

TOMATO PROCESSING AND PREPARATION OF TOMATO POWDER

Abstract

Tomato is a highly perishable vegetable crop and seasonally grown. It contains high amount of lycopene. Due to its perishable nature, the matured tomatoes are damaged rapidly and difficult to transport. To prevent these types of losses, its processing and value addition is most important. In this context, development of different value added products from tomato pulp and dried tomato powder has been considered in this study. Drying of tomato powder is most difficult due to its high hygroscopic nature. Freshly ripened tomato contains about 94% of moisture and is also a rich source of minerals and vitamins like vitamin A and C. Drying and dehydration reduce moisture content in the tomato products, which increases the shelf-life of the products by retarding the bacterial propagation. There are different methods of drying of tomato pulp such as conductive drying, drum drying, agitated thin film drying, refractance window drying, sun drying, tunnel drying, spray drying and foam mat drying. Spray drying technique is most suitable for the preparation of tomato powder but it is costlier. In view of reduced production cost foam mat drying technique is most suitable for tomato powder.

Keywords: Tomato processing, Lycopene, Vitamins, Tomato powder

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I. INTRODUCTION

In India, there are so many types of vegetable crops grown and consumed. India ranked second position in the production of fruits and vegetables in the world after China. Vegetable production in India was accounted of 209.14 Million tonnes on 11.37 Million ha during 2021-22 (MAFW, 2023). Tomato is considered as one of the most popular vegetable in India as well as world. It's demand is increased day-by-day in meals because of its appetizing, refreshing and pleasant taste. Total tomato production in India during 2021-22 was 20.69 Million tonnes. Tomato is considered to be as a health promoter due to vitamins content and disease fighting phyto chemicals especially lycopene. Tomato is not only seasonal crop but also contains high moisture as perishable vegetable and deteriorates very fast after collecting, which results their nutritional as well as physical losses. During the peak period of tomato production, about 25% of the tomato is damaged due to mishandling and such losses can be prevented by converting it into various value added products. Tomato fruit contains water and organic compounds (solids) in that 10% is skin and seeds. The content of sugar is positively correlated with total soluble solids in tomato. The sugars are mostly constituted of glucose and fructose and contain about 65% of total soluble solid in fruit juice. On the otherhand the acids are mainly malic and citric acids, organic acids composed about 15% of dry content of fresh tomato (Turhan and Seniz, 2009). The ripened tomato includes about 94% moisture and an abundant source of minerals and vitamins, like vitamin C and vitamin A. The red pigment which is due to content of lycopene in tomatoes perform as an antioxidant, neutralizing free radicals that can damage the cells in the body hindering the lung, breast and endometrial cancer cells and cut down the threat of developing prostate cancer by 45%. Fresh fruits and vegetables are excellent sources of vitamins which are vital for proper growth and development of living beings. Vitamins contains for a small portion of the total dry matter but most importantly required. Minerals commonly found in tomato fruits are K, Ca, Mg and P and may reach 8% of the dry matter. Marketing of fresh tomato in flush season is a great problem because of its short postharvest life, which constitute the high losses during postharvest. Short shelf-life together with insufficient processing facilities results in greater losses in terms of revenue as well as physical losses. Several food preservation methods relied on elimination of water in order to diminish the water activity below a level that causes growth retardation of microorganisms. Moisture content of the product is the most influencing factor on unwanted chemical reactions, which affects the nutritive value of food as well as its organoleptic properties (Gowda *et al.*, 1994).

A huge quantity of these produce lost due to poor handling, storage, transportation and processing facilities. Therefore development of process technologies for preparation of different products and its preservation technologies is advantageous to farmers who produce large quantities of tomatoes. A wide range of tomato products are prepared using concentrated juice or pulp, which needs modern and easily acceptable technology for development of superior quality products.

Drying is a crucial and common procedure for removing moisture from food-related products. The essential idea is that water is necessary for microbes like bacteria, fungi, mold, and others to grow and multiply, which leads to food spoiling and decay. Water must be minimized to extend the shelf life of food goods since it might serve as a possible breeding ground for diseases in the food chain. The final procedure that eliminates moisture from all food component, including fruits, vegetables, grains, legumes, milk, meat, and fish, is drying

and dehydration. Moisture is the primary element in agricultural and food materials that influences the shelf-life of the product through microbial deterioration, oxidation, and changes in the physical structure of the foods. Food materials may be excellently preserved by drying, and a solar dryer is a better food preservation technique for sustainable growth. Before cooking, drying was perhaps the first food preservation technique ever utilized by man. It involves drying out agricultural products to create a product that can be securely preserved for a longer period of time. The tomato's constituents have a complex character that makes it possible to imagine a drying mechanism for tomatoes. Development of tomato powder is the most important for its increased shelf-life and easy handling and storage. Tomato powder can be used for addition to soups, sauces, marinades, baby food, extruded cereal products, fruit purees, *etc.* (Pszczola, 2003). Fruit and vegetable juices are concentrated first up to a certain level of soluble solids by evaporation of moisture and then dried up to 2-3% moisture content. In this process energy conservation as well as product quality was generally maintained. Concentration is the most important unit operation for removal of moisture as it determines the quality and shelf-life of the final product.

II. PROPERTIES OF TOMATO FRUIT

- 1. Physical Property:** Physical properties of tomato fruit are necessary to find the edible/waste portion of the fruits. The physical composition of tomato fruit is presented in Table 1.

Table 1: Physical Constituent of Tomato Fruit

S. No.	Parameters	%
1.	Flesh	77.20 ± 5.50
2.	Skin	15.70 ± 5.00
3.	Seed	6.60 ± 1.00
4.	Edible portion	95.2 ± 3.20
5.	Waste portion	4.8 ± 0.50

Surendar *et al.* (2018) studied the physical composition of tomato fruit and results obtained was flesh about 77.20 ± 5.50%, seed 6.60 ± 1.00% and skin 15.70 ± 5.00% of tomato fruit. Well developed tomatoes were used in this study which was found to be cherish red in colour. The edible portion of tomato was found 95.2 ± 3.20% whereas; waste portion was 4.8 ± 0.50%.

- 2. Chemical Characteristics:** The analysis of chemical characteristics such as TSS, pH, acidity and brix/acid ratio of tomato fruit was done. The results of this analysis are presented in Table 2. The total soluble solid and pH value of tomato pulp were reported to be 2.90 ± 0.05°Bx and 4.21 ± 0.05, respectively (Surendar *et al.*, 2018).

Table 2: Chemical Properties of Tomato Fruit/Pulp

S. No.	Parameters	%
1.	Total soluble solid (TSS), °Bx	2.90 ± 0.05
2.	pH	4.21 ± 0.05
3.	Acidity, %	0.38 ± 0.05
4.	Brix/Acid ratio	4.68 ± 0.05

- 3. Nutritional Composition:** The fresh tomato fruits have been analyzed for its nutritional or compositional qualities. The fresh tomatoes were converted into slurry and it was dried through hot air oven, at $60\pm 5^{\circ}\text{C}$. After drying, it was converted into powder form and analyzed for nutritional value. Moisture content, protein, fat, fiber, ash and carbohydrate content were determined according to standard methods of AOAC (2010). Chemical composition of fresh tomato fruits is depicted in Table 3.

Table 3: Nutritional composition of fresh tomato fruit (Abdulmalik *et al.*, 2014)

S. No.	Composition	%
1.	Moisture	93.1
2.	Protein	0.6
3.	Fat	0.1
4.	Carbohydrate	3.9
5.	Fiber	1.0
6.	Ash	1.3

Moisture content of fresh tomato fruit was found to be 93.1%. Similar types of observations 94.00 and 95.05% moisture content of tomatoes had also found by Thakur and Kaushal (1995). The average value of protein content was found to be 1.6% (wet basis) (Patel 1996). Similar type of finding had also been obtained during experiment (1.0-2.0% protein on wet basis) in tomato by Shibli *et al.* (1995).

Table 3 indicates that fat of fresh tomato was 0.1% (wb) *i.e.* 1.43% on dry matter basis. The fat present in both genotypes SEL-7 and ARTH-3 of tomato was found to be 1.61 and 1.56% dry matter basis, respectively (Gupta *et al.*, 2011). Ash content in tomato fruit was 1.3% on moisture basis (Abdulmalik *et al.*, 2014). Ereifej *et al.* (1997) reported that 0.5 to 0.7% ash content was found in tomato on fresh wet basis. The crude fiber content was found to be 1% in wet basis. Abdel-Rahman (1982) also reported in his research, the similar amount of fiber content 0.56% in tomatoes on wet basis. Carbohydrates content was 3.9% on fresh matter basis.

III. TYPES OF TOMATO PRODUCTS

- 1. Tomato Pulp/Juice:** Fully red coloured ripened tomato fruits were taken for development of tomato pulp. All green, blemished and excessive ripened fruits were discarded from the samples. The yield, colour and flavour of the pulp affect the degree of ripeness of the tomatoes. Tomatoes should be washed completely under running water and dried at room temperature to remove the surface moisture by using fan. After that the dried tomatoes were crushed by using fluted wooden roller-crushers. Screw type juice extractor may also be used for pulping. Tomatoes pulp/juice is the main component used for production of different tomato products such as tomato souses, tomato puree, paste, ketchup, *etc.*

Method of Preparation of Tomato Juice

- **Cleaning:** To remove dust, filth, *etc.* that is present in cracks, wrinkles, folds, and stem cavities but cannot be easily eliminated by mild washing, tomatoes are

cleaned/washed in large quantities of running water.

- **Crushing:** To remove the pulp, cleaned tomatoes are divided into small segments. These tiny bits can also be crushed with fluted roller crushers or by running them through a fruit grater.
- **Pulping:** There are two ways to remove tomato pulp: either by running the crushed or whole tomatoes through a pulper without heating them beforehand (cold break), or by boiling them until they are softened and then removing the pulp in a pulper (hot break). Juice and pulp that enter the pulper's sieves during pulping are collected. The skin and seeds are discarded through other end of pulper.
- **Cold Break Method:** In order to remove the pulp, the tomatoes are immediately sliced or crushed in a fruit grater after being washed. This method is commonly used as a cold break. The cold break process's characteristics are as follows:
 - The natural red coloured tomato juice is released only after heating the skin.
 - The introduction of air during the cold extraction procedure causes the natural vitamin C in juice to be destroyed or oxidized.
 - The slimy quality of the juice may be caused by the natural pectin being broken down by the pectinase enzyme.
 - Cold break juice has a significantly harsher and acidic flavor than hot pulped juice.
 - The cold pulped juice must be treated right away to reduce the likelihood of microbiological burdens or deterioration.

The extraction of juice in cold process is comparatively difficult as less yielding.

- **Hot Break Method:** To make the pulp extraction process in the pulper easier, the diced or crushed tomatoes are boiled in pressure cookers, steam jacketed stainless steel kettles, or aluminum pans until they are soft. The following are some benefits of hot pulping methods:
 - Hot pulping kills pectinase, an inherent enzyme that hydrolyzes pectin to produce low-consistency extracted juice by hydrolyzing the pectin.
 - Heating causes the juice to release naturally occurring lycopene, which gives skin its red color.
 - In order to stop microbial growth, it also creates fractional sterilization of juice.
 - It aids in preventing the oxidative enzymes from damaging the juice's ascorbic acid.
 - Hot pulping produces more juice than cold pulping does.

By putting the crushed tomatoes through a continuous spiral press or pulper, the tomato juice or pulp is extracted.

- **Continuous spiral press:** This device presses tomatoes against a tapered screen of fine mesh using a lengthy spiral screw. As seeds and peel are removed from the lower end of the sieve, the juice is drained through the screen.
- **Pulper:** The pulper has a fine stainless steel horizontal cylinder inside. While the pieces of skin, seeds, fiber, etc. are collected through another end of the machine, the fine pulp is forced to pass through the sieves or screens by the swift rotation of the heavy paddles inside the cylinder. On a smaller scale, however, heated crushed tomatoes can be manually filtered through stainless steel sieves.



Figure 1: Continuous Spiral Press Pulper



Figure 2: Fruit Pulper

2. Concentration of Tomato Juice/Pulp: Evaporation of moisture from juice reduces volume and weight of juice, which results immediate advantages in economically to handling and storage. Nearly all fruit and vegetable juices are concentrated before dehydrated or dried. This may be because of removal of moisture being able to more economical in highly efficient evaporators than in dehydration equipment. Evaporation technique is widely used for concentration of fluids. The concentration of dry solid in the fluid will increase by evaporation of fluid. The following reasons for application of evaporation are:

- Reduction in the volume of fluid will reduce the cost of handling and storage.
- Quality and stability of the product can be improved by removal of moisture.
- Removal of water will increase the shelf-life of the products.
- Product should have a high concentration of solids.
- Recycling of purified fluid can be obtained by condensation of the vapour evaporated.

There are different methods used for concentration of tomato juice:

- Concentration using double effect evaporator
 - Concentration using rotary vacuum evaporator
 - Concentration using reverse osmosis processing
 - Concentration by CO₂ hydrate formation
- **Concentration using Double Effect Evaporator:** Tomato juice is concentrated in double effect evaporator which has a capacity of 12,000 kg water/h evaporation. The tomato juice circulates easily by convection in the second effect evaporator. The

condensing vapour obtained from the first effect is utilized for heating of the juice. The concentrate is moved by gravity through an automatic level regulator into the first effect of the evaporator following pre-concentration in the second effect. A turbine circulates the concentrate by pumping it down the heating tubes. The product temperature in the first effect (58-60 cm Hg vacuum) is 60°C and in the second effect (69-70 cm Hg vacuum), it is 40°C.

- **Concentration using Rotary Vacuum Evaporator:** Tomato juice is concentrated by using rotary vacuum evaporator. Set the water bath at the temperature of $3\pm 1^\circ\text{C}$ higher than the desired concentration temperature. The tomato juice contained initial soluble solids at about 5.5°B is entered into holding chamber and rotates slowly till the desired temperature of juice is attained. Once the required temperature gained by the juice, the vacuum is created inside the equipment and juice level is maintained under boiling condition throughout the process. As the concentration increases, the level required vacuum increases in order to maintain boiling condition of concentrating juice. In the concentration of juice at 45 and 55°C temperature, initial time required for first run is 30 min and then increases by 30 min for every successive run. But at 65 and 75°C, initial run time is 15 min and then followed by 15 min increase in each successive run. The process is continued till the required concentration is achieved after which the sticking of the material on the flask will be seen. At the end, vacuum is freed and the concentrated juice is removed from the flask or chamber.
- **Concentration using Reverse Osmosis:** Juice concentration using a membrane is thought to be a good alternative to heat methods, however the membrane may become contaminated as the product is concentrated, and the procedure is expensive.

The tomato juice produced using this concentration process was of a greater caliber than that produced using any other widely used heating and evaporation method. In the concentration task, it is crucial to regularly and steadily create highly concentrated tomato juice at lower production costs and with simple process control, without overloading the reverse osmosis apparatus. Reverse osmosis techniques that have historically been used to concentrate tomato juice include single-stage single-pass, multi-stage single-pass, and multi-stage circulation techniques. Tomato juice is made to either flow through the units in a straight line or to circulate around them in multi-stage systems where a number of tubular membrane modules are aligned in series over two or more stages. By using such a multi-stage approach, it is possible to produce products that are quite highly concentrated, but the apparatus for the concentration is expensive, which has a negative impact on the cost of manufacturing. Additionally, it is difficult to prevent quality degradation and bacterial contamination at unit connections due to the challenging process control. As a result, these methods have been deemed impractical and single-stage single-pass techniques are now more widely used. In these techniques, tomato juice is forced to flow through a concentration unit that has a number of serially connected tubular membrane modules only once. Japanese Patent Publication Tokko 61-48904 described a method for controlling tomato juice in a laminar flow area with Reynold's number less than 3000, its linear speed at 80 cm/s or less at the opening to the concentration unit, and the pressure loss at less than 35 kg/cm^2 as the focus of concentrating tomato juice by

reverse osmosis in a single-stage single-pass process. Another method of regulating the sludge volume of tomato juice at 5% or higher and the pressure loss at less than 40 kg/cm² was disclosed in the Japanese Patent Publication Tokko 59-53824. However, using either of these approaches, it remains problematic to consistently and steadily acquire highly concentrated goods since the equipment for reverse osmosis concentration has a tendency to become overwhelmed on a rare occasion.

- **Concentration by CO₂ Hydrate Formation:** The concentration process brought about by the production of gas hydrate is similar to freeze concentration. The creation of gas hydrate crystals during gas hydrate concentration replaces the ice formation, which is the distinction. The gas hydrate synthesis above 0°C uses less energy than the freeze concentration technique.

The main component of the CO₂ hydrate concentration was a stainless-steel reactor with a magnetic stirrer. Up to 25 MPa of pressure is intended to be used when operating the reactor. By pumping coolant from a thermostat with a stability of 0.01 K inside the jacket around the cell, the reactor temperature may be managed. The temperature of the reactor is monitored using two Pt-100 resistance thermometers with the accuracy of 0.1 K, placed in the centre and bottom of the reactor, respectively. The pressure within the reactor is measured using a pressure transducer with a 0.01 MPa precision. The data logger is used to keep track of the reactor's pressures and temperatures. The liquid-filled cell is dipped into the temperature-controlled water bath. The evacuated cell is then filled with CO₂ gas from a gas cylinder via a pressure-regulating valve until the cell's internal pressure reaches the appropriate level. The valve in the line linking the cell and cylinder is closed after the temperature and pressure have stabilized, and the agitator is then set to begin rotating in the device. The temperature then gradually drops to allow the hydrate to develop. A drop in pressure can be used to identify hydrate production within the cell. The temperature then rises by 0.1 K increments. To achieve equilibrium in the cell, the temperature has remained constant for 4 hours at each stage. For each experimental run in this system, a P-T graph will be drawn, from which the hydrate dissociation point will be noted. As a result, the P-T curve's steepest shift in slope is regarded as the hydrate dissociation point, where all hydrate crystals have dissociated. The stirrer will be turned off once hydrate formation is complete. This shows that the necessary tomato juice concentration has been reached.

There is no change occur on CO₂ hydrate phase equilibrium situations in the tomato juice because the most of tomato juice (94%) contains water and the most of the residuals have fewer action on equilibrium temperature and pressure of CO₂ hydrate formation (Andersen and Thomsen, 2009). The high dehydration ratio is obtained with high feed pressure due to more hydrate formation. The dehydration ratio is a relationship of temperature with the feed pressure. Lower temperature is favourable for tomato juice concentration but lower temperature needs more consumption of refrigeration energy. This means that high pressure of feed is more suitable for tomato juice concentration than reduced temperature. Various researchers studied the formation rate of CO₂ hydrate for concentration of juices (Tajima *et al.*, 2005, Daimaru *et al.*, 2007, Sloan and Koh, 2008).

3. Methods of Tomato Powder Production

There are different methods of production of tomato powder. These methods are discussed below:

- **Conductive Drying:** Conductive drying is a viable option to turn tomato puree into powders because it can be energy efficient, and it is especially appropriate for pastes, slurries, and concentrated solutions (Devahastin and Mujumdar, 2006; Sahni and Chaudhuri, 2012). For the manufacturing of tomato powder, conductive dryers fall into three categories: drum dryers (DD), agitated thin film dryers (ATFD), and refractance window dryers (RWD) (Fudym *et al.*, 2003; Nindo and Tang, 2007; Pawar *et al.*, 2011).
- **Drum Drying:** With viscous pasty or pureed foods such as pre-gelatinized starches, mashed potatoes, caseinate, and fruit purees, drum drying is effectively used (Kalogianni *et al.*, 2002; Rodriguez *et al.*, 1996). The puree is placed onto the revolving drum's outside, where it swiftly dries gratefully to heat supplied via the steel wall from condensing steam (Daud, 2006). The drum's hot surface can then be used again after the dried product layer has been scraped off. According to Nindo and Tang (2007), drum drying is one of the more energy-efficient drying methods since it uses 40% less energy on average than spray drying. However, because the product is exposed to boiling temperature before reaching wall temperature, there is a risk of rigorous quality loss. Although the capital expenses of vacuum drum dryers (VDD) continue to be an issue, the thermal damage can be decreased by applying lowered pressure to lower the boiling temperature (Qiu *et al.*, 2018).

For drying tomato puree, two different types of pilot scale double drum dryers—a normal drum dryer (DD) and a vacuum drum dryer (VDD) can be taken into consideration. Two hollow steel drums with a 0.30 m exterior diameter and 0.30 m length make up the drum dryer. The drums' interiors are heated by steam at pressures ranging from 1.0 to 3.0 bars, producing hot walls with temperatures between 99.6 and 133.5°C. The drums' rotational speed can be controlled at 1.6 RPM. The vacuum drum dryer, which consists of two steel drums with exterior diameters of 0.20 meters and lengths of 0.48 meters, is enclosed in a vacuum chamber and run at low pressure (60 mbar). By employing steam at various pressures (0.5 to 3.0 bar), the drums are heated to temperatures ranging from 81.3 to 133.5°C while rotating at a preset speed of 2.6 RPM. To prevent vapour condensation, the temperature in the vacuum chamber is kept at 80°C. Both types of drum dryers maintain a 0.2 mm space between the two drums. Before putting the puree into the dryer, the temperature of the drum is stabilized. The produced puree is manually poured evenly and at varying moisture contents (0.80 to 0.82 kg/kg wet basis) onto the heated feeding pool and then travels through the gap of the drums, forming a thin coating on the drum surface. The dried sample is scraped from the drum surface with doctor blades after being moved about three-quarters of the way around the drum. For subsequent research, the product gathered under the same drying circumstances is combined collectively (Qiu *et al.*, 2019).

- **Agitated thin film drying (ATFD):** Agitated thin film drying is a continuous drying process carried out at low pressure. The main components of the ATFD are an inner rotor with predetermined blades and a cylindrical drying chamber with a heating jacket. The heated surface is covered with a thin film of liquid feed that is stirred up and disseminated by the blades. Gravity causes a liquid to flow downward as it progressively transitions from one condition to another, from liquid to paste to solid. The dried solid product is divided into tiny bits by the rotor blades. The entire procedure may be executed with ease and at low pressure, making it suitable for goods that are sensitive to heat and oxygen (Pawar *et al.*, 2011). Nevertheless, the material's characteristics, such as its stickiness and viscoelasticity, play a major role in how well an ATFD performs in drying a certain substance. High tip velocities of the blades produce a greater shearing action, which can make the process healthier for the characteristics of the product, but it can also cause localized overheating from friction and thermal damage to the product (Qiu *et al.*, 2018).

The ATFD consists of a rotor with three permanent blades and a cylindrical drying chamber with a heating jacket. The drying chamber has an internal diameter of 0.20 m, an effective length of 0.40 m, and a blade diameter of 0.198 m. About 1.0 mm separates the blade tip from the heated surface. Prior to drying, the drying chamber is pre-heated with steam via the wall to the required temperature (60, 75, or 80 °C). The produced puree is then injected into the system at a flow rate of approximately 6 kg/h (0.86 and 0.93 kg/kg, wb). Depending on the probability of scraping the dried product from the drying surface, the blades' rotating speed ranged from 500 to 700 RPM. The dried product is gathered at the dryer's base for later analysis. According to Qiu *et al.* (2019), the complete system is run at a lower pressure of 50 mbar.

- **Refractance window drying (RWD):** A relatively new moderate drying method called refractive window drying has been used to dry pureed or sliced fruits and vegetables under atmospheric circumstances (Abonyi *et al.*, 2002; Zotarelli *et al.*, 2015). RWD involves drying a thin layer of the food product over hot water that is circulated on a conveyor belt made of transparent polyethylene. The dried film is transferred to a cooling water bath when drying is complete, where it cools below the glass transition temperature to prevent stickiness and make scraping off easier (Azizi *et al.*, 2017). According to Moses *et al.* (2014), RWD is used for heat-sensitive materials that require a low drying temperature. As very thin films must be cast in order to accommodate adequate drying rates, RWD is constrained in terms of capacity, throughput, and scale-up (Shende and Datta, 2018).

Refractance window drying can be done using a system that was traditionally made (ILVO, Melle, Belgium). The dryer has a 3 m total useable length in the direction of the belt action, divided into a 2 m heating component and a 1 m cooling section. Conveyor belt is made of polyethylene terephthalate. The produced puree is continuously applied to the plastic conveyor belt during drying with a film thickness of roughly 1.5 mm (0.80 to 0.82 kg/kg wet basis). Because the tomato puree is highly viscous and contains tissue particles, applying thinner films of tomato puree (between 0.5 and 0.7 mm) with the supplied

applicator is challenging. It was discovered after numerous tests that a minimum of 1.5 mm thickness is required for the creation of uniform tomato puree films. Puree film is gradually dried while being transported across the surface of circulated hot water (between 85 and 95°C), and then it is cooled down by circulation of cold water (30°C). An air suction hood (20°C) over the puree with an average air velocity of 1.5 m/s causes the water to separate from the film. A speed of 0.1 m/min is used to start the belt moving. The dried product is scraped off by scraper and collected at the end of the belt,

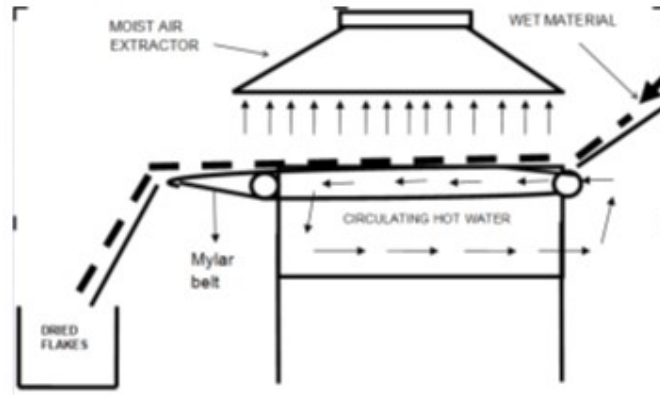


Figure 3: Diagram of Refractance Window Drying System

- **Sun Drying:** It is natural source of heat by sun rays and required longer time for drying than other methods. Drying also depends on climatic condition of atmosphere.

➤ **Pre-Treatment Given Prior to Dehydration Process**

The tomato pieces receive the following treatment:

- Dipped in a solution of 1 g/100 g CaCl_2 (1:1 w/w) for 10 min at room temperature.
- Dipped in Potassium Metabisulphite (KMS) 0.2 g/100 g solution (1:1) at room temperature for 10 min.
- Dipped in a solution containing 1 g/100 g CaCl_2 in combination with 0.2 g/100 g for 10 min.
- Immersed in 7 g/100 g NaCl solution at 80°C for 5 min.

After receiving dip treatments, pretreated tomato slices are properly drained and used for solar dehydration.

- **Dehydration:** The dehydration of tomatoes involves the use of a sun dryer. Galvanized steel solar dryer with 5 mm thick transparent glass covering it has dimensions of 1.0 m × 1.0 m × 1.5 m and is tilted at an angle of 30-35° to the south east for maximum solar radiation. Four flat plate photo cells have been installed in the dryer to capture solar energy, which is then utilized to power four small fans, facilitating the dehydration process. The equipment is placed in an open area

where it can be dried by the sun light. Treated tomatoes are placed in the trays at a rate of 3 kg/m^2 , where they are allowed to dehydrate under direct sun light (8-10 h/day). With a load density of 4.7 kg/m^3 and slow moving speed of 1 m/h at temperature of $65 \pm 2^\circ\text{C}$ alongwith air velocity of 1.2 m/s , tomato slices are spread out on the perforated continuous conveyor (tunnel dryer). Slices of tomato must exit the drying chamber after 6 to 7 hours of processing. The flow diagram for production of tomato power is shown in Fig. 4.

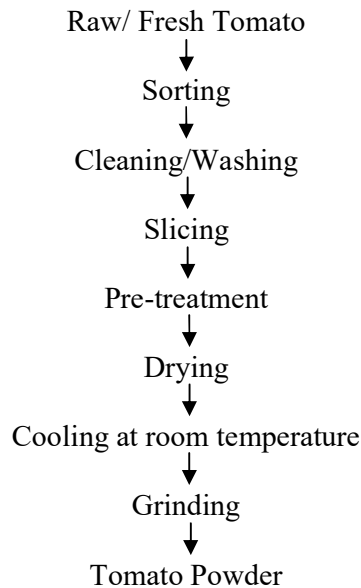


Figure 4: Flowchart for Production of Tomato Powder

- **Tunnel Drying:** Using this kind of machinery, fruits and vegetables are dried in bits on semi-continuous basis at large throughputs. It consisted of a tunnel with a cross-sectional area of $2 \text{ m} \times 2 \text{ m}$ and a length of up to 24 m. On trays made of slatted wood or metal mesh, the wet food components are distributed in uniform layers. On trucks, the trays are organized in stacks with clear intervals kept between them to allow the drying air to pass through. Loaded vehicles are fed into the tunnel one at a time, over a set length of time. One truck enters at the wet end, at the same time a truck of dry product is taken out from the other end. The movement of air through heater and between the spaces of trays in the tunnel is performed by fan. The velocity of air usually employed is $2.5 - 6 \text{ m/s}$ (Brennam *et al.* 1981). Tunnel dryers are usually categorize in terms of the relative direction of material and air motion. In the tunnel dryer diagram (Fig. 5), full arrows are employed to represent concurrent drying action and dashed arrows to represent countercurrent operation.

The characteristics of the concurrent flow process are:

- At the wet end of the tunnel, large evaporation rates can be achieved since a relatively high air temperature can be employed without endangering the material

by overheating it. Due to modest shrinkage, the product's low bulk density is caused by the high initial drying rate.

- As the product moves down the tunnel it comes into contact with cooler moist air. The drying rate falls off and heat injury to the product is reduced.
- Due to inadequate drying conditions at the dry end of the tunnel, it is challenging to obtain very low moisture contents.

The countercurrent or cross-flow system has the following characteristics:

- At the wet end of the tunnel initially low drying rate recorded because of the air has poor drying characteristic. This produces shrinkage of cellular material providing a bulky product.
- At the dry end, low moisture products obtained because of hot air at that end and risks of overheated products may occur.
- This system is more economical than the concurrent system in the use of heat.

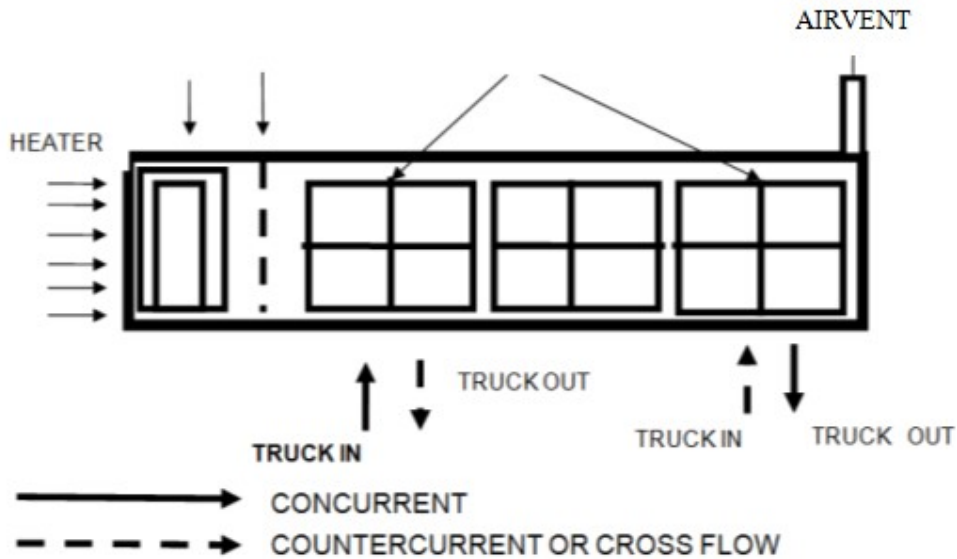


Figure 5: Schematic Diagram of Tunnel Dryer

Manufacturing of tomato powder the following five steps are recommended:

- **Choice of tomato:** ripened tomatoes are selected, which is free from disease and mould.
- **Washing:** Use clean water and running water in a large container to wash the recently harvested tomatoes.
- **Slicing:** Make slices of the tomato at a thickness of 0.5 cm.
- **Drying:** Use solar drying for small-scale production, but cover with mosquito netting to avoid contamination. Hot air dryers are utilized in large-scale production.
- **Milling:** The slices were ground in a hammer mill and then filtered through a screen with an appropriate mesh size.

- **Procedure:** The tomato pieces are first preheated to the required temperature (between 70°C and 80°C) in a tray dryer. In order to ensure that hot air passes through all of the sample's particles evenly, the sample is often poured out rather thinly onto trays. Air currents, heated trays or shelves on which the trays are placed, conduction from heated surfaces, or radiation from heated surfaces can all be used to heat the trays. Typically, air is heated in tray dryers to remove the damp vapour.

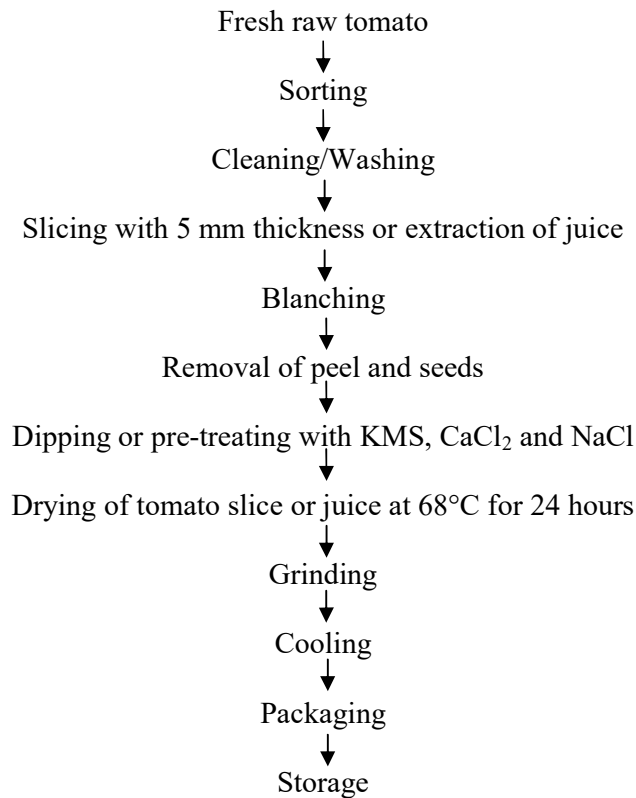


Figure 6: Flow diagram for the preparation of tomato powder using tunnel drying

- **Spray Drying:** By spraying the feed into a hot drying medium, feed can be converted from a fluid condition to a dried particle form. The spray drying method is unique and significant because it produces dry particles from a liquid feed in a single processing step.

The drying of solutions and slurries uses this type of dryer extensively in the food business. In the drying chamber, the food ingredient is introduced as tiny droplets and immediately comes into contact with a stream of hot air. By employing an atomizer, a fine spray is produced. As a result, drying happens very quickly, producing dry powder. The principal benefits of spray drying include:

- Short drying time,
- Suitable for large scale production with low drying cost,
- High production rate,

- Superior flavor, appearance and solubility of product,
- The plant can be easily automated,
- No product contamination,
- Continuous single-step operation,
- Uniform product,
- Gentle drying,
- High thermal efficiencies.
- Less labours required.

The following exterior parts of a spray drier are:

- Heating and circulating air system
- Atomizer (spray forming device)
- A drying chamber and
- A product collector.

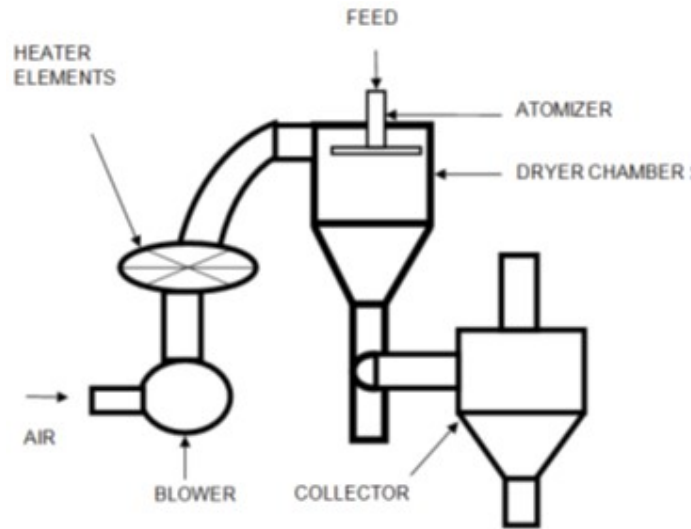


Figure 7: Schematic diagram of a spray dryer

Even though a variety of items have been successfully dried using the equipment, spray drying is one of the most versatile techniques for drying fruit juice. The primary challenge in handling and transporting fruit juice powder produced in spray dryers is the naturally hygroscopic and thermoplastic nature of fruit juice. Two complex issues arise in the creation of fruit juice powder, the first of which relates to the stickiness of the powder and its handling, and the second of which is associated with a fruit juice natural property that prevented powder production (Chegini and Ghobadian, 2007). A critical example of a product that is extremely challenging to spray dry is tomato pulp, which has a low glass transition temperature due to the low molecular weight sugar contains in it (Goula *et al.*, 2007).

Dextrose and laevulose, which have a glass transition temperature (T_g) of 31 and 5°C, respectively, make up the majority of the sugars found in tomato products. According to Goula *et al.* (2007), "stickiness" is a phenomena that represents some

materials' propensity to aggregate and/or cling to solid surfaces in contact. It can be divided into two types: adhesion (particle to solid wall surface stickiness) and cohesion (particle to particle stickiness). In recent years, the low glass transition temperature of sugar products such fruit juices has been linked to the stickiness issue. Such powders may not deposit as much if the wall temperature is kept below the powder's glass transition temperature. To dry these sugar-rich products, the dryer's design must be changed, or additives (such maltodextrin at an 8% concentration) must be introduced before drying in order to raise the glass transition temperature. To maintain a low wall temperature, spinning air broom systems may occasionally be connected to the spray dryer (Mani et al., 2002). The spray dryer was configured with an exit air temperature of 90°C and an intake air temperature of 160°C. The dryer's surface area is increased by the atomizer by spraying tiny droplets there. Heat transmission occurs more quickly and results in the production of dried powder because liquid droplets have a larger surface area. The feed rate (feed pump setting), initial concentration of feed solid, feed temperature, feed rate, atomizer pressure, compressed air flow rate in the atomizer, flow rate of drying air, and inlet air temperature were the regulated parameters that had an impact on the process and dryer efficiency. Figure 7 depicts a spray dryer's schematic diagram.

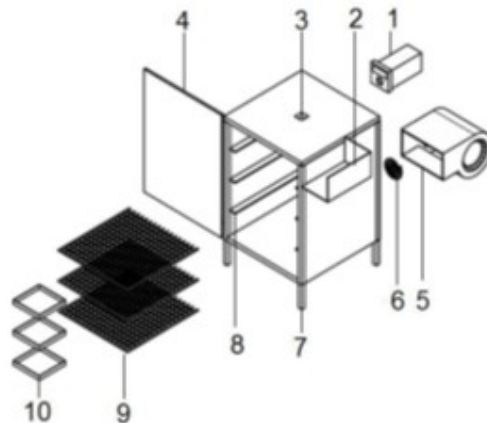
The glass transition temperature is the point at which a polymer transforms from having a hard, glass-like structure to one that resembles rubber. The two member tomato polymers' at different transition temperatures of 31 and 5°C showed the reason why tomatoes produced in a single chamber at a single temperature during spray drying were sticky and generally inconsistent.

In addition to the difficulties in producing powder in a spray dryer, the energy consumption of the equipment makes it unsuitable for a procedure meant to conserve extra output and add value.

- **Foam Mat Drying:** When compared to alternative techniques for drying non-foamed materials in the same dryer type, foam-mat drying is thought to be advantageous since it allows for the drying of foams at lower temperatures. The dryer only has to be in operation for a brief period of time since the addition of air or gas increases the surface area, which increases exposure to heat. In the process of drying by foam, a liquid is broken down using a variety of tools to create stable foam that is then dried by the evaporation of water in the thin layers. The technique of foam-mat involves, drying the thin layered foamed material by heated and dehumidified air at normal pressure and accounted to be great cheaper than vacuum, freeze and spray drying methods. The food quality is also impacted by the structure, expansion, and stability of the foam, which play a significant role in the transfer of moisture during drying. Foam-mat drying enables the processing of difficult-to-dry biomaterials, like tomato paste, as well as the creation of materials that can be easily rehydrated and maintain a number of quality indicators, including color, aroma, texture, and nutritional content.

Olaoye and Obajemihi (2017) investigated certain process variables, such as the concentration of the foaming agent and foam stabilizer that may affect the drying rate and quality of the dried powder. With egg white percentages ranging from 5-15% and stabilizer carboxyl methyl cellulose (CMC) at various concentrations (0.2, 0.4,

and 0.8%), all the pulp-filled containers were foamed. The liquids are stirred in a blender for a set period of time (3 minutes) to create foams. Onto a mechanical dryer, the containers have been loaded (Figure 8). Before loading the samples, the dryer is operated for 10 minutes at 70°C with thermometers used to check that the temperature has stabilized. The drying process is considered complete when the samples reach a moisture content of 4.5% (db), and the mean time taken by this approach is around 4 hours. During the drying process, the samples are weighed in a weighing scale on an hourly basis to determine their moisture loss and record it. The dried tomato samples are scraped with scrapers, allowed to cool, and then wrapped in polythene bags.



1 – Heat regulator; 2 – Heat regulator frame; 3 – Chimney; 4 – Door; 5 – Blower; 6 – Heating element; 7 – Frame/Stand; 8 – Tray holder; 9 – Main tray; 10 – Loading tray

Figure 8: Exploded view of the Mechanical Dryer

The foam stabilizer and foaming agent had non-significant influence on the drying rate of foam-mat dried tomato powder. In this study faster drying rate was achieved with samples treated with 10% foaming agent (egg white) and 0.80% foam stabilizer (CMC) concentration. The foaming agent concentration was significantly effected on protein content but non-significant effect by foam stabilizer concentration on protein content of tomato powder. Vitamin C content is an imperative quality characteristic which is found to be significantly affected by foaming agent and non-significantly affected by foam stabilizer.

4. Nutritional Quality of Tomato Powder: The production of tomato powder involves the concentration of the nutrient composition and the removal of moisture; it is invariably combined with additional ingredients based on the drying process, tomato maturity, weather circumstances, etc. Some of these provide the completed items desirable attributes. Using A.O.A.C. (2010) recommended techniques, the moisture, protein, fat, fiber, ash, and carbohydrate content of tomato powder was determined. Table 4 lists the approximate composition of tomato powder.

The flow and other mechanical properties of a powdered food are significantly influenced by the moisture content of the powder. The manner, extent, and humidity of the drying process all play a significant role (Lawal, 2004). Moisture content of tomato

powder developed through cabinet dryer was 8.12% (sarker *et al.*, 2014). Protein (14.32%), fat (3.33%), ash (9.35%), fiber (9.78%) and carbohydrate (54.59%) were found in the tomato powder developed by cabinet drying method. These findings differ slightly from those reported by Mozumder *et al.* (2012) who measured the tomato powder's moisture (5.9%), protein (13.9%), fat (3%), ash (10.72%), pH (4.25), and acidity (6.05%).

Table 4: Proximate Composition Of Tomato Powder

S. No.	Composition	%
1.	Moisture	8.12
2.	Protein	14.32
3.	Fat	3.33
4.	Carbohydrate	54.59
5.	Fiber	9.78
6.	Ash	9.35

- 5. Effect of drying on Proximate Composition of Tomato Powder:** The proximate composition of tomato powder is impacted by drying procedures or techniques. Surendar *et al.* (2018) investigated how different drying techniques affected the proximate composition of tomato powder. They discovered that the moisture content of tomato powder obtained using various drying techniques varied from 5.42 to 5.80%, falling below the recommended range of 4 to 8% for commercial tomato powder. Comparing spray drying (5.42%) and cabinet drying (5.51%), foam mat drying revealed the highest moisture content (5.80%). The moisture content was not significantly affected by the drying technique.

The protein content of tomato powder was varied from 12.36 to 13.96%. The protein content was observed to be maximum in cabinet dried follow by foam mat and spray dried products. Protein may have been removed from tomatoes in part because salt binds to protein during drying, which may have caused the protein level to drop. In particular, non-enzymatic browning, which was found to occur greater in fresh tomato than dried powder (Surendar *et al.*, 2018, Rao *et al.*, 2011), could be associated to changes in protein concentration.

For cabinet drying, foam-mat drying, and spray drying, the fat content was found to be 2.80%, 3.00%, and 3.20%, respectively. The fat content of the foam mat dried powder was a little higher than the cabinet dried but lower than the tomato powder that had been spray dried. The lower moisture level of spray dried powder compared to cabinet and foam mat dried powder was the cause of its higher fat content (Mozumder *et al.*, 2012). The range of the crude fiber content in tomato powder was 9.2 to 9.86%. The tomato powder's ash content ranged from 10.36 to 10.82%. The drying process and level of homogenization may be to blame for the variation in the values of ash and fat content. The majority of the soluble solids in tomatoes are sugars, which are crucial flavor-enhancing ingredients. The carbohydrate percentage of tomato fruit varies from 1-1.22% in immature fruit to 0.1-1.5% in red ripe fruit depending on maturity, cultivar, and ripening conditions. The texture of fruit is satisfactory only when enough quantities of pectase, calcium and pectin are present.

6. Effect of Drying on Functional Properties of Tomato Powder: Table 5 displays how drying affects the functional qualities of tomato powder. Water absorption capacity refers to the amount of water that remains contained after the application of an external force, such as centrifugation whereas the water holding capacity refers to the amount of water that is retained within the gel system's structure without the application of any external force, other than gravity and atmospheric pressure (Shanna *et al.*, 2002). The cabinet drying process recorded the maximum water retaining capacity (10.87g/g). More details on phytochemicals are provided, which will help us understand how they behave in foods (Guillon and Champ, 2000; Surendar *et al.*, 2018).

Table 5: Effect of Drying on Functional Properties of Tomato Powder

S. No.	Parameter	Value
1.	WHC, g/g	10.87
2.	WAC, g/g	8.00
3.	OAC, g/g	4.80
4.	Swelling capacity, ml/g	2.56

IV. STORAGE OF TOMATO POWDER

Powder is a highly hygroscopic in nature and absorbed moisture at high relative humidity environment. Therefore its storage is difficult while not taking proper care during selection of packaging materials for this product. Tomato powder were packed into three types of packaging materials such as high density polyethylene (HDPE), medium density polyethylene (MDPE) and laminated aluminum foil (LAF) pouches and studied storage stability of the product. Changes in moisture, lycopene, protein, fat, ash, polyphenol, acidity, *etc.* during storage of tomato powder packed into different packaging pouches for six months were determined (Sarker *et al.*, 2014).

Changes in quality parameters of tomato powder in the storage period are presented in Table 6. Changes in moisture content of tomato powder packed in LAF, HDPE and MDPE pouches were found to be non-significant. Maximum moisture (9.45%) was found for tomato powder packed in MDPE, whereas the minimum value of moisture (8.15%) was found in product packed in LAF after six months of storage. Rehydration ratio of tomato powder diminished with the raise in moisture content and its rate was more in HDPE and MDPE pouches than that in LAF pouches. The maximum rehydration ratio of the tomato powder was found 6.4 in LAF pouches, which is observation resulted by Jay (2000) who reported the rehydration ratio is usually decreased as increase in moisture content.

Table 6: Moisture, Protein, Fat, Ash, pH, Acidity and Rehydration Ratio of Tomato Powder in Different Packaging Materials during Storage

Parameter	Storage period (months)									
	0	LAF			HDPE			MDPE		
		2	4	6	2	4	6	2	4	6
Moisture (%)	8.12	8.12	8.19	8.25	8.21	8.70	9.12	8.25	9.0	9.45
Protein (%)	14.3	14.3	13.4	10.3	13.6	11.19	8.69	12.6	9.36	8.54
Fat (%)	2.1	2.1	2.0	1.86	2.0	1.80	1.63	1.99	1.79	1.58

Ash (%)	9.22	9.22	9.32	9.45	9.25	9.37	9.52	9.27	9.38	9.55
pH	4.30	4.30	4.21	3.77	4.23	4.14	3.64	4.23	4.12	3.58
Acidity (%)	6.0	6.05	6.5	8.0	6.1	6.58	8.5	6.1	6.60	8.53
Rehydration ratio	6.45	6.45	6.43	6.4	5.35	5.1	4.5	5.35	5.0	4.3

According to Table 6, as storage time extended, tomato powder's pH decreased and its acidity rose. Similar to but faster than the rate for powder stored in LAF pouches, the pH of tomato powder placed in HDPE and MDPE pouches decreased over time. Because pH 4.5 frequently reduces the multiplication of microbes in the final product during industrial processing (Giordano *et al.*, 2000), the pH value (3.77) is best for processing of tomato products. In both HDPE and MDPE pouches, tomato powder's protein level decreased considerably. In comparison to LAF pouches, both HDPE and MDPE pouches had a high rate of fat reduction in tomato powder.

After six months of storage, the fat content in HDPE and MDPE pouches decreased from 2.1 to 1.63% and 1.58%, respectively, whereas the value (1.86%) was kept in LAF pouches. With an increase in storage time, tomato powder's ash level increased in all packaging materials. After six months, MDPE pouches had the highest ash concentration (9.55%), while LAF pouches had the lowest (9.545%).

Ascorbic acid, lycopene, and beta-carotene concentration variations over the course of storage are shown in Table 7. This table shows that during storage, the ascorbic acid content of tomato powder declined abruptly from 35.1 to 3.05 mg/100g and 1.96 mg/100g in both HDPE and MDPE pouches. Due to their inadequate oxygen barrier properties, both HDPE and MDPE pouches had a significant rate of ascorbic acid degradation. However, the LAF pouches had a significantly reduced rate of deterioration and, after storage, had a greater value (11.51 mg/100g).

Table 7: Ascorbic Acid, Lycopene and β -Carotene Content of Tomato Powder Packed in Different Packaging Materials during Storage

Packaging materials	Storage period (months)	Ascorbic acid	Lycopene	β -Carotene
LAF	0	35.1	18.34	4.57
	2	25.1	12.57	3.39
	4	19.76	8.85	3.29
	6	11.51	2.29	1.71
HDPE	0	35.1	18.34	4.57
	2	17.3	10.76	3.65
	4	12.39	5.79	2.72
	6	3.05	1.45	1.29
MDPE	0	35.1	18.34	4.57
	2	14.45	9.89	3.3
	4	8.23	4.01	2.17
	6	1.96	1.13	1.06

Both HDPE and MDPE dramatically reduced the amount of lycopene in tomato powder, from 18.34 to 1.45 mg/100g and 18.34 to 1.13 mg/100g, respectively. In LAF pouches, a significant reduction in lycopene content was observed. After six months of storage, Rao *et al.* (2011) observed that the lycopene content of the tomato powder packed in polyethylene bag was 2.39 mg/100g, which was lower than the value of the powder's lycopene content (2.29 mg/100g) in LAF pouches.

In comparison to LAF pouches, the decrease rate of β -carotene in tomato powder packed in HDPE and MDPE pouches was noticeably higher. After six months, the LAF had the highest concentration of carotene (1.71 mg/100g), and the MDPE pouches had the lowest (1.06 mg/100g). According to Dutta *et al.* (2005), the decreased value of carotene contents in both HDPE and MDPE pouches was caused by their inadequate gas and oxygen barrier properties as well as sufficient temperature and storage environment or humidity control. They also emphasized that temperature, storage time, and storage conditions all affect the amount of carotene in dried samples.

All the quality parameters have significantly affected by both storage period and packaging materials. Laminated aluminum foil is the best packaging material for storage of tomato powder and the extended shelf-life of powder can be obtained.

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