain (CIA, 2017). In 2016, Mexico, the Netherlands,

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and Spain accounted for 25.1% ($2.1 billion), 19% ($1.6 billion) and 12.6% ($1.1 billion) of the world's total tomato exports, respectively (CIA, 2017). India stands at second position in the production of tomato in the world. The share of Maharashtra in the total production is 4.85 per cent. The study was conducted in Nashik district of Maharashtra, as it contributes to about 30 per cent of the total production of the state and comes in the top ten tomato producing districts in the country (Madhumoorthy and Sundaramoorthy, 2018).

Tomato varieties are roughly divided into several categories, based mostly on shape and size:

– "Slicing" or "globe" tomatoes are the usual tomatoes of commerce, used for a wide variety of processing and fresh eating.

– "Beefsteak" tomatoes are large tomatoes often used for sandwiches and similar applications. Their kidney-bean shape, thinner skin, and shorter shelf life makethe commercial use impractical.

· "Oxheart" tomatoes can range in size up to beefsteaks, and are shaped like large strawberries.

– "Plum tomatoes", or paste tomatoes (including pear tomatoes), are bred with a higher solids content for use in tomato sauce and paste, and are usually oblong.

– "Pear tomatoes" are obviously pear-shaped, and are based upon the San Marzano types for a richer gourmet paste.

– "Cherry" tomatoes are small and round, often sweet tomatoes generally eaten whole in salads.

– "Grape" tomatoes, a more recent introduction, are smaller and oblong, a variation on plum tomatoes and used in salads.

– "Campari" tomatoes are also sweet and noted for their juiciness, low acidity, and lack of mealiness. They are bigger than cherry tomatoes, but are smaller than plum tomatoes.

Nutritional value of tomatoes:

Tomatoes are nutritious and low in calories. One medium sized tomato provides 57 per cent of Recommended Daily Allowances (RDA) of vitamin C, 25 per cent RDA of vitamin A and 8 per cent RDA of iron, yet it has only 35 calories. Besides being eaten fresh, the versatile tomato can be baked, stewed, fried, juiced or pickled and can be used in soups, salads and sauces.The composition and nutritive value of tomatoes and its products are given in the Table 1.

Tomatoes are now eaten freely throughout the world, and their consumption is believed to benefit the heart, among other organs. They contain the carotene lycopene, one of the most powerful natural antioxidants. In some studies, lycopene, especially in cooked tomatoes, has been found to help prevent prostate cancer, lycopene has also been shown to improve the skin's ability to protect against harmful UV rays. A study done by researchers at Manchester and Newcastle universities revealed that tomato can protect against sunburn and help keeping the skin looking youthful. Natural genetic variation in tomatoes and their wild relatives has given a genetic plethora of genes that produce lycopene, carotene, anthocyanin and other antioxidants.

Major tomato growing countries in the world (2014)

Country	Production (million ton)	Area (million ha.)	Yield (ton/ha.)
China	52.72	1.00	52.63
India	18.74	0.88	21.24*
USA	14.52	0.16	88.85
Turkey	11.85	0.32	37.13
Egypt	8.29	0.21	38.73
Iran	5.97	0.16	37.54
Italy	5.62	0.10	54.51
Spain	4.89	0.05	89.29
Brazil	4.30	0.06	89.29
Uzbekistan	2.29	0.07	35.14
Others	41.70	2.00	20.83
World	170.89	5.01	33.99

Source: Horticulture Statistics at a Glance -2017 *for 2016-17 – 24.4 MT per ha.

The commercially important tomato fruit can vary in colour, size and shape (Vaughan and Geissler, 1997). The fruit contains a large quantity of water, vitamins and minerals, low amounts of proteins and fats and some carbohydrates. It also contains carotenes, such as lycopene (which gives the fruit its predominantly red colour) and β-carotene (which gives the fruit its orange colour). Modern tomato cultivars produce fruits that contain upto 3 per cent sugar of fresh fruit weight. It also contains tomatine, an alkaloid with fungicidal properties. The concentration of tomatine decreases as the fruit matures and tomatine concentration contributes to determining the taxonomy of the species. Thus, it can be useful in crop breeding for cultivated tomatoes (OECD, 2008; Spooner *et al.*, 1993).

Post harvest losses of tomatoes:

Tomato being a climacteric fruit, the start of ripening is accompanied by a rapid rise in respiration rate called 'respiratory climacteric' during which oxidative breakdown of complex substrates occur, ageing follows, leading to product deterioration. Also tomatoes being fleshy fruits, continue to lose water after harvest. This results in a wilted, dull appearance that reduces the eye appeal and freshness and eventually becomes unmarketable. Losses in quantity and quality occur between harvest and consumption.

Primary factors responsible for post-harvest produce losses include poor pre-harvest measures, adoption of poor production techniques (varieties with low shelf-life, imbalance use of nutrients, insect pest and disease infestation and abiotic stresses), non-application of pre-harvest recommended treatments/practices, harvesting at improper stage and improper care at harvest and post-harvest problems, non-removal of field heat, dumping produce, moisture condensation causing pathogen infestation, packaging in bulk without sorting and grading of produce, improper transportation and storage and distant and time consuming market distribution. These losses bring low return to growers, processors and traders and country also suffers in terms of foreign exchange earning (Kader, 1992). Evidence suggests that these losses tend to be the highest in those countries where the need for food is greater; some authorities put post-harvest losses of sweet potatoes, tomatoes, bananas and citrusfruit sometimes as high as fifty per cent (FAO, 2002).

Physiological disorders:

Chilling injury:

Tomatoes are chilling sensitive at temperatures below 10°C (50°F) if held for longer than 2 weeks or at 5°C (41°F) for longer than 6-8 days. Consequences of

Table 1: Composition of tomato and tomato products, 100 g

	Tomato		Tomato Juice				Tomato puree (Pulp)	ketchup	Tomato paste
	Fresh	Canned	Regular	Concentrated	Dehydrated	Cocktail			
Water (%)	93.50	93.70	93.60	75.00	1.00	93.00	87.00	68.60	75.00
Food energy (Calories)	22.00	21.00	19.00	76.00	303.00	21.00	39.00	106.00	82.00
Protein, g	1.10	1.00	0.90	3.40	11.60	0.70	1.70	2.00	3.40
Fat, g	0.20	0.20	0.10	0.40	2.20	0.10	0.20	0.40	0.40
Total carbohydrate:, g	4.70	4.30	4.30	17.10	68.20	5.00	8.90	25.40	18.60
Fibre, g	0.50	0.40	0.20	0.90	3.10	0.20	0.40	0.50	0.90
Ash, g	0.50	0.80	1.10	4.10	17.00	1.20	2.20	3.60	2.60
Calcium, mg	13.00	6.00	7.00	27.00	85.00	10.00	13.00	22.00	27.00
Phosphorus, mg	27.00	190.00	18.00	70.00	279.00	18.00	34.00	50.00	70.00
Iron, mg	0.50	0.50	0.90	3.50	7.80	0.90	1.70	0.80	3.50
Sodium, mg	3.00	130.00	200.00	790.00	3934.00	200.00	399.00	1042.00	38.00
Potassium, mg	244.00	217.00	227.00	888.00	3518.00	221.00	426.00	363.00	888.00
Vitamin A (I.U.)	900.00	900.00	800.00	3300.00	13100.00	800.00	1600.00	1400.00	3300.00
Thiamin, mg	0.06	0.05	0.05	0.20	0.52	0.05	0.09	0.09	0.20
Riboflavin, mg	0.04	0.03	0.03	0.12	0.40	0.02	0.05	0.07	0.12
Niacin, mg	0.70	0.70	0.80	3.10	13.50	0.06	1.40	1.60	3.10
Ascorbic acid, mg	230.00	17.00	16.00	49.00	239.00	16.00	33.00	15.00	49.00

chilling injury are failure to ripen and develop full colour and flavour, irregular (blotchy) colour development, premature softening, surface pitting, browning of seeds, and increased decay (especially black mold caused by *Alternaria* spp.). Chilling injury is cumulative and may be initiated in the field prior to harvest.

Physical disorders:

Tomatoes are sensitive to many production and environment-genetic interaction disorders which may be manifested during postharvest ripening or postharvest inspection. Fertilizer and irrigation management, weather conditions, insect feeding injury, asymptomatic virus infection and unknown agents may interact to affect postharvest quality. Examples are blossom end rot, internal white tissue, rain checking, concentric and radial cracking, puffiness, persistent green shoulder and gray wall.

Pathological disorders:

Diseases are an important source of postharvest loss depending on season, region and handling practices. Commonly, decay or surface lesions result from the fungal pathogens Alternaria (*Black mold rot*), Botrytis (*Gray mold rot*), Geotrichum (*Sour rot*) and Rhizopus (*Hairy rot*). *Bacterial soft rot* caused by *Erwinia* spp. can be a serious problem particularly if proper harvest and packinghouse sanitation is not used. Treatment with hot air or hot water immersion (55°C for 0.5 - 1.0 min.) has been effective in preventing surface mold but has not been used extensively for commercial treatments. CA can be effective in delaying fungal growth on the stem-end and fruit surface. Greenhouse tomatoes marketed on-the-vine ("cluster tomatoes") is very susceptible to Botrytis gray mold, especially if film-wrapped in a tray.

Post harvest technology:

Tomato is an important dietary source of vitamins and minerals. A major problem with the storage and marketing of fresh tomatoes is their relatively fast deterioration in quality and short shelf life. Hence, different post-harvest technologies are employed in reducing the losses and extending the shelf-life.

Tomatoes are harvested at various stages of ripeness and the storage conditions employed differ with each stage. Rapid cooling soon after harvest is essential for optimal postharvest keeping quality. The pre-cooling endpoint is typically 12.5°C (55°F). Forced-air cooling is the most effective practice but room cooling is more common. Placing containers of warm tomatoes in a refrigerated space, known as room cooling, is recommended. To aid room cooling and prevent the buildup of heat of respiration, containers of tomatoes should be loosely stacked with space between the containers to allow for sufficient air circulation. In general pre-cooling is required only if the fruit temperature is higher than 26-27°C and ripening is to be delayed. Although fully ripe tomatoes may be held at 2-5°C for a few days prior to consumption (not longer, since colour loss and softening may occur), fruit that are mature green or at the turning or breaking stage should not be subjected to temperature lower than 12°C as chilling injury may occur, with adverse consequence for subsequent ripening and quality.

Post harvest treatments prior to storage:

Maturity:

Maturity of fruits and vegetables is an indication of the development of the crop as a marketable product. Selection of right stage of maturity for harvest is an important aspect, which has considerable influence on storage life and quality and final acceptance by the consumer. Physiological maturity is the stage of development when maximum growth and maturation has occurred in tomatoes. Commercial horticultural maturity is the stage of development required by the market. Maturity at harvest affect its marketability and storage life, nutritional content, freshness and flavour. There are six maturity stages *viz.,* mature green, breaker, turning, pink and light red. Tomato fruits are harvested at the required ripeness stage for marketing or consuming. Usually tomatoes are harvested at colour break stage for distant markets and fully red /ripe stage for local markets.

Harvest:

The objective of harvesting is to pick the fruits at the proper stage of maturity, with a minimum damage, as rapidly as possible and at a minimum cost best achieved by hand harvesting in most fruits and vegetables. Harvesting can be done by hand and by mechanical means which have their merit and demerit. Tomatoes are usually harvested manually by twisting the fruits with thumb and finger and retain calyx with the fruits. Avoid any injury to fruit. Harvesting should be done either in the early morning hours or in the evening hours. Harvested

produce should be kept in a cool place and must be pre-cooled before sorting or grading.

Grading:

During grading of fruits, damaged, rotten and cracked fruits should be removed. Only healthy, attractive, clean and bright fruits should be selected. The grades are mostly based on the condition and the quality of the fruits and not specifically on their size. However, on the basis of the size of the fruits three grades are formed: small (<100 g), medium (100-255 g) and large (> 255 g). Retailers normally do size grading for the local market. Internal urban markets have differential prices for size grades as against ungraded fruit. Bureau of Indian Standards has specified 4 grades *viz.,* Super A, Super, Fancy and Commercial for tomato crop. By using equipments, tomatoes are typically separated by size on one or more sizing belts. A rotating bar grader may be suitable alternative for the small producer. It is important on such a line that the belt and roller speed and the drop height be minimized and that all impact surfaces be well padded. A layer of 3/8- to 1/2-inch closed-cell foam with a smooth, washable outer surface should be adequate. Open-cell foam or scraps of carpeting are better than nothing but are very difficult to keep clean and generally do not provide the proper level of protection. Lines should be inspected for sharp projections that might injure the fruit and should be kept free of dirt and trash. A daily cleaning with a strong chlorine solution (1/2 pint of 5.25 % chlorine bleach per gallon of water) followed by a clean water rinse will help prevent the buildup of decay organisms on packing equipment.

Storage:

The main objective in storage after harvest is to control the rate of ripening to extend the marketing period. As the tomatoes are chilling sensitive, the recommended storage temperatures differ depending on the fruit maturity. A storage temperature of 13°C with 90-95 per cent relative humidity is recommended for slow ripening. At this temperature, most varieties keep in good condition for 2-3 weeks and change colour very slowly. In cold storage, unripe tomatoes can be stored for 4 weeks at a temperature of 8-10°C with 85-90 per cent relative humidity. Fully ripe fruits are stored at 7°C with 90 per cent relative humidity for 1 week.

The temperature and RH recommended for the commercial storage of tomatoes at each stage of maturation, recent research has concentrated largely on physiological and biochemical changes during the ripening process. Although fully ripe tomatoes may be stored for a short time at low temperatures, nevertheless adverse effects on fruit quality may occur. For example, the ripe fruit that has been stored at 5°C were significantly less aromatic, less sweet and more acidic than corresponding fruit stored for the same length of time at 20°C. According to Maul *et al.* (2000) the poor aroma is due to loss of principal volatile components. Van Dijk *et al.* (2006) developed models to forecast the loss of weight and firmness of tomatoes during storage at various temperatures. He also reported that the temperature (3-25°C) and stage of ripening influence the enzyme activity during storage. The activity of polygalacturonase increased and pectin methyl esterase decreased over time, while β galactosidase was at first induced and subsequently inactivated. Enzyme changes during ripening also determine the changes of flavour and aroma constituents of the fruit. A temperature related increase in scavenging enzymes indicating that fruit stored at high temperatures are susceptible to loss of fruit integrity.

An experiment was conducted in Bangladesh to study the effect of chlorine, packaging and storage conditions on quality and shelf-life of tomato by Nasrin *et al.* (2008). Tomato treated with chlorine; packed in perforated (0.25%) polyethylene bag and kept at ambient temperature 20-25°C and relative humidity (70-90%) condition resulted in substantial reduction in losses caused by decay and weight loss. This treatment combination also considerably delayed compositional changes in TSS, total sugar, reducing sugar, vitamin-C, β-carotene, etc. Under this condition, shelf-life of tomato had extended upto 17 days as compared to non-treated and kept in ambient condition without packaging or packed in gunny bag for 7 days only.

Tomatoes are sensitive to chilling injury, particularly during the early stages of ripening; the use of low temperatures for tomato storage is restricted. There are recent studies showed that pre- storage treatments aimed to retaining fruit quality during storage and reducing the susceptibility of fruit to chilling injury. One of them is treating the fruits under heat. Heat treatment has also been proposed as a means of inhibiting microbial activity and fruit cracking under conditions of high humidity in modified atmosphere packaging change in cherry

tomatoes (Ali *et al*., 2004). According to Saltveit (2001), the application of heat shock (dipping the fruit at 45°C for 10 minutes) to tomatoes prior to exposure to low temperatures increases their resistance to chilling injury. Soto – Zamora (2005 a) exposed mature green tomatoes to heat treatments (34 or 38°C and 95% RH for 24 hours) prior to storage at 4°C for four weeks in an attempt to reduce chilling injury. Since neither the thermal injury induced at this temperature nor chilling injury during the storage was reduced such heat treatment is not appropriate for tomato storage. Wang (2006) reported that methyl jasmonate and methyl salicylicate reduced chilling injury in tomatoes, while at the same time increasing the expression of genes responsible for the synthesis of het shock proteins and also assists in the development of resistance to disease during low temperature storage.

Ethylene treatment:

Ethylene is a naturally occurring, odorless, tasteless gas produced by many types of produce, including tomatoes. Mature green tomatoes exhibit accelerated ripening in the presence of ethylene. In commercial practice, mature green tomatoes are exposed to supplemental ethylene treatment to hasten ripening and to ensure uniform ripening throughout a lot. Tomatoes may be exposed to an ethylene concentration of 100 to 150 ppm for 24 to 48 hours at a temperature of 70 to 75° F and 90 per cent relative humidity. Immature tomatoes may be ripened with the application of ethylene, but the resulting fruit will not be of good quality. Likewise, fruit beyond the breaker stage will not benefit from the application of ethylene since the process has been initiated already by the tomato's own ethylene. However, there is some evidence that additional ethylene may speed the ripening process. Although there are many large, commercial tomato ripening facilities, small-scale growers and packers often find it convenient to build and operate small on-farm facilities. A tomato ripening room must be nearly airtight to prevent the escape of ethylene. Small ethylene gas generators may be purchased or rented for this purpose. Care should be exercised in mixing tomatoes with other types of produce in storage and transit. The ethylene gas given off by many ripening fruits (such as apples, cantaloupes and bananas) will hasten the ripening of tomatoes located nearby. Common storage of mature green tomatoes with ripe tomatoes should be avoided also for the same reason. A mixture of 3 per cent oxygen and 97 per cent nitrogen will extend the life of mature green tomatoes upto six weeks at 55°F without noticeable decline in appearance and taste. Lower oxygen levels will produce an off-flavour.

Controlled or modified atmospheres storage:

Controlled or modified atmospheres have been shown to delay ripening during storage. Batu (2003) observed that after 60 days storage of mature green or rose tomatoes at 13 or 15°C, those stored under controlled atmospheres of 5.5% O_2 + CO_2 (3.2, 6.4 or 9.1%) were less acceptable in terms of sweetness and aroma than those stored in air. Moreover, even short-term storage of red, almost fully ripe tomatoes under conditions of low or zero O_2 (e.g. in N_2 for 35 hours) adversely affects fruit aroma, due to a reduction in C-6 compounds and isobutylthiazole and an increase in ethanol and acetaldehyde (Boukobza and Taylor, 2002). Modified atmospheres resulting from the enclosure of tomatoes in polyethylene or other forms of plastic packaging may also delay fruit ripening and prolong storage life. Srinivasa *et al.* (2006) stored green, physiologically mature tomatoes in cartons covered with chitosan (biodegradable membrane) for 30 days at 27±1°C. Fruit showed better colour retention and firmness not only in relation to the control (fruit stored in air) but also in comparison with those enclosed in low-density polyethylene (LDPE) film. By contrast, Kantola and Helen (2001) found that the sensory quality of organically grown tomatoes stored for 3 weeks at 11±1°C and 75-85% RH in perforated LDPE, cellophane or biodegradable bags was not affected by the packaging material. However, these results apparently reflect the level of O_2 within the containers, since Muratore *et al.* (2005) showed that the quality characteristics (vitamin C, carotenoids) of plum tomato could be preserved satisfactorily in modified atmospheres produced by enclosure of fruit in biodegradable or polyolefin films only when the O_2 permeability of the film was sufficient to prevent anaerobic respiration. The inclusion of an ethylene adsorbent (granular activated carbon) within polypropylene bags in which tomatoes at the turning stage were stored at 8°C, reduced the level of ethylene within the storage atmosphere for 21 days. Colour change, softening and weight loss were reduced and low oxygen levels in modified or controlled atmospheres also inhibit polygalacturonase activity, thus,

reducing the rate of fruit softening (Kapotis *et al.*, 2004). Enrichment of the storage atmosphere with ozone, which may be of value in reducing the microbial activity of sliced tomatoes, causes a transient increase in respiration, resulting in increased fructose, glucose, ascorbate and fumarate levels, both in intact and sliced fruit (Aguayo *et al.,* 2006).

Packaging:

There are different modes of packaging. Generally, container-packing is considered ideal for packing fruits or vegetables because these are easy to handle, provide good protection from mechanical damage, have adequate ventilation and convenient for merchandising. They could easily carry printed information about the product packed and are helpful in advertising about the product. Fancy containers such as fibre board boxes, or wooden or plastic crates, are often used for high-value products. Inexpensive containers such as bamboo baskets or nylon net sacs are commonly used for low-priced products. CFB cartons offer available alternative to the traditional wooden boxes. Apart from this, polyethylene bags (PE), corrugated container box with a General Purpose Polystyrene (GPPS) liner, Polystyrene (PS) trays, expanded PS trays and Polyethylene Terephthalate (PET) clamshell container and transported in bulk within a corrugated containers are used. Tomatoes harvested at breaker stage and packed in 300 gauge polyethylene bags with three vents recorded minimum changes in moisture, total soluble solids, acidity and sugars than the control fruits. The organoleptic score was high in above acceptable limits for these fruits with a shelf life of 42 days (Naik *et al.*, 1993). Minimum weight loss of 77.5 g was recorded for tomatoes packed in black polyethylene bags. While, a maximum weight loss of224.16 g occurred for unpacked fruits. The best colour retention and firmness was noted in black polyethylene bags (Badshah *et al.*, 1997).

Transport:

Tomatoes are highly perishable in nature hence, quick means of transportation is necessary. Tomatoes are transported by road through tractors, trucks and also by rail and air to distant markets. Village produce is transported to the nearby towns and city market only by road.

Cool chain:

Cool chain is essential during the transport of export quality commodity all the way from the farm to the customer. This helps in maintaining the temperature inside the box at the same low level as in the cold storage.

The various stages of the cool chain are:

– Cold store at the farm.

– Refrigerated truck from farm to the airport

– Cold store at the airport.

– Building up of the pallet in a cold store at the airport.

– Loading the aircrafts directly from the cold store in a short time.

– Cargo aircraft maintains cold store temperature in hold.

– Off-loading direct into a cold store in the receiving country.

– Refrigerated truck to the customers.

Processing of tomatoes:

Need for processing tomato :

Main objective of tomato processing is to supply wholesome, safe, nutritious and acceptable food to consumers. Tomatoes and tomato-based foods are low in calories and possess antioxidant micronutrients. Tomato is a valuable raw material for processed products such as ketchup, sauce, juice, soups etc. The recent scientific advances have revolutionized tomato processing industries. Tomato products have good export potential especially in the Middle East.

Tomato is a climacteric fruit with a short shelf-life under ambient storage conditions. When harvested at the mature green stage, it ripens within 8 days and shrivels thereafter resulting in loss of appearance and texture besides physiological loss in weight, cellular integrity and in some cases even nutritional loss. Due to perishable nature of tomato fruits, it creates glut during production season and becomes scanty during off season. Hence, there is a need to protect this perishable crop from post harvest losses so as to safeguard the grower's investment and ensure ready availability of the crop to the consumers at affordable prices throughout the year.

Importance of processing:

Tomato in India occupies second position amongst the vegetable crops in terms of production. Another encouraging trend has been that India's production level of processed tomato has risen by 50 per cent. The main objective of processing is to supply wholesome, safe, nutritious and acceptable food to consumers throughout

the year. Tomatoes and tomato-based foods are considered healthy for the reason that they are low in calories, but possess a remarkable combination of antioxidant micronutrients.

A number of tomato products e.g. ketchup, juice, puree, paste, sauce, pickles are available in the market. These are items of common use in households, hotels, restaurants, institutions. Tomato puree is used as a substitute to fresh tomato during cooking. Ketchup is a sweet spicy food. Tomato juice is nutritious and appealing juice in taste. Tomato sauce tastes sweet and sour. Both sauce and ketchup are consumed with food and snacks. Tomato is a valuable raw material used for processed products such as juice, puree and paste, ketchup/sauce, and canned whole. The recent scientific advances have revolutionized tomato processing industries.

India ranks first in the world in production of fruits and second in vegetables, accounting roughly 10 and 15 per cent, respectively, of total global production. India have a strong and dynamic food processing sector playing a vital role in diversifying the agricultural sector, improving value addition opportunities and creating surplus food for agro-food products.Presently, a mere 2.2 per cent of fruits and vegetables are processed, even as the country ranks second in the world in terms of production. This is comparatively low when compared to other countries like Brazil (30%), USA (70%) and Malaysia (82%).The National policy aims to increase the percentage of food being processed in the country to 10 per cent by 2010 and 25 per cent by 2025. Food processing adds value, enhances shelf-life of the perishable agro-food products and encourages crop diversification. The market size of the food processing industry is likely to increase from Rs. 4600 billion in 2003-04 to Rs. 8200 billion in 2009-10, and to Rs. 13,500 billion in 2014-15.In the coming years India's share in the global processed food industry will get a raise from one per cent to three per cent.

However, over the last few years, there has been a positive growth in fruit and vegetable processed products such as ready-to-serve beverages, fruit juices and pulps, dehydrated and frozen fruits and vegetable products, tomato products, pickle, convenience veg-spice pastes, processed mushrooms and curried vegetables. As per the data maintained by Food Safety and Standards Authority of India under Ministry of Health and Family Welfare, the installed capacity of fruits and vegetables processing units (FPO licensed units) has increased from 26.38 lakh tones as on 01.01.08 to 30.89 lakhs tones as on 01.01.09.

Due to increasing standards of living in the cities and the rapid urbanization taking place in the rural areas, consumption of tomato based products is expected to go up steadily. At present, the market of ketchup/puree, especially in the urban areas, is dominated by some brands. Some Medium and Small Companies are also engaged in its production. The Indian Food processing industry will continue to prosper, thanks to the rising income levels and modernized food retail stores. The food processing sector is likely to be the driving seat for the Indian economy.

Market structure:

Nearly 100 per cent of processing tomatoes are produced and sold under contract between growers and processing firms. Firms that contract for processing tomatoes are typically manufacturers of raw tomato paste. This paste is eventually used to make sauces, ketchup, etc. and can be stored for upto 18 months (Economic Research Service (ERS) 2005). Processing tomatoes harvested from the field are transported to the manufacturing plant and transformed into paste within 6 hours after harvest. The small window between harvest and conversion into tomato paste necessitates a manufacturing industry in close proximity to farm production areas.The raw paste is eventually sold to remanufacturing companies which add water, spices, flavorings and other additives to make specialized retail products such as sauces and ketchup. In the past, a single manufacturer often produced both bulk paste and retail products. However, in more recent years the processing industry has begun to specialize either in manufacturing bulk tomato paste or producing retail products (ERS, 2005).

Value added tomato:

Value addition is the most suitable process to use and form the bulk of tomato. The demand for tomato processing is more because there is a need to preserve the product for cooking purposes out of season or to add value for extra income. The most important methods of preparing value added products are concentration (to a paste or purée) and drying either fruit pieces or making to a powder. High quality 'salad' tomatoes fetch the highest value when sold fresh and in good condition. They

can be used for processing, unless for home use to save excess at the height of the season.

Tomato products:

The processed tomato can be divided into the following end user categories:

– Peeled tomatoes
– Concentrate
– Tomato pulp
– Tomato paste
– Dehydrated tomatoes
– Tomato powder
– Ketchup
– Tomato juice, strained tomatoes and diced tomato.

Cultivars suited for processing:

Roma (Indian Agricultural Research Institute) – prolific bearer, determinate, good foliage cover, excellent bearing, elliptical fruit shape with yellow stem end fruits thick at stem end. Punjab Chhuhara (Punjab Agricultural University) – determinate, good foliage cover, profile bearer, fruits elliptical in shape with yellow stem end. S-152 (Indian Agricultural Research Institute) – prolific bearer, determinate, good coverage, fruits egg shaped with yellow stem end, borne in bunches, suitable for canning and long distance transportation. It is known as all-purpose variety and known as Pusa Gaurav. Studies on tomato cultivars for processing industry revealed that NDT 120, Pant Bahar and NDT 101 were highly suitable for the production of quality juice, ketchup and chutney, respectively.

Raw material quality:

Tomatoes should be ripe, red and firm to soft, free of all mould growth (by cutting out infected parts) and free of stems, leaves, dirt and other soils (by washing). It is less important if the tomatoes have surface blemishes or splits/cracks (provided these are not infected) and in most processes they will be cut or pulped.

Dehydration of tomato:

Dehydration is the process of slowly removing water from tomatoes in order to preserve them. Drying time depends on the variety of the tomato, the humidity in the air during the drying process, the thickness of the slices or pieces and the efficiency of dehydrator or oven. Firm, ripe, meaty tomatoes dry best. This type of tomato is usually oval shaped and called an Italian, Roma, plum, pear or paste tomato. These tomatoes contain fewer seeds and more pulp and produce a better dried tomato. Varieties that contain a lot of water or gel, such as Beefsteaks, are not recommended. The secret to successfully dehydrating tomatoes is to control the temperature and air circulation. If they are dried at too low a temperature, 90°F or less, the tomatoes will dry too slowly and bacteria or mold can grow. At too high a temperature, 170°F or higher, the tomatoes will cook, or harden on the outside (case harden), while the insides remain moist and spoilage will also occur.

Properly dried tomatoes have a dark red colour and feel dry and leathery, but not hard and brittle. They should not be "tacky" or moist. When touched in the center, no tomato pulp should stick to the finger. Dried tomatoes are used for making tomato flakes and powder. The dehydrated tomato can be rehydrated.

Dried tomatoes may be rehydrated in a variety of ways. Tomatoes may be added directly to soups and stews, or may be soaked in water, wine, bouillon or vegetable juice to cover. They usually rehydrate within 1 to 2 hours. If they are soaked for more than 2 hours, or overnight, they should be refrigerated. Using boiling liquid speeds up the soaking time. The soaking liquid may be used in cooking.

Tomato flakes and powders:

To crumble dried tomatoes, it should be put into the freezer for 5 minutes and then it is crushed. To produce flakes or powder from dried tomato it should be dried beyond the "leathery" stage to a more brittle consistency. Tomato flakes can be made by crushing the dehydrated tomatoes with a mallet, rolling pin or by crushing them in the hands. Powders are finer than flakes and are made in a food processor or blender.

Canning of tomatoes:

Canned tomatoes are prepared from red ripe tomatoes as whole, diced, sliced or in wedges. The fruit may or may not be peeled, but stems and calices should be removed. Tomatoes which are ripe are selected, washed in water and then scalded in boiling water or steam for 2 to 3 minutes to crack the skin and facilitate its subsequent removal. The peeled and trimmed are then filled in cans and common salt is added at the rate of 1 per cent. Sometimes a little sugar is also added. Calcium

salts, varying from 0.015 to 0.08 per cent by weight of the finished products can also be added. Other ingredients such as organic acids, spices, oil and flavourings can be added upto 10 per cent. Tomatoes are canned either as a solid pack *i.e.* without the addition of tomato juice or as a standard pack ie with addition of tomato juice. Generally, for safe processing long cooking for 45 to 60 minutes in boiling water is necessary. Diced tomatoes are very popular. Stewed tomatoes are canned tomatoes containing onion, celery and peppers.

Diced tomato:

Diced tomatoes are thosetomatoes that have been diced. In the United States it refers to canned chunks of plum tomatoes in tomato juice or tomato puree. Calcium chloride is added to stabilize the cell structure of the canned tomatoes, gives a firmer texture. Available sizes of tomatoes are regular (roughly 2 cm or 7/8 in) for long-cooked dishes and petite (roughly 1 cm) for quicker applications. A relatively recent arrival in the processed tomato market are often more flavourful than commercially produced fresh tomatoes. Diced tomatoes may also be preserved by using high pressure processing which is a non-thermal technology.

Tomato powder:

This special fruit is spray dried in large amounts from a concentrated paste. The tomato powder is made from hot break paste or cold break paste. The paste used is strained free of skin, seeds and long fibres and is concentrated to a maximum of 45° Brix for hot break and 50° Brix for cold break.

Freezing of tomatoes:

Tomatoes may be frozen as sliced, chopped or pureed. Select firm, ripe tomatoes for freezing. Sort the tomatoes, discarding any that are spoiled. Cut the stem scar, cut in to desired shapes and freeze. Tomatoes do not need to be blanched before freezing. Whole tomatoes are not an item of frozen commerce. They lose turgor and hence, texture on freezing and are no longer suited to the uses common for fresh tomatoes. Chopped or pureed whole tomatoes can be frozen and stored for 6 to 9 months at 0°F for use in further processing. Other tomato products such as purees, sauces and pastes can readily be frozen. They are commonly employed as ingredients in other frozen products. Freezing provides an advantage of colour stability compared to other storage methods.

Commercial products of tomato:

Fresh tomatoes are very refreshing and appealing but cannot be stored for a long period. Often, they are sold at distress prices during the peak harvest season and nearly 25 per cent of the produce is spoiled due to mishandling. Such losses can be avoided by converting tomatoes into delicious products.

Tomato juice:

Plant ripe, fully red coloured fruits are selected and all green, blemished and over-ripe fruits are discarded. A good quality juice should be of deep red colour, possess the characteristic taste and flavour of tomato, contain about 0.4 per cent acid (in terms of citric acid), be uniform in appearance and have high nutritive value. In addition the juice should contain 0.5 per cent salt, 15 per cent sugar. For the production of 1 liter of juice, 10 g of sugar, 5 g of salt, 1 g of citric acid and 1 g of sodium benzoate should be added. Tomato juice/pulp can be extracted by hot or cold pulping. Hot pulping is superior to cold pulping because of easy extraction of juice besides higher yield, less oxidation of vitamin C and less chances of microbial spoilage. On commercial scale, a pulper or continuous spiral press is used for juice extraction but in homes tomatoes are strained through a steel sieve. The juice is heated upto 82-88°C for 2 minutes and hot filled in bottles. Then the bottles are sterilized and cooled.

Tomato puree and paste:

Tomato pulp without skin or seeds, with or without added salt and containing not less than 9 per cent of salt free total solids, is known as medium tomato puree. It can be concentrated further to heavy tomato puree, which contains not less than 12 per cent solids. If this is further concentrated so that it contains not less than 25 per cent total solids, it is known as tomato paste. On further concentration to 33 per cent or more of solids, it is called concentrated tomato paste.

Tomato pulp is prepared from ripe tomatoes in the same manner as tomato juice. Concentration of the pulp can be done either in an open kettle or in a vacuum pan. In the former, most of the vitamins are destroyed and the product becomes brown. On the other hand, use of vacuum pans, which are expensive, help to preserve the

nutrients and also reduce the browning to a great extent. In vacuum pans, the juice is boiled at about 71°C. Ordinarily tomato juice can be concentrated to 14-15 per cent solids in an open kettle, but for obtaining higher concentrations a vacuum pan is required. Moreover, sterilization of the product is also possible in a vacuum pan. While cooking in an open kettle, a little butter or edible oil is added to prevent foaming, burning and sticking. The end point of cooking of puree and paste can be determined either with a refractometer or by measuring the reduction in volume.

Tomato sauce/ ketchup:

It is made from strained tomato juice or pulp with the addition of spices, salt, sugar and vinegar (onion and garlic are added optionally) and contains not less than 12 per cent tomato solids and 25 per cent total solids. About one-third of the total sugar required is added at the time of commencement of boiling to intensify and fix the red tomato colour. If the whole quantity of sugar is added initially, the cooking time will be longer and the quantity of pulp will be adversely affected. Generally, the sugar content in ketch up/sauces varies form 10-26 per cent. On the other hand, salt bleaches the colour of the tomato product; it is, therefore, desirable to add it towards the end of the cooking process. Spices are generally added in powdered form to the product by spice bag method. Instead of whole spices, essential oils of spices, oleoresins and spice extract can also be used. Essential oils, however, do not give the characteristic true aroma of whole spice but oleoresins provide true aroma. At present, spice extract is used in many industries for sauce/ ketchup preparations. These do not adversely affect the colour of the product and are generally added a few minutes before the end of cooking. The salt content of the product should be 1.3-3.4 per cent. Good quality vinegar is essential for the preparation of high quality sauce/ketchup. It should contain 5.0-5.5 per cent acetic acid and should be added when the product has thickened sufficiently, so that the acid is not lost by volatilization. Tomato sauce/ketch up generally contains 1.25-1.5 per cent acetic acid. Sometimes glacial acetic acid (100 % acetic acid) is used which is colourless and cheaper than vinegar. In order to increase the viscosity and prevent the separation of pulp from clear juice, pectin can be added to the extent of 0.1 –0.2 per cent by weight of the finished product.

Quality evaluation of processed tomato products:

Quality makes a product what it is. It is the combination of attributes or characteristics of a product that have significance in determining the degree of acceptability of the product to a user and that determines its value or worth. As used by the industry, it is a concept involving degree: degree of purity, strength, flavour, colour, size, maturity, workmanship, condition and any other distinctive attribute or characteristic of the product. Thus, the term quality, without being defined in terms of some standard, means little. The trade also uses the term to mean the finest product attainable. From past experience food processors have learned that high-quality products never fail to sell. This is true because the consumer recognizes the brands that maintain their quality at the standard set for that particular product. Many large companies attain their position by the control of quality of the products they process.

Waste from tomato:

The tomato waste consists of skin and seeds, which are difficult to handle. The volume of waste is huge and unutilized due to lack of adequate technology. The industries are dumping waste into open spaces, which acts as breeding ground for pests.The peel and seed waste of tomato is about 40 per cent of fresh fruit processed. So there is a need to develop a technology to utilize the waste from this industry.

The peel of tomato contains the following:

– Proteins - 100.8g
– Ash - 256.4g
– Fibre - 299.4g per kg and
– Lycopene - 734 µg /g on dry weight basis.

It contains lutein, β– carotene, cis β– carotene and also has Flavonols, Quercitin and Kaempferol (5-10 mg/ kg). Its major function is cardio protective role.

Lycopene recovery from tomato industry significantly improves the economy. It is used for making potent antioxidants for formulating health supplements. High recovery of lycopene (77-88%) can be obtained from peel of tomato by treament with enzymes followed by extraction with solvents. Super critical fluid extraction yields purer fraction of lycopene. Lycopene tablets are more effective in controlling cholesterol and triglyceride levels in blood.

Tomato seed:

The seeds and the skin of the tomato that are most

nutritious, both are typically removed from most tomato based products. Tomato seed oil is stable and is an ideal ingredient choice for incorporating the nutritive benefits of tomato seeds, particularly the high lycopene content, within personal care products.

Seeds of tomatoes contain essential fatty acids, anti-oxidants, vitamins, minerals, carotenes including lycopene and phytosterols and other important nutrients.

– Method of extraction : Cold pressed
– Shelf-life : 2 Years

Tomato seed oil properties:

– High linoleic (Omega-6) essential fatty acid content (Approximately 50-70%)

– High oleic (Omega-9) fatty acid content: (Approximately 10-25%)

– Contains upto 1 per cent linolenic acid (Omega-3 essential fatty acid)

– Good source of essential amino acids including lysine

– Rich in copper, iron, manganese and zinc

– Reported to block UVA/UVB ray.

Cosmeceutical uses:

Tomato seed oil is stable, highly penetrating oil. It is a remarkably nutritive addition to facial creams, antiwrinkle serums, anti-aging formulations, lip care products, hair products, make-up, sun care preparations, shaving products cosmeceutical formulations. It is suitable for dry, oily and combination skin.

Recycling of tomato waste:

Tomato processing produces waste and consists of skin and seeds, which is difficult to handle. Vermi-composting is one of the modern technologies to handle organic waste. Earthworms ingest, grind and degrade the organic matter enzymatically with the help of micro-organisms into soil conditioner. It is rich in plant growth hormones, enzymes and nutrients in an easily available form. The feed mix was prepared by mixing tomato waste with cattle dung and fed to African worms. It took about 90 days for worms to convert waste into odourless, granular and dark brown compost. The vermin-compost is rich in nitrogen, phosphorous and potassium with carbon: nitrogen ratio in the range of 15:1 is good for plant growth. Vermin technology is useful in converting the tomato industry waste into compost at a low cost. This technology makes the processing environment-friendly along with good economic returns. Moreover, this technology ensures recycling of the organic matter back to farm in shortest possible time.

SWOT analysis of tomato-processing industry infrastructure in India:

Strengths:

– Round the year availability of raw materials.

– Vast network of manufacturing facilities all over the country.

– Vast domestic market.

– Availability of new reliable and better accuracy instruments and equipments.

Weakness:

– Consumer acceptibility is low.

– Lack of information on need based production system.

– Lack of varities for industrial processing tomatoes (Dried/ sliced tomato and canned tomato).

– There is more awareness for fresh tomato and not for processed tomato.

Opportunities:

– Large production and material base offers vast potential for tomato processing activities.

– Creating awareness for processed tomato products

– Ensuring safety

– Developing techniques to meet the export potential of processed tomato products.

Challenges:

– Competition from global players

– Loss of trained manpower to other industries and other professions due to better working conditions prevailing there may lead to further shortage of manpower.

– Rapid developments in contemporary and requirements of the industry may lead to fast obsolescence.

Conclusion:

Tomato is available throughout the year. During peak harvest season the price may go cheap (during glut season) and during lean season the price may go up. The tomato processing industries have to go for a need based production system. Moreover, there is a demand for

processed tomato products in Europe, American and Middle East countries. Due to the above reasons the tomato processing industry have avenues for export oriented processed tomato products.

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