PROCESSING AND PRESERVATION OF TOMATO LEATHER

A THESIS

BY

MOULUDA SOHANY

Roll No. 1105038

Session: 2011-2012

Semester: January-June, 2012

MASTER OF SCIENCE

IN

FOOD ENGINEERING AND TECHNOLOGY

DEPARTMENT OF FOOD ENGINEERING AND TECHNOLOGY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

JUNE, 2012

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DEDICATED TO MY BELOVED PARENTS

ABSTRACT

The present study was conducted to prepare the tomato leather together with determination of chemical composition and its shelf life study. Tomato leather was processed in five types differing in the ingredients. The shelf life of tomato leathers were studied for 120 days storage period. Chemical analyses and organoleptic tests were carried out during the 120 days at the interval of 20 days. Sensory evaluation, by serving the tomato leathers to the panelists, was done and the secured scores were analyzed with ANOVA and DMRT at the significance level of $P < 0.05$. At this level color, flavor, texture, taste and overall acceptability were found significant with LSD values of 0.6996, 0.7367, 0.7694, 0.8349 and 0.7279 respectively. Treatment 2 (Tomato leather with lemon juice and vinegar) was best for color. Treatment 3 (Tomato leather with lemon juice, vinegar and tamarind) was best for flavor, texture, taste and overall acceptability. Negligible changes in moisture, ash, protein and fat contents were observed in the prepared tomato leathers. For normal room temperature ($28^{O}C$-$30^{O}C$) storage, a shelf life of 80 days was found without any change in color and flavor. After 80 days, changes in color and flavor were found. After 120 days the product and even the packaging material AFP (Aluminum Foil Paper) was deteriorated. A shelf life of 120 days was found for the refrigerated storage temperature ($12^{O}C$) and from the first day to the 120th day no change in color and flavor was found. Weight was almost the same in the whole study. The overall study introduced an easy and effective technique for the preservation of tomato as tomato leather. The shelf life of tomato leather was found 120 days at the refrigerated storage temperature ($12^{O}C$) storage and the shelf life was 80 days at the normal room temperature storage ($28^{O}C$-$30^{O}C$).

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The Author

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INTRODUCTION

CHAPTER I

INTRODUCTION

Tomato, *Lycopersicon esculentum* belongs to the family *Solanaceae* and is one of the most popular and widely grown vegetables in the world. Tomato, ranking 1st in the world for vegetables, accounts for 14% of world vegetable production over 100 million metric tons per year with the leading countries being China United States, India, Turkey and Italy (FAO, 2010). The tomato is native to the Americas. Aztecs and Incas initially cultivated it as early as 700 A. D. Europeans first saw the tomato when the conquistadors reached Mexico and Central America in the 16th century (The California Tomato Commission, 1997).

Tomato is botanically classified as a fruit. Actually it is a berry, but many people think of it as a vegetable. The U.S. Department of Agriculture, for example, has defined it as vegetable (Tracy *et al.*, 2004).

Tomato is an herbaceous sprawling plant growing to 1-3 m in height with weak woody stem. The flowers are yellow in color and the fruits of cultivated varieties vary in size from cherry tomatoes, about 1–2 cm in size to beefsteak tomatoes, about 10 cm or more in diameter. Most cultivars produce red fruits when ripe. A fruit is the edible part of the plant that contains the seeds, while a vegetable is the edible stems, leaves, and roots of the plant. Only the fruits of this plant are eaten since the leaves often contain potentially problematic concentrations of certain alkaloids. Tomatoes have fleshy internal segments filled with slippery seeds surrounded by a watery matrix. Tomatoes are available in a variety of shapes, and colors including red, yellow, orange, and pink. Tomatoes may be round, oblate (fruit are flattened at the top and bottom), or pear-shaped (Stanley, 2005).

Tomato varieties are commonly divided into categories, based mostly on shape, use and size (small to large). Cherry, which are sweet tomatoes, usually eaten whole in salads. Plum, which is pear-shaped, meatier and ideal for tomato products, also called Italian or Roma. Slicing, which is round or globe-shaped, used mainly for commerce and processed products. Beefsteak, is round, juicy, largest sized varieties used mainly for sandwiches. Other varieties include heirlooms and yellow/orange tomatoes (USDA, 2012).

No other vegetable or fruit is more widely used or consumed than the tomato. From pizza to ketchup to sun-dried tomatoes and all in between, the tomato has an infinite number of applications on the dinner table. They can even be candied and used in cakes. Fried green tomatoes are a popular Southern dish. It is consumed worldwide as a raw salad, cooked or as processed food item such as sauce, ketchup, jam, jelly, pickles, puree, soup etc. Tomato has very few competitors in the value addition chain of processing.

Tomato is one of the most important "protective foods" because of its special nutritive value. It contains a number of nutritive elements almost double compared to fruit apple and shows superiority with regard to food values. Tomatoes are rich in fiber, and are cholesterol free.

Recently a great deal of attention has been focused on the tomato and its products. Studies from Giovannucci, *et al*. (1995) reported that the consumption of tomatoes, tomato sauce and pizza was associated with a reduced risk of developing digestive tract and prostate cancers. Tomatoes are also one of the main parts of the Mediterranean diet, which has been associated with a low mortality from cardiovascular troubles. Because tomatoes constitute the almost exclusive source of lycopene, this pigment could be one of the active agents of this protection.

Experimental studies reported that lycopene exhibited antioxidant activities suppressed cell proliferation (Levi *et al*., 2000) and interfered with the growth cancer cells (Clinton *et al.*, 1996). However, tomatoes are also rich sources of the essential nutrients like vitamin C, potassium and folic acid, as well as beta-carotene, gamma-carotene, selenium, flavonoids and phenolic acids which may exhibit antioxidant, immune stimulant, photo protector or even chemo preventive activities in *invitro* and animal models. In consequence, several of these constituents would contribute to the disease- preventive properties (Debjit *et al*., 2012).

Tomato is consumed raw as salad, or cooked curry, sauce, ketchup, puree, in soups, pickle and many other forms in Bangladesh too. It is very desiring ingredient to increase the taste, color, flavor, texture and consistency in many dishes. Cooked tomato along with different dishes increases the palatability and the nutrition value.

Tomato is highly perishable with 93%-95% moisture content and rapidly deteriorates after ripening. About 35 percent of the total production of fruit and vegetables are spoiled and lost after harvest due to lack of processing, storage and transport facilities (Ahmed, 1995).

The freshness and textural quality of tomatoes distort during freezing and canning. Tomatoes could be preserved in better way in the form of various products such as Tomato juice, puree, cocktail, paste, ketchup, sauce, jelly, soups, powder and Tomato chutneys etc.

One of the best ways of utilizing and preserving fresh tomatoes is processing them into leathers. Leathers, although not very popular, is manufactured by dehydrating a fruit puree into a leathery sheet (Raab and Oehler, 1999). Leathers can be consumed as a confection or cooked to give a sauce. Leathers make delicious, wholesome and nutritious high-energy snacks for backpackers, campers and active children. They are relatively light in weight, easy to prepare and a good way to use left-over canned fruit and slightly over-ripe fresh fruit. Fruit leathers can be eaten as is, or made into a beverage by combining 5 parts water with 1 part leather in a food blender. They also can be used in pie fillings, in cooking and as a dessert topping. These products add variety to a healthy diet and possess dietary fiber, vitamins and minerals while providing a good energy intake (Kendall and Sofos, 2007).

Most importantly The production of tomato leather would reduce wide fluctuation of prices in peak harvesting period and the off-season product would reduce the volume and minimize transportation cost so that consumer will get good quality product at a minimum price.

Considering the above information as accumulated the present study was carried out to achieve the following objectives:

1. To prepare tomato leather
2. To determine chemical composition of the prepared tomato leather.
3. To study the shelf life of the product

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

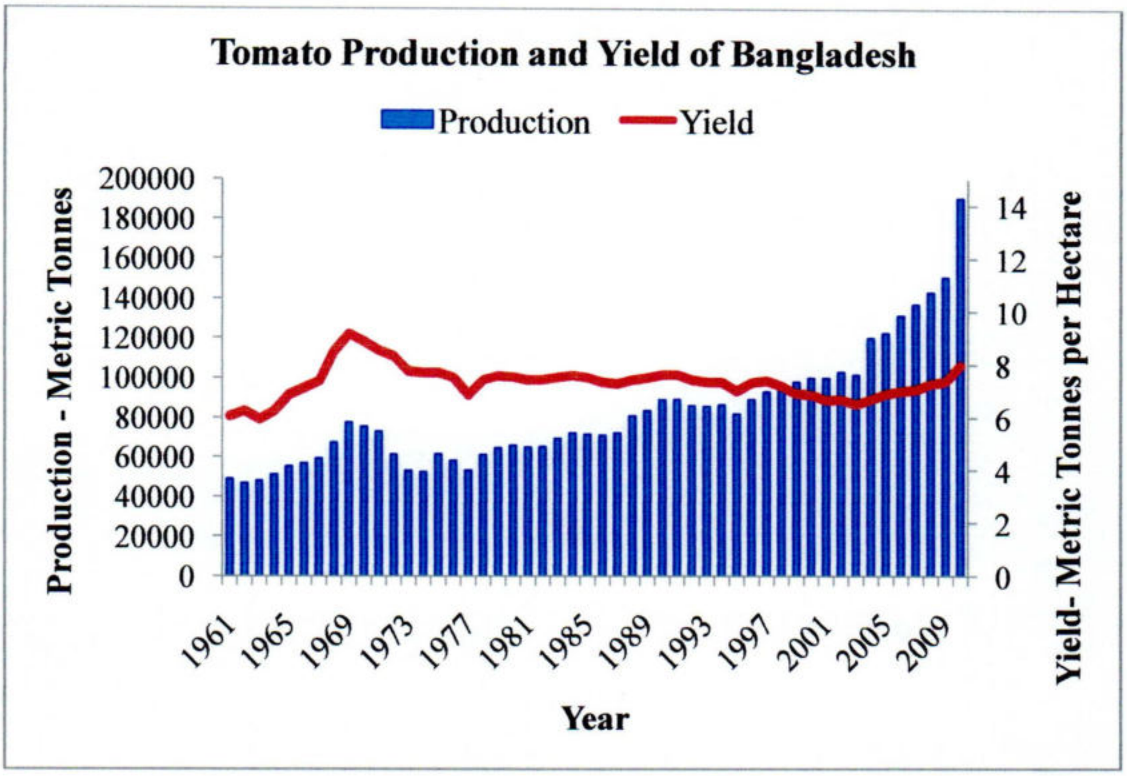
The processing and preservation of tomato as "Tomato Leather" is mainly practiced as home purpose and the sources are not wide. Work done on Tomato leather is very limited hence the present review is done on the allocation of the other fruit and vegetable leather types that have been studied before by many sources. Some related literatures of previous workers are listed in this chapter.

2.1 Tomato Production

About 150 million tons of tomatoes were produced in the world in 2009. China, the largest producer, accounted for about one quarter of the global output, followed by United States and India. According to FAO (2010), global tomato production amounted to 27.6 million tons in 1961. The threshold of 50 million tons was reached in 1978 and 100 million tons in 1999. Considering an annual growth rhythm of 3.5%, global tomato production, which can be roughly assimilated to global consumption – amounted to 141 million tons in 2009.

Oxhearts, Marglobe, Sunmargino, Roma VF, Pusa, Rubi are some popular tomato varieties grown in Bangladesh. Tomato is usually plants in November-December; seedlings of 25-30 days and planted crops are ready for harvest in 80-90 days; average yield is 40-50 m tons/ha. According to FAO (2010), the area of tomato cultivation is about 24,000 ha with the production of about 20, 0000 metric tons. The area of production has increased from 8,071 ha to 14,985 ha since 1961 to 2001 with the production of 48,905 metric tons to 10, 0000 metric tons.

FAO (2010) report also shown that, in the last 10 years (2001-2010) the area as well as the production has increased about 59% and 91%. The production in 2010 has recorded to 19, 0213 metric tons with the yield of 7.9864 metric tons per ha. The following Figure 2.1 is representing the tomato production and yield from the year 1961 to 2010 on the basis of FAOSTAT, 2010. From Figure 2.1 it is clearly found that the yield of tomato was highest in 1969 and there is only a small increase in the yield from the period of 1961 to 2010.



Source: FAOSTAT, 2010.

Figure 2.1: Bangladesh Tomato Production (1961- 2010)

2.2 Commercial Importance of Tomato

Tomato is a commercially important vegetable through out the world both for the fresh fruit market and the processed food industries (Atherton and Rudich, 1986).

Tomatoes are an incredibly versatile food. Tomato can be eaten in hundreds of forms. Ripe red tomatoes with their juicy subtle sweetness enhance the flavor and taste of many dishes. They are delicious eaten raw, in salads or on sandwiches and take on a wonderful sweetness when cooked. Their high acid content makes them a perfect food for canning. Salad tomatoes have a flavor, color and texture that satisfy the consumer's preference. At the same time they are suitable for post-harvest handling and marketing, even over large distances. In addition, processing tomatoes have the rheological characteristics required by the relevant food processing industry (Kelly, 2010).

Growth rate for processed tomato consumption is close to 3 % per year, from 1999 to 2009, the global consumption of tomato products (expressed as fresh equivalent) increased from 28 to 40 million tons. The total tomato consumption increased from 109 million tons in 1999 to 141 million tons in 2009 (Paris, SIAL, 2010).

Processed tomato products have wide applications in house hold consumption, food processing industry, snacks foods, hotels, restaurants and fast food joints. As per FAO (2010) statistics, in quantitative terms world trade of tomato and tomato products for the year 2004-2005 was around 9.5 Million tons valued at approx US $ 8.9 billion. The leading exporters of fresh tomato in the world are Mexico, Spain, Syria, Turkey, Netherlands, Jordan, USA and Belgium. USA dominated the world in import of fresh tomatoes, importing around 0.94 million tons, valued at US $ 1.1 billion in the year 2004-2005. The other major importers of fresh tomatoes are U.K, Netherlands, Germany and France. Traded quantum of tomato paste in the year 2004-2005, was 2.2 million tons valued at US $ 1.7 billion, supplied mainly by Italy, China, Turkey, Spain, USA and Portugal. China dominates the world in tomato paste and puree exports, with the capacity of the former product presently estimated at 1 million tons which deemed to be doubled in the last three years, with actual production between 500, 000 – 750, 000 tons per year.

2.3 Tomato as Food

Tomato is one of the most nutritious vegetables and used in various dishes in various ways over the world. Tomatoes may be consumed fresh or processed to canned whole peeled tomatoes. Raw tomato and cooked tomato have different format to work for the body. Tomato products can be grouped into many end-use categories like peeled, concentrated, partially dehydrated, strained and diced tomatoes, Tomato juice, pulp, paste, powder and ketchup. Tomatoes can be also eaten as salad, cooked puree, tomato and vegetable juice blend, stewed tomatoes, spaghetti sauce, pickle, sauce, tomato vegetable leather, soup, curry etc. (Pauline and Brennand, 2005).

Tomatoes are an excellent source of vitamin A, vitamin C, and potassium. Cooked or heat processed tomatoes contain more lycopene, because cooking helps to release lycopene from the tomato cells. Since cooking reduces vitamin C, however, the 'British Tomato Growers' Association suggests eating a range of fresh and cooked tomatoes.

As a food tomato provides several health benefits. Tomatoes can make people healthier and decrease the risk of conditions such as cancer, osteoporosis and cardiovascular disease. People who eat tomatoes regularly have a reduced risk of contracting cancer diseases such as lung, prostate, stomach, cervical, breast, oral, colorectal, esophageal, pancreatic and many other types of cancer. Lycopene and the newly discovered bioflavonoids in tomatoes are responsible as cancer fighting agents. Not only raw tomatoes but also cooked or processed tomato products such as ketchup, sauce, and paste, are counted as good sources of cancer prevention. Tomato is also good for liver and kidney health. Tomato has detoxification effect in the body due to the presence of chlorine and sulfur in tomatoes. Chlorine works in stimulating the liver and its function for filtering and detoxifying body wastes. Sulfur in tomatoes protects the liver from cirrhosis, too. Tomato juice is known as good energy drink and for rejuvenating the health of patients on dialysis. Taking tomatoes and tomato products could reduce the risk of cardiovascular diseases because of lycopene in it. Taking tomato with food that contains animal fat, butter, cheese, pork, egg, beef and other fried food will prevent hardening of the arteries. Therefore, tomato can reduce high blood pressure, too. Red ripened tomato is a powerful antioxidant. Vitamin E and lycopene in tomato prevents LDL oxidation effectively. Tomato is an excellent fruit or vegetable for rapid skin cell replacement. Tomato juice can be used for healing sunburn because of its unique vitamin C. Tomato juice restores body from fatigue and sleepiness. Vitamin A and C is important for bone growth, cell division and differentiation, for helping in the regulation of immune system and maintaining surface linings of eyes, respiratory, urinary and intestinal tracts. Vitamin C is important in forming collagen, a protein that gives structures to bones, cartilage, muscle and blood vessels. It also helps maintain capillaries, bones and teeth and aids in the absorption of iron (Debjit *et al*., 2012).

2.4 Storage and Preservation of Tomatoes

Fully ripe tomatoes can be stored for 4-7 days at 45 ^{O}F -50^{O}F. For slightly under ripe, this time can be extended to 2-3 weeks. Unripe tomatoes should not be refrigerated. Tomatoes picked green in the fall can be wrapped individually in newspaper and stored for months in a cool, but not freezing location. An alternate method of salvaging tomatoes in the fall before freezing is to pull up the vines and hang them in a cool location. Tomatoes that begin to show signs of spoilage should be removed. Storage time can be extended for months, but quality will decrease. Temperature has a major affect on storage life (Pauline and Brennand, 2005).

However, marketing of fresh tomato during the season is a great problem because of its short postharvest life, which leads to high postharvest losses. Short shelf life coupled with inadequate processing facilities results in heavy revenue loss to the country. Therefore development of preservation methods is beneficial to farmers who produce large quantities of tomatoes. A wide variety of tomato products are prepared using concentrated juice or pulp, which needs high cost technology for good quality products. Therefore development of low cost processing and packaging methodologies to produce shelf-stable and convenience products are the prime requirements of present competitive market (Jayathunge, 2012).

The demand for tomato processing usually arises from a need to preserve the product for home use (inclusion in stews, soups, curries etc.) out of season or to add value for extra income. Traditionally, the most important methods used are concentration (to a paste or puree) and drying either fruit pieces or to a powder (Azam Ali, 2008).

2.4.1 Preservation of Tomatoes

Tomatoes are generally considered to be acidic, but their pH can vary significantly depending on their degree of ripeness and their variety. In general, the more ripe the tomato, the higher (less acidic) is the pH. The pH of whole, ripe tomatoes ranges from 4.3 to 4.9, putting some tomatoes in the low-acid range (defined as a pH greater than 4.6).

2.4.1.1 Freezing of Tomatoes

Tomatoes may be frozen whole, sliced, chopped, or pureed. Additionally, freezing of tomatoes can be done as raw or cooked, as juice or sauce, or prepared in the recipe of choice. Thawed raw tomatoes may be used in any cooked-tomato recipe. Freezing causes their texture to become mushy. Tomatoes should be seasoned just before serving rather than before freezing.

2. 4.1.2 Drying of Tomatoes

Dehydration removes water from tomatoes in order to preserve them. The amount of time it takes to dry tomatoes depends on the tomato variety, the air's humidity during the drying process, the thickness of the tomato slices or pieces, and the efficiency of the dehydrator or oven. The secret to dehydrating tomatoes successfully is to control the temperature and air circulation. If held at too low a temperature (32^{O}C) the product will dry too slowly, giving bacteria or mold a chance to grow. At temperatures of 77^{O}C or more, the tomatoes cook or harden on the outside, while the inside remains moist, allowing spoilage. Optimum drying temperatures are 57.2^{O}C to 60^{O}C.

2.4.1.3 Canning of Tomatoes

This is a method of preserving tomatoes in acidic condition under high pressure, which destroys and prevents the growth of any organism. To prevent spoilage, acidic foods such as tomatoes need to be heated to temperatures that destroy yeasts, molds, and bacteria. This heat treatment can be accomplished either in the water bath canner or by a brief process in a pressure canner (Tracy *et al.*, 2004).

Other methods may include Concentration, Juice, Squash, Ketchup, Sauce etc.

2.5 Origin of Tomato Leather

Tomato leathers are not as practiced as the fruit leather. Fruit leathers are prepared from a long time. By following the fruit leather tomato leather is done. Fruit leathers are dehydrated fruit-based products that are eaten as candy or snacks, and presented as flexible stripes or sheets. They receive this name because of the final product aspect (it is shiny and has the texture of leather).

The origin of fruit leathers may go back to the Persian Empire. They are known as "Pestil" in Turkey, "Bastegh" or "Pastegh" in Armenia, "Qamar al deen" in Lebanon, Syria and other Arab countries and "Fruit roll" or "Fruit leather" in the United States. The last denomination is possibly more usual in the scientific literature (Maskan *et al.*, 2002).

Due to its novel and attractive structure, and for being products that do not require refrigeration, they constitute a practical way to incorporate fruit solids, especially for children and adolescents. Fruit leathers allow leftover ripe fruits to be preserved. Moreover, fruit pulp left from making jellies, during prolonged time in reduced volumes may also be converted into leathers. In recent years, their popularity has increased, transforming from a homemade preparation into an industrial product. Fruit leathers provide nourishing snacks and are easy to prepare. Fruit leathers are pectic gels obtained by dehydrating fruit purees to produce restructured, attractive flexible sheets, which retain shape. The process of pectic gelification leading to a fruit leather has the following requirements: a soluble solid content greater than 55% w/w [w/w = (Mass of solute/ Mass of solution) × 100], composed of fruit pulp and optionally, by added saccharides. Besides, the pH of the formulation must be of 3.5 or below. Pectins with high degree of esterification are necessary as well (Damodaran *et al.*, 1995)

2.5.1 Ingredients of Tomato Leathers

Early work described the physicochemical properties and sensorial attributes of pectic gels. On the basis of the previous works done with the other fruit leather types, the ingredients for tomato lather can be chosen.

Chan and Cavaletto (1978) used additives in the formulation (sugar and sodium bisulfite) and carried out sensory evaluations on the final product stored at the temperature $18^{O}C$, $24\ ^{O}C$ and $38^{O}C$ during 1, 2 and 3 months. Sulfure dioxide inhibited browning during both processing and storage. An alcohol-soluble color index and residual SO_2 levels both served as measures of product quality. They suggested the use of SO_2 in the manufacture of papaya leather and low storage temperatures.

Quintero and Giner (2010) analyzed apple leather quality for formulations with and without preservative agents over a storage period of 6 months at room temperature.

Bains, *et al.* (1989) prepared leathers from a commercial fruit puree, using one and two drying stages, and compared the total drying time. They concluded that the shorter process does not necessarily leads to a better quality product.

Kendall and Sofos (2007) formulated fruit leather by adding 1⁄2 teaspoon of ascorbic acid crystals or 2 tablespoons lemon juice per 2 cups of fruit to protect the color and help destroy bacteria during drying. They suggested, if desired, adding 1 to 2 tablespoons of sugar, corn syrup or honey per 2 cups of fruit. A small amount of spice (1⁄4 teaspoon cinnamon or a dash of nutmeg) may also be added per 2 cups puree, for taste variety.

Azam Ali, (2008) suggested the pH must be 4 or below and advised to add citric acid if the pH is high.

2.5.2 Drying of Leather

Direct sun drying, solar drying, convection oven drying and electric cabinet drying are some of the drying methods that can be used in processing fruit leathers (Raab and Oehler, 1999).

Drouzas, *et al.* (1999) reported the use of combined drying technologies to prepare leathers. Demarchi, *et al.* (2010) evaluated the influence of pretreatment on final product structure as well as the effect of hot air drying on color and antioxidant retention in apple leathers with and without preservative agents. They concluded that losses of antioxidant activity are more dependent on drying temperature than on drying time. Moyls (1981) focused on dryer conditions, evaluating characteristics such as the space between trays and the fluid-dynamic regime of the drying air.

Kendall and Sofos (2007) reported that various drying methods can be applied for leather drying. For oven drying, they suggested to spray a cookie sheet to a depth of 1/8 to 1/4-inch placed in the oven at the lowest setting (140^{O}F to 145^{O}F). The trays of puree to be placed on the oven rack and to leave the door open 2 to 6 inches, depending on the oven door. The fruit concentrate should dry in 4 to 10 hours. The same for dehydrator, drying temperature is controlled at 140^{O}F to 145^{O}F and the drying time will be 4 to 10 hours.

Tracy, *et al.* (2004) described for sun drying the temperature should be minimum 32^{O}C. The prepared sheet should be placed about $\frac{1}{2}$ to 1 inch (1 to 3cm) apart cut-side-up, on clean wooden, plastic, chromed or non-stick-coated drying trays which is covered with fine netting or cheese cloth to keep insects off. Air must circulate around and under each tray. It will probably take at least 5 to 6 days, and perhaps as long as a week, to complete the sun drying process. The time will vary according to the air temperature and the size and type of tomatoes being dried. For further protection oven drying can be done before storage.

Direct sun drying has also been used to produce acceptable guava leather (Jain and Nema, 2007). Despite its reliance on climatic conditions, solar drying is increasingly becoming a popular method of drying fruits in tropical countries (Agona *et al.*, 2002).

Solar drying is cheap compared to other advanced methods of drying since it relies on energy from the sun, requires low or no electric power and the dryers are relatively cheap and easy to construct (ICUC, 2003).

This makes it suitable for use in rural areas with limited electrification and frequent load shedding commonly practiced in Bangladesh. The use of such a low cost processing technology can help fruit growers to increase their income by encouraging full utilization of locally available produce as raw material.

2.5.3 Storage of Leather

Kendall and Sofos (2007) also instructed the storage that after loosening the edge of the leather from the plastic wrap or pan, the leather should be loosely rolled in plastic wrap or waxed paper in one piece. The roll should be stored in one piece or cut into 1-inch strips. The strips or rolls of leather should be placed in a plastic bag, glass container, paper bag or other container. Until the leather is not completely dry, the container lid should not be tightened nor the bag opening twisted tightly. If the leather has not dried completely, it may become sticky or develop mold growth during airtight storage. Fruit leather should be stored in a cool, dry and dark place. It will retain good quality for up to one year in the freezer, several months in the refrigerator, or one to two months at room temperature ($70^{O}F$).

2.5.4 Types of Leathery foods

Different works have done with different leather types at different time. Most of the leather passed through chemical analysis, sensory evaluation, microbial count, quality during storage, color and texture acceptability and shelf life of the product. Most of the products maintained a high acceptability after 90 days at normal room temperature.

Demarchi, *et al.* (2010) prepared 'Apple Leather' using 78.98% apple puree, 9% sucrose, 9% polydextrose, 3% aqueous solution of citric acid (0.302 M) and 0.02% sucralose. pH 3.4; Water activity 0.69 and 23% moisture content (wet basis) was found in the study.

Quintero, *et al.* (2010) established 'Apple Leather', adding 79gm apple puree, 18gm sucrose, 3gm solution of citric acid (0.302 M), 30gm water and potassium metabisulfite (MBK) equivalent to 100 ppm (Parts Per Million) SO_2. In the study pH 3.3; 23% moisture content (wet basis) and storage stability of 6 month was found.

Gujral and Khanna (2002) prepared 'Mango Leather'. Added mango puree, 2% potassium metabisulfite, soy protein concentrate, skim milk powder, sucrose at tree concentrations levels (0, 4.5%, and 9%).

Azeredo, *et al.* (2006) developed 'Mango Leather' using mango puree (without additives) and pH 3.8 was found. Chan and Cavaletto (1978) conducted their study on 'Papaya Leather'. They added papaya puree, sugar (10%w/w) and sodium bisulfite (552 – 1105 ppm) and pH 3.5 and 12%-13% moisture content was found.

Ashaye, *et al.* (2005) prepared papaya and guava leather using 20% sugar, 0.2% citric acid o.1% sodium benzoate to 80% of their pulp. Papaya leather contained 18% moisture content, 2.1% protein, 1.49% fat and 2.67% ash. Guava leather contained 16% moisture content, 2.67% protein, 1.37 % fat and 2.87% ash.

2.6 Tomato Leather

Usually drying the tomato sauce forms the tomato leather. USDA (2009), has prepared tomato sauce using 2 tablespoons vegetable oil, 1 medium onion, chopped, 3 garlic cloves, chopped 1 pound fresh tomatoes, seeds removed and chopped 1 tablespoon dried basil, oregano, or Italian seasoning, 1⁄2 teaspoon black pepper, 1⁄4 teaspoon salt, 1 teaspoon sugar, 3 tablespoons tomato paste.

2.7 Packaging of Tomato Leather

Ahmed (1997) mentioned that packaging and storage were quality control criterion of any product. Storage stability depended on packaging. Good packaging and storage condition extend the storage duration.

A report of FAO (1997) indicated that good packaging had the following characteristics.

- It protects product from injury.
- It eliminates individual handling of the produce and facilitates transport and marketing.

It protects the product from contamination by microorganism and filth.

2.8 Nutritive Value of Tomato

Apart from its characteristic flavor and aroma, tomato is also a good source of vitamin C and significant sources of vitamin A and B (Robinson, 1976). It has about 20mg - 25mg ascorbic acid per 100gm (Dike and Atchey, 1986). The mineral content of tomato is high and varies from 0.3 and 0.6% (Gould, 1983).

Table 2.1: Nutritional Value of Ripe Tomato (USDA, 2009)

Ripe Tomatoes

Nutritional value per 100gm (3.5oz)

Energy	74 kJ (18 kcal)
Carbohydrates	3.9gm
Sugars	2.6gm
Dietary fiber	1.2gm
Fat	0.2gm
Protein	0.9gm
Water	94.5gm
Vitamin A equiv.	42 μ (5%)
Vitamin C	14mg (17%)
Vitamin E	0.54 (4%)
Potassium	237mg (5%)

Jayathunge (2012) mentioned in his study that even though the ripe tomato contains about 94% moisture, it is an excellent source of minerals and vitamins. Tomato contains large amounts of vitamin C and A, providing 40 % and 15 % of the daily value, respectively. Moreover, the lycopene, red pigment contains in tomatoes act as an antioxidant, neutralizing free radicals that can damage cells in the body inhibiting the lung, breast, and endometrial cancer cells and cut down the risk of developing prostate cancer by 45%.

Most often associated with lycopene (a carotenoid phytonutrient widely recognized for its antioxidant properties), tomatoes provide a unique variety of phytonutrients. Included are additional carotenoids (including beta-carotene, lutein, and zeaxanthin); flavonoids (including naringenin, chalconaringenin, rutin, kaempferol, and quercetin); hydroxycinnamic acids (including caffeic, ferulic and coumaric acid); glycosides (including esculeoside A) and fatty acid derivatives including 9-oxo-octadecadienoic acid (Dilis and Trichopoulou, 2010).

Tomatoes are an excellent source of free radical-scavenging vitamin C and vitamin A as well as bone-healthy vitamin K. They are a very good source of enzyme-promoting molybdenum; heart-healthy potassium, vitamin B6, folate and dietary fiber; blood sugar-balancing manganese. In addition, tomatoes are a good source of heart-healthy magnesium, niacin, and vitamin E; energy-producing iron, vitamin B1, and phosphorus; muscle-building protein, and bone-healthy copper (Visioli and Riso, 2003).

Rui (2002), Cornell assistant professor of food science, found that heat processing actually enhanced the nutritional value of tomatoes by increasing the lycopene content - a phytochemical that makes tomatoes red that can be absorbed by the body, as well as the total antioxidant activity. Vitamin C content decreased by 10 to 29 percent because of heating when compared with raw, uncooked tomatoes, released as oxygen, are metabolized by the body. While the antioxidant activity in tomatoes is enhanced during the cooking process, vitamin C loss occurs when the food's ascorbic acid is oxidized to dehydroascorbic acid and other forms of nutritionally inactive component.

Table 2.2: Nutrition Information of Tomato (USDA Nutritive Value of Foods)

	Calor-ies	Fiber, g	Vit. A IUs	Vit. C mg	Calcium mg	Iron mg	Potas-sium mg	Sodium mg
Raw tomato, 2 3/5 inch diameter	26	1.4	776	32	6	.55	273	11
Canned tomatoes, 1/2 cup	20	1.1	140	11	37	1.1	226	12
Canned tomato juice, 1/2 cup	21	0.5	547	22	12	0.52	278	12
Dried tomatoes, 1/4 cup	35	1.7	118	5.3	15	1.23	463	283

Source: USDA Food Composition, USDA Nutrient Data Laboratory (2004).

Table 2.3: Nutrition Information of Tomato sauce

1 serving (1/2 cup)			
Calories	80	Dietary fiber	2gm
Calories from Fat	40	Sugar	4gm
Total Fat	5gm	Protein	1gm
Saturated Fat	0gm	Vitamin A	40 RAE
Cholesterol	0gm	Vitamin C	13mg
Sodium	8gm	Calcium	25mg
Total Carbohydrate	2gm	Iron	1mg

Source: USDA (2009)

The percent Daily Value (DV %) for tomato established in the rating system is given in Table 2.2. For most of the nutrient ratings, the system used the government standards for food labeling that are found in the U.S. Food and Drug Administration's "Reference Values for Nutrition Labeling".

Table 2.4: Nutrient Rating for Tomato

Tomatoes, 1.00 cup raw, 180.00 grams, 32.40 calories				
Nutrient	**Amount**	**DV(%)**	**Nutrient Density**	**Food Ratings**
vitamin C	22.86 mg	38.1	21.2	excellent
vitamin A	1499.40 IU	30.0	16.7	excellent
vitamin K	14.22 mcg	17.8	9.9	excellent
potassium	426.60 mg	12.2	6.8	very good
molybdenum	9.00 mcg	12.0	6.7	very good
manganese	0.21 mg	10.5	5.8	very good
fiber	2.16 g	8.6	4.8	very good
vitamin B6	0.14 mg	7.0	3.9	very good
folate	27.00 mcg	6.8	3.8	very good
copper	0.11 mg	5.5	3.1	good
vitamin B3	1.07 mg	5.3	3.0	good
magnesium	19.80 mg	5.0	2.8	good
vitamin E	0.97 mg	4.8	2.7	good
vitamin B1	0.07 mg	4.7	2.6	good
phosphorus	43.20 mg	4.3	2.4	good
protein	1.58 g	3.2	1.8	good
tryptophan	0.01 g	3.1	1.7	good
choline	12.06 mg	2.8	1.6	good
iron	0.49 mg	2.7	1.5	good

Foods Rating	**Rule**
excellent	DV>=75% OR Density>=7.6 AND DV>=10%
very good	DV>=50% OR Density>=3.4 AND DV>=5%
good	DV>=25% OR Density>=1.5 AND DV>=2.5%

Source: WHF, 2010

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted in the laboratory of the Department of Food Engineering & Technology, Hajee Mohammad Danesh Science & Technology University, Dinajpur, Bangladesh.

3.1 Sample Collection

Ripe tomatoes were purchased from a commercial farm and transported to the laboratory. Diseased and damaged fruits were discarded to minimize biological variability. Other ingredients were collected from the locally available market. Distilled water was used for all the analyses. Polypropylene bags, Aluminum foil and standard grade chemicals required for the work done were used from the laboratory stock.

3.2 Equipment Needed

- Plastic wrappers
- Blender
- Knife
- Double boiler or pressure cooker
- Large, heavy saucepan for concentrating the purees
- Solar dryer or Nylon net or cheesecloth for sun drying

3.3 Preparation of Tomato Leather

2kg fresh ripe tomatoes were taken and washed with clean water. With a clean sharp steel knife tomatoes were sliced longitudinally into four pieces. Tomatoes were then boiled in a pressure cooker. Then skin removed from the tomatoes. The tomato then blended in a blender with specified amount of garlic (0.75%) and zinger (0.5%). The tomato pulp then heated slowly in an open pan, stirred constantly to prevent burning. By carefully doing this the bright red color can be retained (Azam Ali, 2008). During heating all other ingredients such as 11.5% sugar, 1% salt, 0.1% chili powder and 0.9% mixed spice powder were mixed. This was done five times to prepare five samples. After 15 minutes of cooking, in different sample, lemon juice (3%); lemon juice (3%) and Vinegar (3%); lemon juice (3%), vinegar (3%) and tamarind (15%); and lemon juice (3%) and tamarind (15%) were added respectively to differentiate between samples. Nothing was added for the fifth sample.

By heating for 20 minutes a very thick mixture was obtained. The concentrate was then purred and spread in a thin layer onto a polythene sheet. Then the sheet was dried in a solar drier until it became soft and rubbery. Test for dryness was done by touching the leather in several places. When it was properly dried, it was easy to peel from the plastic wrap. After loosening the edge of the leather from the plastic wrap, it was cooled.

Finally the leathers were termed as:

- **Treatment 1 (T_1):** Tomato Leather with lemon juice
- **Treatment 2 (T_2):** Tomato Leather with lemon juice and vinegar
- **Treatment 3 (T_3):** Tomato Leather with lemon juice, vinegar and tamarind
- **Treatment 4 (T_4):** Tomato Leather with lemon juice and tamarind
- **Treatment 5 (T_5):** Control Tomato Leather with only constant ingredients

The Tomato leathers were then cut into pieces and stored in airtight packaged in single layer polypropylene bags and aluminum foil paper.

3.4 Chemical Analyses

Ripe tomato and Tomato leather types were analyzed to determine the proximate analysis such as moisture, ash, fat, protein, total carbohydrate, vitamin C, acidity and pH.

3.4.1 Moisture

Moisture Content was determined adopting AOAC (1984) method.

At first, the weights of empty dry crucibles were taken and 5gm samples were taken in each dried crucible. The crucibles with samples were dried in an air oven at $100^{O}C$ for 24 hours or more until the weight became constant. The crucibles were cooled in desiccators. The crucibles were removed from desiccators and weighed soon after reaching room temperature.

The loss in weights was taken as the moisture loss of the sample and the percent of moisture content in the samples were calculated by using the following formula:

$$\% \text{ Moisture} = \frac{\text{Loss of weight}}{\text{Weight of sample}} \times 100$$

3.4.2 Ash

AOAC method (1984) was used to determine the total ash content.

2gm of each sample were taken in dry, clean porcelain dishes and weighed accurately. Hot air oven method was applied to remove the moisture. Then the samples were burnt on an electric heater. These were done to avoid the loss of sample in the muffle furnace under higher temperature. Then samples were transferred into the muffle furnace and burned for 4-6 hours at a temperature of $550^{O}C$ and ignited until light gray ash resulted (or to constant weight). The samples were then cooled in desiccators and weighed. The ash content as expressed as:

$$\% \text{ Ash} = \frac{\text{Weight of Recidue}}{\text{Weight of sample}} \times 100$$

3.4.3 Fat

AOAC method (1984) was used to determine crude fat content of the samples.

The dried sample remaining after moisture determination was transferred to a thimble and the top of the thimble was plugged with a wad of fat free cotton. The thimble was dropped into the fat extraction tube of a soxhlet apparatus. The bottom of the extraction tube was attached to a soxhlet flask. Approximately 75ml or more of anhydrous ether was poured through the sample in the tube into the flask. The top of the fat extraction tube was attached to the condenser. The sample was extracted for 16 hours or longer on a water bath at $70\,^{O}C$-$80^{O}C$. At the end of the extraction period, the thimble from the apparatus was removed and distilled off most of the petroleum ether by allowing it or collected in soxhlet tube. The petroleum ether was poured off when the tube was nearly full. When the petroleum ether had reached small volume, it was poured into a small, dry (Previously weighed) backer through a small funnel containing plug cotton. The flask was rinsed and filtered thoroughly using ether. The ether was evaporated on steam bath at low temperature and was then dried at $100^{O}C$ for 1 hour, cooled and weighed. The difference in the weights gave the ether soluble material present in the sample.

The percent of crude fat was expressed as follows:

$$\% \text{ Crude Fat} = \frac{\text{Weight of petroleum ether soluble material}}{\text{Weight of sample}} \times 100$$

3.4.4 Protein

Protein content was determined using AOAC (1984) method. The accepted method was as follows:

Reagent:

1. Concentrated H_2SO_4
2. Digestion mixture.
    - Potassium Sulphate = 100gm
    - Copper Sulphate = 10gm and
    - Selenium dioxide = 2.5gm
3. Boric acid solution = 2% solution in water
4. Alkali solution = 500gm sodium hydroxide dissolved in water and diluted to 1 liter.
5. Mixed indicator solution = Bromocresol 0.1gm and Methyle red 0.2gm dissolved in 100 ml ethyl alcohol
6. Standard HCI = 0.1 N

2gm of each sample were taken in a 250ml of Kjeldahl flask. 2gm of digestion mixture was added with the sample. 25ml of concentrated sulfuric acid was added for oxidation. The flask was placed in an inclined position on the stand in digestion chamber, heated continuously until frothing ceased and then simmered briskly. The solution became clean in 15-20 minutes, continued heating for 45 minutes. After cooling, 100ml water was added and transferred quantitatively to a 1 liter round bottom flask; the final volume was about 500ml. Added gently down the side enough NaOH solution to form a precipitate at cupric hydroxide and immediately connected the flask to stream-trap and condenser. To a 500ml conical receiving flask 50ml of boric acid solution, 50ml distilled water and 5 drops of indicator solution were added. Positioning the condenser distillation was carried out for 40 to 45 minutes or until about 250ml of distillate was obtained.

The contents receiving was titrated against hydrochloric acid solution, the end point was marked by a pink color and the readings for blank sample was also determined and deducted from the titration. A protein conversion factor was used to calculate the percent protein from nitrogen determination. Percentage of nitrogen and protein calculated by the following equation:

$$\% \text{ Nitrogen} = \frac{(A-B) \times \text{Normality of HCL} \times \text{Volume made up of the digest} \times 100 \times 14}{\text{Aliquot of the digest taken} \times \text{weight of the sample} \times 1000} \times 100$$

$$\% \text{ Protein} = \% \text{ Nitrogen } \times \text{ Protein Factor}$$

3.4.5 Total Carbohydrate

Total carbohydrate content of foods has, for many years, been calculated by difference, rather than analyzed directly. Under this approach, the other constituents in the food (protein, fat, water, ash) are determined individually, summed and subtracted from the total weight of the food. This is referred to as total carbohydrate by difference and is calculated by the following formula: 100-(weight in grams [protein + fat + water + ash] in 100g of food).

It should be clear that carbohydrate estimated in this fashion includes fiber, as well as some components that are not strictly speaking carbohydrate, e.g. organic acids. Total carbohydrate can also be calculated from the some of the weights of individual carbohydrates and fiber after each has been directly analyzed.

3.4.6 Vitamin C

The reagents used for the estimation of vitamin C were as follows:

i) Metaphosphoric acid (3%)

ii) Standard ascorbic acid solution

iii) Dye solution

For estimation of ascorbic acid, the following steps were followed:

3.4.6.1 Standardization of Dye Solution

5ml standard ascorbic acid solution was taken in a conical flask and 5 ml Metaphosphoric acid (HPO_3) was added to it and then shaken. A micro-burette was filled with Dye solution and the mixed solution was titrated with Dye using phenolphthalene as indicator. Dye factor was calculated using the following formula:

$$\text{Dye Factor} = \frac{0.5}{\text{Titre}}$$

3.4.6.2 Preparation of Sample

20gm of sample was blended and homogenized in a blender with 3% mataphosphoric acid solution. The homogenized liquid was transferred to a 250ml volumetric flask and made to volume with metaphosphoric acid solution. Content of flask was then thoroughly mixed and filtered.

3.4.6.3 Titration:

5ml of the aliquot was taken in a flask and titrated with standard dye solution, using phenolphthalein indicator. The ascorbic acid content of the sample was calculated using the following formula:

mg of ascorbic acid/100gm of sample = $\frac{T \times D \times V1}{W \times V2} \times 100$

Where,

T = Titer

D = Dye factor

V1 = Volume made up

W = Weight of sample taken for estimation

V2 = Aliquot of extract taken for estimation

3.4.7 pH

The pH meter was first standardized using buffer of pH 7.00. Then for determining the pH of raw red tomato and Tomato Leather, a buffer of pH 4.00 was sufficed. Again the pH meter was standardized using this buffer and checked the pH of sample.

3.4.8 Titrable Acidity

20gm of sample was blended and homogenized in a blender with distilled water and carefully transferred to a 250ml beaker. The mixture was boiled for 1 hour periodically adding water to replace the loss by evaporation. Cooled and transferred to a 100ml volumetric flask. Then volume was made to 100ml and filtered. 30ml of the filtered liquid was titrated against 0.1N NaOH using phenolphthalein as an indicator. The titration was done in triplicate and titrable acidity was calculated from the following relationship:

$$\%\ \text{Titrable Acidity} = \frac{T \times N \times V1 \times E}{W \times V2 \times 1000} \times 100$$

Where,

T = Titer

N = Normality of NaOH

V1 = Volume made up

E = Equivalent weight of acid

W = Weight of sample taken for estimation

V2= Volume of sample taken for estimation

3.5 Sensory Evaluation of Tomato Leather

For statistical analysis of sensory data five different types of tomato leathers were evaluated for color, flavor, texture and overall acceptability by a panel of 10 testers. All the testers were the students and teachers of the faculty of Agro Industrial and Food Processing Engineering of Hajee Mohammad Danesh Science and Technology University, Dinajpur. The panelists were briefed before evaluation. Five types of leathers were presented as randomly coded sample to the 10 panelists. The test panelists were asked to rate the different leathers presented to them on a 9 point hedonic scale with the ratings of: 9 = Like extremely; 8 = Like very much; 7 = Like moderately; 6 = Like slightly; 5 = Neither like nor dislike; 4 = Dislike slightly; 3 = Dislike moderately; 2 = Dislike very much and 1 = Dislike extremely. The results were evaluated with Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT) procedures of the Statistical Analysis System (SAS, 1985).

3.6 Storage and shelf life Study of Tomato Leather

For the observation of shelf life of Tomato leather, all the samples prepared from the treatments were packaged in single layer polypropylene bags (SLPP) and aluminum foil paper (AFP) and were airtight. The samples were observed by storing at normal room temperature ($28^{O}C$-$30^{O}C$) and at refrigeration temperature of $12^{O}C$ for 120 days. The sample identification for both storage temperatures is given in Table 3.1 and Table 3.2.

For storage quality and shelf life observation, weight of each sample was recorded and organoleptic observations were done. These were done at every twenty days interval. Off flavor, discoloration and/or any spot or any physical break down of each sample was recorded for 120 days.

Table 3.1 Sample Identification for Storage at Normal Room Temperature ($28^{O}C$ -$30^{O}C$)

Sample ID	Treatment No.	Packaging
100 A	1	SLPP
200 A	2	SLPP
300 A	3	SLPP
400 A	4	SLPP
500 A	5	SLPP
101 A	1	AFP
201 A	2	AFP
301 A	3	AFP
401 A	4	AFP
501 A	5	AFP

SLPP = Single Layer Polypropylene Bag

AFP = Aluminum Foil Paper

Here, the left number (1, 2, 3, 4, and 5) indicates the treatment number. The numbers '00' indicate the packaging material SLPP and the numbers '01' indicate the packaging material AFP. The right alphabet 'A' means normal room temperature storage.

Table 3.2 Sample Identification for Storage at Refrigeration Temperature (12^{O}C)

Sample ID	Treatment No.	Packaging
100 B	1	SLPP
200 B	2	SLPP
300 B	3	SLPP
400 B	4	SLPP
500 B	5	SLPP
101 B	1	AFP
201 B	2	AFP
301 B	3	AFP
401 B	4	AFP
501 B	5	AFP

SLPP = Single Layer Polypropylene Bag

AFP = Aluminum Foil Paper

Here, the left number (1, 2, 3, 4, and 5) indicates the treatment number. The numbers '00' indicate the packaging material SLPP and the numbers '01' indicate the packaging material AFP. The right alphabet 'B' means refrigerated temperature storage.

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The tomato leather is a ready to eat snack prepared from tomato. Tomato leather was studied for its acceptability with different ingredients and shelf life at room temperature ($28^{O}C-30^{O}C$) and at refrigeration temperature ($12^{O}C$). The acceptability and shelf life were evaluated through organoleptic taste testing procedure along with chemical analysis. The consequences obtained were discussed in this chapter.

4.1 Chemical Analysis

4.1.1. Chemical composition of ripe tomato

Ripe tomato was analyzed for its chemical composition. Red tomato was analyzed for moisture, ash, fat, protein, vitamin C and total carbohydrate content. The red raw tomato contained 94.6% moisture, 0.3% ash, 0.1 fat%, 0.6% protein and 4.4% carbohydrate, which approximates are similar to those found in MEXT (2011) and USDA (2009).

Table 4.1: Chemical composition of Ripe Tomato

Parameter	In this study	MEXT	USDA database
Moisture content	94.6%	94%	94.5%
Ash	0.3%	0.5%	0.5%
Fat	0.1%	0.1%	0.2%
Protein	0.6%	0.7%	0.9%
Carbohydrate	4.4%	4.7%	3.9%

Vitamin C content in ripe tomato was found 19.8mg/100gm which is similar to those found by Lincoln, *et al.* (1943) and Matthews, *et al.* (1973). Lincoln, *et al.* (1943) found a fresh, ripe tomato fruit weighing 100gm contains 10.4mg-44.6mg ascorbic acid. Matthews, *et al.* (1973) worked on vitamin C content in different tomato varieties and found that the mean value for all 41 varieties was 15.0 mg/l00g, and the range of vitamin C content of these varieties varied from 10.7mg/100gm to 20.9 mg/l00gm on wet weight basis.

4.1.2. Chemical composition of Tomato leathers

Chemical composition of the prepared tomato leathers was analyzed and the results were shown in Table 4.2.

Table 4.2: Chemical Composition of Tomato Leathers Just After Preparation

Parameter	T_1	T_2	T_3	T_4	T_5
Moisture (%)	13.28	13.74	13.11	12.94	12.88
Ash (%)	0.783	0.761	0.845	0.853	0.756
Fat (%)	2.31	2.35	2.31	2.32	2.30
Protein (%)	3.75	3.85	3.86	3.69	3.71
Vitamin C (mg/100gm)	10.76	11.32	12.04	11.65	9.34
pH	3.5	3.3	3.2	3.3	3.5
Acidity (%)	0.203	0.213	0.252	0.214	0.197

T_1: Tomato Leather with lemon juice
T_2: Tomato Leather with lemon juice and vinegar
T_3: Tomato Leather with lemon juice, vinegar and tamarind
T_4: Tomato Leather with lemon juice and tamarind
T_5: Control Tomato Leather with only constant ingredients

The moisture contents of the different tomato leathers were in the range of 12%-13%. Ashaye, et al. (2005) prepared papaya and guava leather and found the moisture content respectively 18% for papaya leather and 16% for guava leather. Azeredo, et al. (2006) developed 'Mango Leather' and found the moisture content 12%-13%.

It was observed that the moisture content of the ripe tomato was significantly higher than the tomato leathers (Table: 4.1 and Table 4.2). The moisture contents of the different tomato leathers were not significantly different from each other. This difference could be due to drying during processing to leather.

Protein content and fat content of the leather were significantly higher than the ripe tomato which is similar to the study conducted by Ashaye, et al. (2005) and USDA (2009). Ash content of the different leathers was not significantly different from each other but higher than the ripe tomato. This could be due to due to reduction in moisture content as a result of processing and varietal influence.

Vitamin C content of the leathers was significantly lower than the fresh ripe tomato due to processing. Vitamin C is known to be unstable as temperature increases because when heated the food's ascorbic acid oxidized to dehydroascorbic acid (Rui, 2002).

The pH of the leathers was not significantly different from each other (Table: 4.2) which are similar to Azeredo, *et al.* (2006); Quintero, *et al.* (2010) and Demarchi, *et al.* (2010).

Chemical composition of Tomato leathers was determined during the storage period. The change in moisture, ash, fat and protein contents were determined with time during the storage period.

For moisture change in tomato leathers (Appendix 1.1) it was found that during the storage period Treatment 1, Treatment 2, Treatment 3, Treatment 4 and Treatment 5 contained 13.28%, 13.44%, 13.11%, 12.94% and 12.88% moisture immediately after preparation and 13.31%, 13.45%, 13.14%, 12.95% and 12.90% moisture after 120 days respectively. The change in moisture content is shown in Figure 4.1.

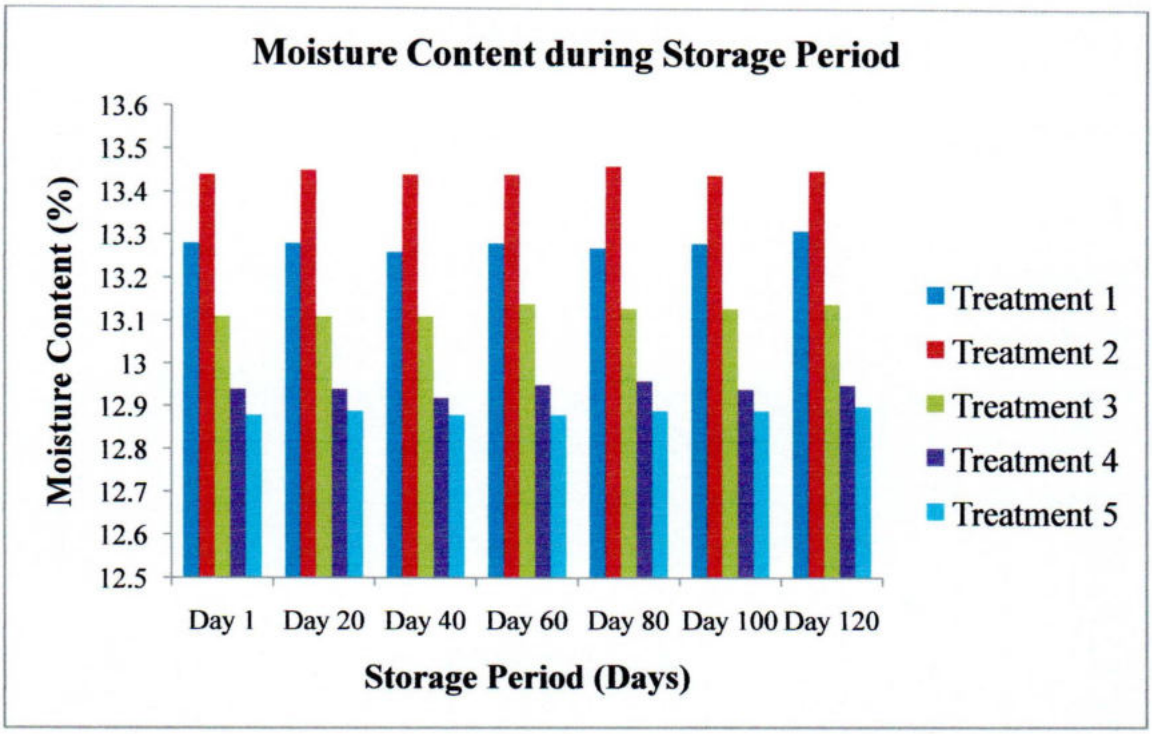


Figure 4.1: Moisture Content (%) in Tomato Leathers during the Storage Time

Figure 4.1 showed that, during the storage period there was very slight change in moisture content among the different treatments, which is negligible.

In case of ash content of tomato leathers (Appendix 2.1) Treatment 1, Treatment 2, Treatment 3, Treatment 4 and Treatment 5 contained 0.783%, 0.761%, 0.845%, 0.853% and 0.756% ash content immediately after preparation. After 120 days of storage period which was 0.786%, 0.764%, 0.848%, 0.859% and 0.761%; this is shown in Figure 4.2.

Figure 4.2 showed that there was no specific change in ash content in all the treatments during the storage period.

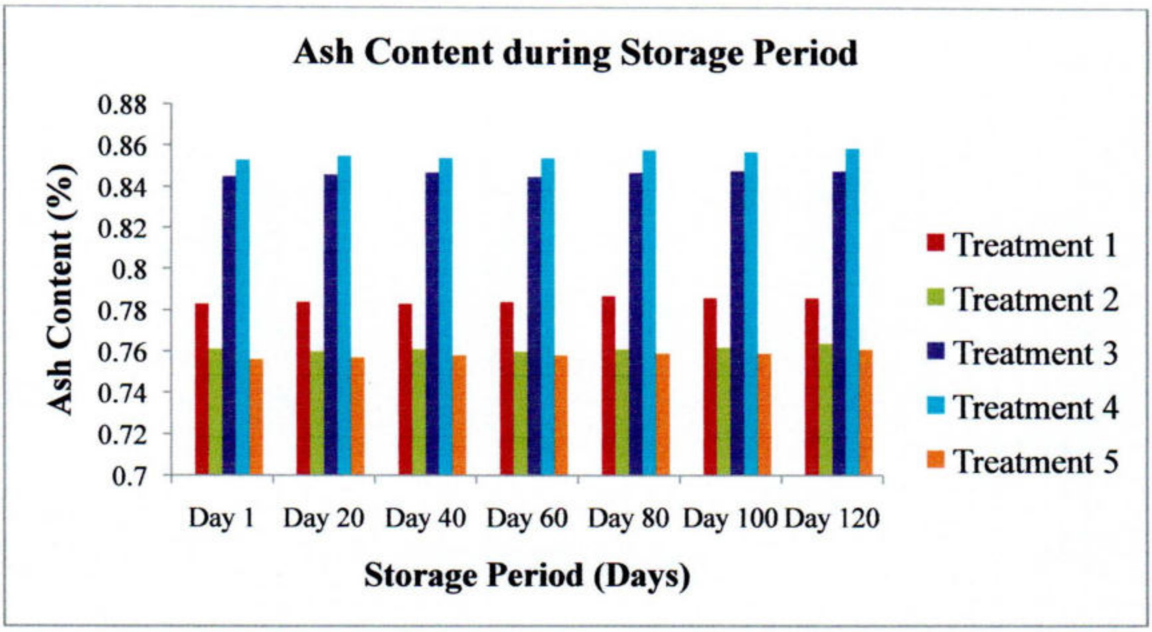


Figure 4.2: Ash Content (%) in Tomato Leathers during the Storage Time

For fat content (Appendix 3.1) it was found that Treatment 1, Treatment 2, Treatment 3, Treatment 4 and Treatment 5 contained 2.31%, 2.35%, 2.31%, 2.32% and 2.30% fat content just after preparation which was 2.33%, 2.36%, 2.33%, 2.34% and 2.32% respectively at the last day of storage. The change in fat content is shown in Figure 4.3.

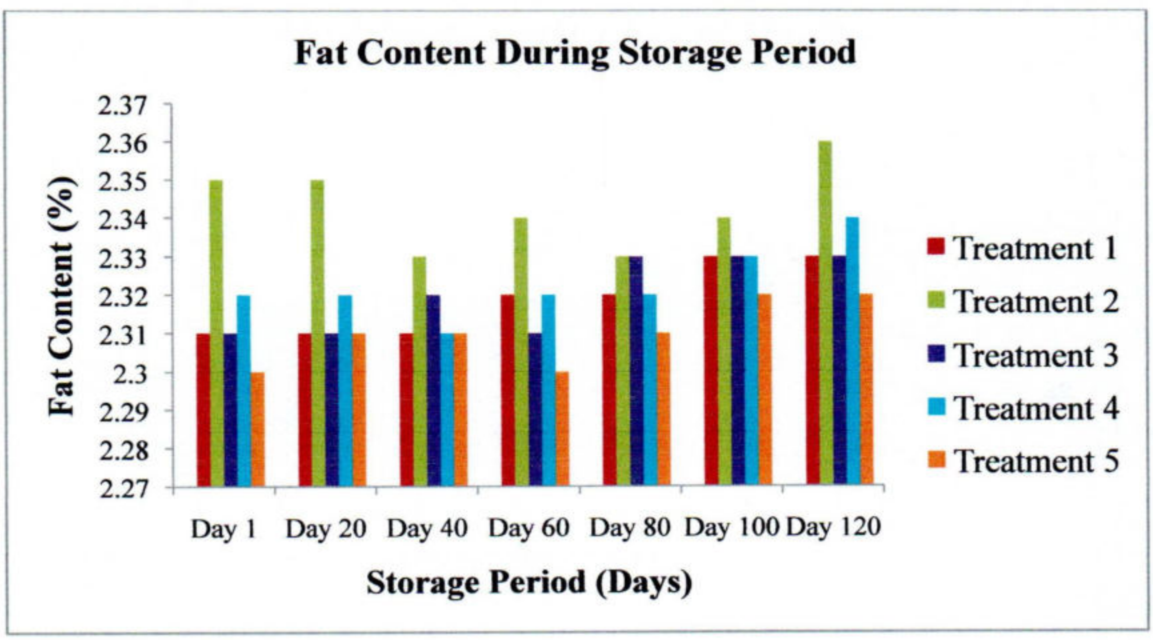


Figure 4.3: Fat Content (%) in Tomato Leathers during the Storage Time

Slight increase in the fat content of all the treatments is observed in Figure 4.3 during the120 day's storage period. This could be due to technical error of the measuring procedure and this difference is not significant.

It was found that (Appendix 4.1) Treatment 1, Treatment 2, Treatment 3, Treatment 4 and Treatment 5 contained 3.75%, 3.85%, 3.86%, 3.69% and 3.71% protein content at the day of preparation. After 120 days the protein content of Treatment 1, Treatment 2, Treatment 3, Treatment 4 and Treatment 5 became 3.77%, 3.88%, 3.87%, 3.71% and 3.72% respectively. Figure 4.4 is representing the change in protein content.

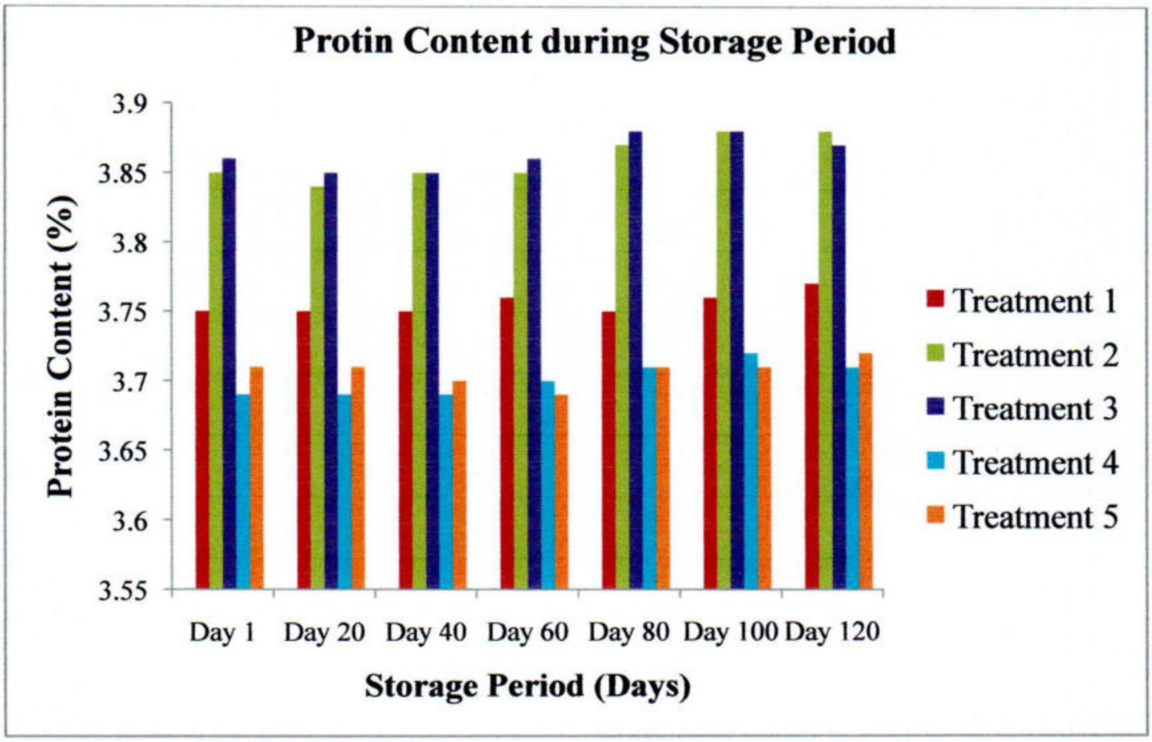


Figure 4.4: Protein Content (%) in Tomato Leathers during the Storage Time

Figure 4.4 showed that the protein content was not that changed during the storage period for all the treatments.

From the figures it was found that moisture content, ash content, fat content and protein content remained more or less same throughout 120 days storage period. The small variation may be due to technical error in measuring procedure and this difference is insignificant.

4.2 Sensory Evaluation

A panel of ten panelists was selected from the students and teachers from the faculty of Agro Industrial and Food processing Engineering, Hajee Mohammad Danesh Science and Technology University, Dinajpur. The tomato leathers were evaluated by the panelists in ascending order of 9 point hedonic scale with the ratings of: 9 = Like extremely; 8 = Like very much; 7 = Like moderately; 6 = Like slightly; 5 = Neither like nor dislike; 4 = Dislike slightly; 3 = Dislike moderately; 2 = Dislike very much and 1 = Dislike extremely. The panelists scored showing their degree of preference in respect of color, flavor, texture and overall acceptability of the tomato leathers. The results were evaluated with Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT) procedures of the Statistical Analysis System (SAS, 1985).

The responses were tabulated in tables (Appendix 5.1, 6.1, 7.1, 8.1, 9.1). The mean scores for color, flavor, texture, taste and overall acceptability of five types of tomato leathers are given in Table 4.3.

Table 4.3: Mean Scores of Tomato Leathers for Different Sensory Attributes

Treatment code	Sensory attributes				
	Color	Flavor	Texture	Taste	Overall Acceptability
T_1	6.5^{c}	6.6^{bc}	5.4^{c}	6.5^{bc}	5.9^{c}
T_2	7.6^{a}	7.5^{ab}	6.6^{ab}	7.1^{b}	6.9^{b}
T_3	7.1^{abc}	7.8^{a}	7.2^{a}	8.1^{a}	7.8^{a}
T_4	6.8^{bc}	7.2^{ab}	6.4^{ab}	6.8^{b}	6.1^{c}
T_5	7.5^{ab}	5.9^{c}	5.9^{bc}	5.8^{c}	5.4^{c}
LSD $P<0.05$	0.6996	0.7367	0.7694	0.8349	0.7279

T_1: Tomato Leather with lemon juice
T_2: Tomato Leather with lemon juice and vinegar
T_3: Tomato Leather with lemon juice, vinegar and tamarind
T_4: Tomato Leather with lemon juice and tamarind
T_5: Control Tomato Leather with only constant ingredients

4.2.1 Color acceptability

For color preference a two-way analysis of variance ANOVA (Appendix 5.1 and Appendix 5.2) was carried out and there was significant ($P<0.05$) difference in color acceptability among the leathers as the calculated F-value (3.5505) is less than the tabulated F-value (2.6335). The DMRT result (Appendix 5.3) showed that color difference of the treatment T_1, T_2, T_3, T_4 and T_5 are almost similar and T_1 gained score 6.5 which can be ranked as 'like slightly'; T2 gained score 7.6 which can be ranked as 'like moderately'; T_3 gained 7.1 can be ranked as 'like moderately'; T4 gained 6.8 which can be ranked as 'like slightly'; T_5 scored 7.5 and can be ranked as 'like moderately'. Treatment T_2 secured the highest score and was best suited for color among the all treatments.

Light colored fruit leather tends to darken upon drying (Ashaye, 2002). Solar dried leathers lost more of color probably because of the longer drying time they under went. Fresh tomato contains lycopene which is responsible for the red color. Change in the colour occurred because these pigments are sensitive to temperatures above 22°C (Bauernfeind, 1981). Using additives like ascorbic acid and sodium metabisulphite the change in color could be minimizd (Che Man *et al.*, 1997)

4.2.2 Flavor acceptability

In case of flavor preference among the treatments ANOVA analysis (Appendix 6.1 and Appendix 6.2) showed that there was significant ($P<0.05$) difference in flavor acceptability as the calculated F-value (8.5537) is higher than the tabulated F-value (2.6335). From Table 4.7 it is seen that treatment T_3 secured highest score 7.8 for flavor and can be ranked as 'Like very much' and followed by T_2 and T_4 securing score 7.5 and 7.2 can be ranked as 'like moderately'. T_1 secured score 6.6 and ranked as 'Like slightly' and T_5 scored 5.9 can be ranked as 'neither like nor dislike'.

The flavor of products results from volatile substances in the fresh food such as esters, ketones, terpenes, aldehydes and others (Fennema, 1996). Longer drying times may allow for greater loss of volatiles. Jain and Nema (2007) used direct sun drying to produce guava leathers of 15% moisture content with acceptable flavor. The addition of sugar to the guava leather could have enhanced the aroma of the guava leathers. Honey and or sugar can be used to enhance the aroma of fruit leathers

(Raab and Oehler, 1999). It is therefore important to optimise the amount of sugar added for the purpose of enhancing flavour.

4.2.3 Texture acceptability

For texture preference among the treatments (Appendix 7.1 and Appendix 7.2) it was found that calculated F-value (6.4091) is higher than tabulated F-value (2.6335), which means there was significant ($P<0.05$) difference in texture as shown in Table 4.7. Treatment T_3 secured the highest score 7.2 and can be ranked 'Like moderately'. Treatment T_1 secured lowest score of 5.4.

The texture of fruit leathers is generally affected by their moisture content and drying temperatures (Che Man *et al.*, 1997) High temperatures and long drying times are associated withlower moisture content and harder texture. Differences in texture of leathers could also be due to variations in genetic make up of the fruit, rate of water absorption from the surroundings and protein content of the fruit among others (Ashaye, 2005). The texture of fruit leather is also affected by the addition of sugar, which is sometimes done in order to improve the flavour of the leather (Raab and Oehler, 1999).

4.2.4 Taste acceptability

In case of taste preference among the treatments ANOVA (Appendix 8.1 and Appendix 8.2) showed that calculated F-value (8.2587) is higher than tabulated F-value (2.6335), so there was significant ($P<0.05$) difference in texture. From Table 4.7, treatment T_3 secured the highest scores 8.1 for taste and can be ranked as 'Like very much'. Treatment T_5 secured score 5.8 and posed lowest rank 'neither like nor dislike'.

The taste of leather is contributed by the amount of sugars contained in the fresh pulp. Increase in the amount of sugar beyond optimum amounts may, however, reduce the taste ratings thus requiring optimization (Jain and Nema, 2007). Sweetness rating may also depend on the type of the fruit and may also vary during storage [13]. However, guava leather and pawpaw leather were shown to maintain acceptable sweetness ratings within a study period of two months [Ashaye, 2005). Besides sugar and honey, other ingredients such as leaf oregano and garlic-salt among others could be used to improve the taste of solar dried leather (Ashaye, 2002). It is important to note that taste may also be influenced by and may correlate with aroma (Fennema, 1996). Therefore, enhancing aroma may also improve taste acceptability.

4.2.5 Overall acceptability

It was apparent from the results of the ANOVA (Appendix 9.1 and Appendix 9.2) that there was significant ($P<0.05$) difference in overall acceptability of the treatment tested because the calculated F-value (7.9591) is greater than the tabulated F-value (2.6335). These concerns, the overall acceptability of the treatments is not equal. From Table 4.7 it can be seen that the treatment T_3 is the most acceptable product receiving 7.8 out of 9.0 compared to the other sample and can be ranked as 'Like very much'. T_2 owed the second score for overall acceptability 6.9, can be ranked as 'like moderately'. T_1 and T_4 scored 5.9 and 6.1 respectively and can be ranked as 'like slightly'. The last score 5.4 was obtained by T_5, which can be ranked as 'neither like nor dislike'.

Enhancing all other attributes will add to the overall acceptability.

From the overall analysis treatment T_3 (Tomato Leather with lemon juice, vinegar and tamarind) secured the best score for flavor, texture, taste and overall acceptability closely followed by treatment T_2 (Tomato Leather with lemon juice and vinegar) and treatment T4 (Tomato Leather with lemon juice and tamarind). T_2 was best for color and T_3 was very near to T_2. Treatment T_1 (Tomato Leather with lemon juice) was less liked and among all the treatments T_5 (Control Tomato Leather with only constant ingredients) was least liked. So, it can be concluded that T_3 is the best product in this regard.

4.3 Storage and Shelf Life Study of Tomato Leather

Organoleptic observation of all the samples of Tomato leathers during storage period at room temperature ($28^{O}C$-$30^{O}C$) and refrigeration temperature ($12^{O}C$) were observed on the basis of color and flavor by manual perception.at every 20 days interval. Weight of each sample was also recorded at every 20 days interval.

Just after preparation the samples were light/dark maroon in color, spicy natural in flavor. During the storage time the packaged samples were observed after 20 days. Weight, color and flavor everything was same as the day of preparation. No changes observed. The observation of the samples (both at normal room temperature and refrigeration temperature) at the day of preparation and at the 20th day is given in Table 4.4 and Table 4.5.

Table 4.4: Organoleptic observations for the Samples at the Day of Preparation

Sample No.	Color	Flavor	Weight (gm)	Comment
100 A	Maroon	Spicy, Natural	27	–
100 B	Maroon	Spicy, Natural	27	
101 A	Maroon	Spicy, Natural	16	–
101 B	Maroon	Spicy, Natural	16	
200 A	Deep maroon	Spicy, Natural	25	–
200 B	Deep maroon	Spicy, Natural	25	
201 A	Deep maroon	Spicy, Natural	17	–
201 B	Deep maroon	Spicy, Natural	17	
300 A	Deep maroon	Spicy, Natural	30	–
300 B	Deep maroon	Spicy, Natural	30	
301 A	Deep maroon	Spicy, Natural	17	–
301 B	Deep maroon	Spicy, Natural	17	
400 A	Deep maroon	Spicy, Natural	34	–
400 B	Deep maroon	Spicy, Natural	34	
401 A	Deep maroon	Spicy, Natural	16	–
401 B	Deep maroon	Spicy, Natural	16	
500 A	Light maroon	Spicy, Natural	28	–
500 B	Light maroon	Spicy, Natural	28	
501 A	Light maroon	Spicy, Natural	16	–
501 B	Light maroon	Spicy, Natural	16	

Table 4.5: Organoleptic observations for the Samples at the 20th day

Sample No.	Color	Flavor	Weight (gm)	Comment
100 A	Maroon	Spicy, Natural	27	No change found.
100 B	Maroon	Spicy, Natural	27	Same as the first day
101 A	Maroon	Spicy, Natural	16	No change found.
101 B	Maroon	Spicy, Natural	16	Same as the first day
200 A	Deep maroon	Spicy, Natural	25	No change found.
200 B	Deep maroon	Spicy, Natural	25	Same as the first day
201 A	Deep maroon	Spicy, Natural	17	No change found.
201 B	Deep maroon	Spicy, Natural	17	Same as the first day
300 A	Deep maroon	Spicy, Natural	30	No change found.
300 B	Deep maroon	Spicy, Natural	30	Same as the first day
301 A	Deep maroon	Spicy, Natural	17	No change found.
301 B	Deep maroon	Spicy, Natural	17	Same as the first day
400 A	Deep maroon	Spicy, Natural	34	No change found.
400 B	Deep maroon	Spicy, Natural	34	Same as the first day
401 A	Deep maroon	Spicy, Natural	16	No change found.
401 B	Deep maroon	Spicy, Natural	16	Same as the first day
500 A	Light maroon	Spicy, Natural	28	No change found.
500 B	Light maroon	Spicy, Natural	28	Same as the first day
501 A	Light maroon	Spicy, Natural	16	No change found.
501 B	Light maroon	Spicy, Natural	16	Same as the first day

There was no change found in the 40th, 60th and 80th day as well after the day of preparation in the both storage conditions. After 100 days, change in color was observed in the samples kept in normal room temperature in both of the packaging. The color was darkening. Flavor was slightly changed. The change in color and flavor might be due to chemical reaction. No change in weight was found. The organoleptic observations for the samples kept in the normal room temperature after 100 days is given in Table 4.6

Table 4.6: Organoleptic observations for the Samples after 100 days at 28^OC-30^OC

Sample No.	Color	Flavor	Weight (gm)	Comment
100 A	Dark deep Maroon	Spicy but not good	27	Slightly changed color and flavor. Same weight. No spot or physical breakdown. Acceptable
101 A	Dark deep Maroon	Spicy but not good	16	Slightly changed color and flavor. Same weight. No spot or physical breakdown. Acceptable
200 A	Dark deep maroon	Spicy but not good	25	Slightly changed color and flavor. Same weight. No spot or physical breakdown. Acceptable
201 A	Dark deep maroon	Spicy but not good	17	Slightly changed color and flavor. Same weight. No spot or physical breakdown. Acceptable
300 A	Dark deep maroon	Spicy but not good	30	Slightly changed color and flavor. Same weight. No spot or physical breakdown. Acceptable
301 A	Dark deep maroon	Spicy but not good	17	Slightly changed color and flavor. Same weight. No spot or physical breakdown. Acceptable
400 A	Dark deep maroon	Spicy but not good	34	Slightly changed color and flavor. Same weight. No spot or physical breakdown. Acceptable
401 A	Dark deep maroon	Spicy but not good	16	Slightly changed color and flavor. Same weight. No spot or physical breakdown. Acceptable
500 A	Deep maroon	Spicy but not good	28	Slightly changed color and flavor. Same weight. No spot or physical breakdown. Acceptable
501 A	Deep maroon	Spicy but not good	16	Slightly changed color and flavor. Same weight. No spot or physical breakdown. Acceptable

After 120 days, the color was observed to be darker in the samples kept in normal room temperature in both of the packaging. Flavor more changed. Slide change in weight was found. The aluminum foil paper packaging material was deteriorated and was no more suitable. This might be due to the oxidation reaction in the samples in the storage temperature. The Single layer polypropylene bag packaging material was good. The organoleptic observations for the samples kept in normal room temperature after 120 days is given in Table 4.7

Table 4.7: Observations for the Samples after 120 days $28^{O}C$-$30^{O}C$

Sample No.	Color	Flavor	Weight (gm)	Comment
100 A	Blackish Maroon	Spicy off flavor	27.2	Discoloration, flavor and weight change. No spot or physical breakdown. Not acceptable
101 A	Blackish Maroon	Spicy off flavor	16.3	Discoloration, flavor and weight change. No spot or physical breakdown. Not acceptable
200 A	Blackish Maroon	Spicy off flavor	25.1	Discoloration, flavor and weight change. No spot or physical breakdown. Not acceptable
201 A	Blackish Maroon	Spicy off flavor	17.2	Discoloration, flavor and weight change. No spot or physical breakdown. Not acceptable
300 A	Blackish Maroon	Spicy off flavor	30.2	Discoloration, flavor and weight change. No spot or physical breakdown. Not acceptable
301 A	Blackish Maroon	Spicy off flavor	17.3	Discoloration, flavor and weight change. No spot or physical breakdown. Not acceptable
400 A	Blackish Maroon	Spicy off flavor	34.2	Discoloration, flavor and weight change. No spot or physical breakdown. Not acceptable
401 A	Blackish Maroon	Spicy off flavor	16.2	Discoloration, flavor and weight change. No spot or physical breakdown. Not acceptable
500 A	Dark Maroon	Spicy off flavor	28.1	Discoloration, flavor and weight change. No spot or physical breakdown. Not acceptable
501 A	Dark Maroon	Spicy off flavor	16.3	Discoloration, flavor and weight change. No spot or physical breakdown. Not acceptable

No changes were found after 100 days and120 days in all the samples kept in the refrigerator. The color, flavor and weight all were found same as the day of preparation. Both packaging material were fine. The observation after 100 days and 120 days is given in Table 4.8

Table 4.8: Organoleptic observations for the Samples in 100 day and 120 day at 12^{O}C

Sample No.	Color	Flavor	Weight (gm)	Comment
100 A	Maroon	Spicy, Natural	27	Fine and Acceptable
100 B	Maroon	Spicy, Natural	27	
101 A	Maroon	Spicy, Natural	16	Fine and Acceptable
101 B	Maroon	Spicy, Natural	16	
200 A	Deep maroon	Spicy, Natural	25	Fine and Acceptable
200 B	Deep maroon	Spicy, Natural	25	
201 A	Deep maroon	Spicy, Natural	17	Fine and Acceptable
201 B	Deep maroon	Spicy, Natural	17	
300 A	Deep maroon	Spicy, Natural	30	Fine and Acceptable
300 B	Deep maroon	Spicy, Natural	30	
301 A	Deep maroon	Spicy, Natural	17	Fine and Acceptable
301 B	Deep maroon	Spicy, Natural	17	
400 A	Deep maroon	Spicy, Natural	34	Fine and Acceptable
400 B	Deep maroon	Spicy, Natural	34	
401 A	Deep maroon	Spicy, Natural	16	Fine and Acceptable
401 B	Deep maroon	Spicy, Natural	16	
500 A	Light maroon	Spicy, Natural	28	Fine and Acceptable
500 B	Light maroon	Spicy, Natural	28	
501 A	Light maroon	Spicy, Natural	16	Fine and Acceptable
501 B	Light maroon	Spicy, Natural	16	

Throughout the storage period it was found that there was no change in samples at room temperature ($28^{O}C$-$30^{O}C$) from the first day to the day 80 (10 week). A very slight variation in color and flavor among the five different types of tomato leathers was found after 100 days. After 120 days discoloration, off flavor and change in weight was found. The AFP packaging material and the product was not acceptable any more.

For the samples kept in refrigeration temperature ($12^{O}C$) color, flavor, weight and packaging material were found same from the first day to the 120 day (for 4 months). The quality and shelf life was found best at $12^{O}C$ for both packaging.

Kendall and Sofos (2007) found that if dried properly and stored in a cool, dry, dark place the leather will retain good quality for up to one year in the freezer, several months in the refrigerator or one to two months at room temperature.

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

This study was conducted to introduce a preservation method of tomato as Tomato leather, its acceptability and suitable storage of the product. The ripe tomatoes were collected from local market and analyzed for its composition. The tomato had 94.6% moisture content, 0.3% ash, 0.1% fat, 0.6% protein and 4.4% carbohydrate. Five types of tomato leathers were prepared with different ingredients. Fresh tomatoes, by washing, cutting, boiling, blending and cooking with ingredients and sun drying on sheets the leathers were prepared. Then the leathers were packaged and stored at room temperature ($28^{O}C$-$30^{O}C$) and refrigeration temperature ($12^{O}C$). Chemical analysis was done for moisture, ash, fat and protein content at an interval of 0, 20, 40, 60, 80, 100 and 120 days for all the five types of tomato leather. It was found that moisture content, ash content, fat content and protein content remained more or less same throughout 120 days storage period.

Sensory evaluation and organoleptic observation was done during the 120 days storage period. A statistical analysis was carried out on the sensory properties of the five treatments, which showed that flavor, texture, taste and overall acceptability were significant ($P<0.05$). Sensory evaluation showed that Treatment T_2 (Tomato Leather with lemon juice and vinegar) was best for color. Treatment T_3 (Tomato Leather with lemon juice, vinegar and tamarind) was best for flavor, texture, taste and overall acceptability. The study found Treatment T_3 as the best product.

To study the shelf life of the product and storage condition weight measurement and organoleptic observation was done at an interval of 0, 20, 40, 60, 80, 100 and 120 days for all the samples kept in both room temperature and refrigerator. For normal room temperature a shelf life of 80 days was found with out any weight, color and flavor change. After 80 days changes in color, flavor and weight were found and finally after 120 days the products were no more acceptable. The packaging AFP (Aluminum Foil Paper) also started to deteriorate. The samples kept in refrigeration temperature gained a shelf life of 120 days and from the first day to the last day of the 120 days storage period no change in color, flavor and weight was found. So, it is suitable to store the tomato leather at lower temperature in an airtight packaging system. Both SLPP (Single Layer

Polypropylene) bag and AFP (Aluminum Foil Paper) were suitable for refrigeration temperature storage.

This experimental study had led to the conclusion that there is a very low or rather no loss in the moisture, ash, protein and fat content of the treatments taken under study. Thus the processed tomato leather can be eaten many times without thinking of the contamination hazard.

Tomato leather is rarely practiced in Bangladesh. In these five types of tomato leathers, various ingredients were used to increase the taste and improve the shelf life. Solar drying time and low temperature encouraged greater loss of color pigments and aroma compounds as well as browning reactions. So, necessary additives could be used to minimize the loss of color and flavor and to increase the shelf life. Tomato leathers produced in this study were acceptable suggests that such products could be adopted when introduced on the market. Therefore, further studies are still needed to improve the sensory quality of solar-dried leather. Further studies are also needed to evaluate the nutrient retention, microbial stability and shelf life of solar dried leathers in order to establish the suitability of solar drying in processing of tomato leather.

Tomato leather was very much liked by the children who do not like to have vegetable. Most importantly thermal processing enhances the nutritional value of tomatoes by increasing the content of bio accessible lycopene and total antioxidant activity, which are against the notion that processed fruits and vegetables have lower nutritional value. This may create a new image for processed fruits and vegetables. This will have a direct impact on consumer's food selection and will increase their awareness of the health benefits of processed fruits and vegetables in the prevention of chronic diseases.

Tomato leather could satisfy consumer's need for convenience as they are readily available, and easy to use, and better nutritional and economical values. For having lower production cost it can be easily practiced. Tomato leather would reduce wide fluctuation of prices in peak harvesting period. The off-season product would reduce the volume and minimize transportation cost. Consumer will get good quality product at a minimum price and price will be ensured to the farmers. In addition with reducing the production loss this could open up more opportunities for the food industries.

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APENDICES

Appendix 1.1: Moisture Content (%) of Tomato Leather during the Storage Period

Treatment	At the time of Preparation	Storage period (days)					
		20	40	60	80	100	120
1	13.28	13.28	13.26	13.28	13.27	13.28	13.31
2	13.44	13.45	13.44	13.44	13.46	13.44	13.45
3	13.11	13.11	13.11	13.14	13.13	13.13	13.14
4	12.94	12.94	12.92	12.95	12.96	12.94	12.95
5	12.88	12.89	12.88	12.88	12.89	12.89	12.90

Appendix 2.1: Ash Content (%) of Tomato Leather During the Storage Period

Treatment	At the time of Preparation	Storage period (days)					
		20	40	60	80	100	120
1	0.783	0.784	0.783	0.784	0.787	0.786	0.786
2	0.761	0.760	0.761	0.760	0.761	0.762	0.764
3	0.845	0.846	0.847	0.845	0.847	0.848	0.848
4	0.853	0.855	0.854	0.854	0.858	0.857	0.859
5	0.756	0.757	0.758	0.758	0.759	0.759	0.761

Appendix 3.1: Fat Content (%) of Tomato Leathers During the Storage Period

Treatment	At the time of Preparation	Storage period (days)					
		20	40	60	80	100	120
1	2.31	2.31	2.31	2.32	2.32	2.33	2.33
2	2.35	2.35	2.33	2.34	2.33	2.34	2.36
3	2.31	2.31	2.32	2.31	2.33	2.33	2.33
4	2.32	2.32	2.31	2.32	2.32	2.33	2.34
5	2.30	2.31	2.31	2.30	2.31	2.32	2.32

Appendix 4.1: Protein Content (%) of Tomato Leathers During the Storage Period

Treatment	At the day of Preparation	Storage period (days)					
		20	40	60	80	100	120
1	3.75	3.75	3.75	3.76	3.75	3.76	3.77
2	3.85	3.84	3.85	3.85	3.87	3.88	3.88
3	3.86	3.85	3.85	3.86	3.88	3.88	3.87
4	3.69	3.69	3.69	3.70	3.71	3.72	3.71
5	3.71	3.71	3.70	3.69	3.71	3.71	3.72

Appendix 5.1: Rating score for Color of tomato leather

Panelist No.	Treatment No.					Total
	T1	T2	T3	T4	T5	
1	6	8	7	7	9	37
2	7	8	8	7	8	38
3	7	7	6	6	8	34
4	7	7	7	7	8	36
5	4	8	7	6	4	29
6	6	7	8	7	8	36
7	7	8	7	7	8	37
8	6	7	7	6	7	33
9	8	8	7	7	8	38
10	7	8	7	8	7	38
Total	65	76	71	68	75	356
Mean	6.5	7.6	7.1	6.8	7.5	

Hedonic scale used: 9 = Like extremely; 8 = Like very much; 7 = Like moderately; 6 = Like slightly; 5 = Neither like nor dislike; 4 = Dislike slightly; 3 = Dislike moderately; 2 = Dislike very much; 1 = Dislike extremely.

Appendix 5.2: Analysis of variance (ANOVA) for Color

Source	Degree of freedom	Sum of squares	Mean squares	F- value	
				Calculated	Tabulated
Replication	9	14.1	1.567	2.5872	2.1526
Factor A	4	8.6	2.150	3.5505	2.6335
Error	36	21.8	0.606		
Total	49	44.5			

Appendix 5.3: Duncan's Multiple Range Test (DMRT) for Color

LSD value = 0.6996

Sample Code	Original order of means	Sample Code	Ranked order of means
T1	6.5 C	T2	7.6 A
T2	7.6 A	T5	7.5 AB
T3	7.1 ABC	T3	7.1 ABC
T4	6.8 BC	T4	6.8 BC
T5	7.5 AB	T1	6.5 C

Appendix 6.1: Rating score for Flavor of tomato leather

Panelist No.	Treatment No.					Total
	T1	T2	T3	T4	T5	
1	7	7	8	8	7	37
2	7	8	7	7	6	35
3	6	7	9	7	7	36
4	8	8	8	8	5	37
5	3	6	7	6	4	26
6	7	7	7	7	5	33
7	7	8	8	7	7	37
8	6	7	9	8	6	36
9	7	9	7	8	6	37
10	8	8	8	6	6	36
Total	66	75	78	72	59	350
Mean	6.6	7.5	7.8	7.2	5.9	

Hedonic scale used: 9 = Like extremely; 8 = Like very much; 7 = Like moderately; 6 = Like slightly; 5 = Neither like nor dislike; 4 = Dislike slightly; 3 = Dislike moderately; 2 = Dislike very much; 1 = Dislike extremely.

Appendix 6.2: Analysis of variance (ANOVA) for Flavor

Source	Degree of freedom	Sum of squares	Mean squares	F- value	
				Calculated	Tabulated
Replication	9	20.800	2.311	3.4380	2.1526
Factor A	4	23.000	5.750	8.5537	2.6335
Error	36	24.200	0.672		
Total	49	68.000			

Appendix 6.3: Duncan's Multiple Range Test (DMRT) for Flavor

LSD value =0.7367

Sample Code	Original order of means	Sample Code	Ranked order of means
T1	6.6 BC	T3	7.8 A
T2	7.5 AB	T2	7.5 AB
T3	7.8 A	T4	7.2 AB
T4	7.2 AB	T1	6.6 BC
T5	5.9 C	T5	5.9 C

Appendix 7.1: Rating score for Texture of tomato leather

Panelist No.	Treatment No.					Total
	T1	T2	T3	T4	T5	
1	6	8	7	7	7	35
2	5	7	7	7	7	33
3	6	6	7	6	7	32
4	5	6	6	6	6	29
5	3	6	8	6	3	26
6	7	6	8	6	5	32
7	4	7	8	7	6	32
8	7	7	7	7	6	34
9	5	6	7	6	5	29
10	6	7	7	6	7	33
Total	54	66	72	64	59	315
Mean	5.4	6.6	7.2	6.4	5.9	

Hedonic scale used: 9 = Like extremely; 8 = Like very much; 7 = Like moderately; 6 = Like slightly; 5 = Neither like nor dislike; 4 = Dislike slightly; 3 = Dislike moderately; 2 = Dislike very much; 1 = Dislike extremely.

Appendix 7.2: Analysis of variance (ANOVA) for Texture

Source	Degree of freedom	Sum of squares	Mean squares	F- value	
				Calculated	Tabulated
Replication	9	13.300	1.478	2.0152	2.1526
Factor A	4	18.800	4.700	6.4091	2.6335
Error	36	26.400	0.733		
Total	49	58.500			

Appendix 7.3: Duncan's Multiple Range Test (DMRT) for Texture

LSD value = 0.7694

Sample Code	Original order of means	Sample Code	Ranked order of means
T1	5.4 C	T3	7.2 A
T2	6.6 AB	T2	6.6 AB
T3	7.2 A	T4	6.4 AB
T4	6.4 AB	T5	5.9 BC
T5	5.9 BC	T1	5.4 C

Appendix 8.1: Rating score for Taste of tomato leather

Panelist No.	Treatment No.					Total
	T1	T2	T3	T4	T5	
1	7	8	9	7	6	37
2	8	7	7	7	6	35
3	5	8	8	7	7	35
4	7	7	9	6	6	35
5	6	8	7	7	8	36
6	6	7	8	6	5	32
7	7	5	8	7	4	31
8	6	7	9	7	7	36
9	6	6	8	6	5	31
10	7	8	8	8	4	35
Total	65	71	81	68	58	343
Mean	6.5	7.1	8.1	6.8	5.8	

Hedonic scale used: 9 = Like extremely; 8 = Like very much; 7 = Like moderately; 6 = Like slightly; 5 = Neither like nor dislike; 4 = Dislike slightly; 3 = Dislike moderately; 2 = Dislike very much; 1 = Dislike extremely.

Appendix 8.2: Analysis of variance (ANOVA) for Taste

Source	Degree of freedom	Sum of squares	Mean squares	F- value	
				Calculated	Tabulated
Replication	9	8.420	0.936	1.0837	2.1526
Factor A	4	28.520	7.130	8.2587	2.6335
Error	36	31.080	0.863		
Total	49	68.020			

Appendix 8.3: Duncan's Multiple Range Test (DMRT) for Taste

LSD value = 0.8349

Sample Code	Original order of means	Sample Code	Ranked order of means
T1	6.5 BC	T3	8.1 A
T2	7.1 B	T2	7.1 B
T3	8.1 A	T4	6.8 B
T4	6.8 B	T1	6.5 BC
T5	5.8 C	T5	5.8 C

Appendix 9.1: Rating score for Overall Acceptability of tomato leather

Panelist No.	Treatment No.					Total
	T1	T2	T3	T4	T5	
1	7	6	7	6	7	33
2	6	7	8	7	5	33
3	5	7	8	6	6	32
4	7	6	9	6	6	34
5	3	7	8	7	3	28
6	5	8	8	5	7	33
7	6	7	7	7	4	31
8	8	7	8	5	5	33
9	5	6	7	6	6	30
10	7	8	8	6	5	34
Total	59	69	78	61	54	321
Mean	5.9	6.9	7.8	6.1	5.4	

Hedonic scale used: 9 = Like extremely; 8 = Like very much; 7 = Like moderately; 6 = Like slightly; 5 = Neither like nor dislike; 4 = Dislike slightly; 3 = Dislike moderately; 2 = Dislike very much; 1 = Dislike extremely.

Appendix 9.2: Analysis of variance (ANOVA) for Overall Acceptability

Source	Degree of freedom	Sum of squares	Mean squares	F- value	
				Calculated	Tabulated
Replication	9	6.580	0.731	0.6560	2.1526
Factor A	4	35.480	8.870	7.9591	2.6335
Error	36	40.120	1.114		
Total	49	82.180			

Appendix 9.3: Duncan's Multiple Range Test (DMRT) for Overall Acceptability

LSD value = 0.7279

Sample Code	Original order of means	Sample Code	Ranked order of means
T1	5.9 C	T3	7.8 A
T2	6.9 B	T2	6.9 B
T3	7.8 A	T4	6.1 C
T4	6.1 C	T1	5.9 C
T5	5.4 C	T5	5.4 C