ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
FACULTY OF TECHNOLOGY
DEPARTMENT OF CHEMICAL ENGINEERING

Development of Tomato Juice and Sauce From improved Varieties

By

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A thesis submitted to the School of Graduate Studies of Addis Ababa University in partial fulfillment of the requirements for the Degree of Master of Science in Food Engineering

November 2009
Addis Ababa

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Acknowledgement

I would like to express my sincere appreciation to my advisors Dr. Ing. Nureligne Tefera and Ato Adamu Zegeye. I would like to extend my heartfelt gratitude to my family for giving me great support in my entire carrier. I am also grateful to Hintsaselassie Seifu and all lab assistants in the Chemical Engineering Department. Deep appreciation goes to the Ethiopian Health and Nutrition Research Institute, Merti Agro-Processing Share Company workers for their cooperation and tireless assistance throughout my research work. Above all, I thank God for his unreserved help to finalize this thesis.

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Acronyms

ADM - Archer Daniels Midland Company
AHA - American Heart Association
AOAC - Association of Analytical Chemists
AVRDC Asian Vegetable Research Center
CRD - Completely Randomized Design
CSA - Central Statistical Authority
EHNRI - Ethiopian Health and Nutrition Research Institute
ES - Etiopian Standard
EU - European Union
FAO - Food and Agriculture Organization
HTST - High-Temperature, Short-Time
MAPSCo - Merti Agro-Processing Share Company
MARC - Melkasa Agricultural Research Center
MPN - Most Probable Number Method
NTSS - Natural Tomato Soluble Solids
PG - Polygalacturonase
PME - Pectin Metylesterase
SPSS - Statistical Package for Social Sciences
USDA - United States Department of Agriculture
WHO - World Health Organization
WPTC - World Processing Tomato Council

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Abstract

The favorable climatic condition, the vast irrigation sources, the abundant labor and other factors of Ethiopia are viable for the production and processing of tomato and other fruits. The present study has been initiated to evaluate the existing manufacturing process, and test the suitability of three tomato varieties for juice and sauce production. This helped to see the technological advantages for the production of good quality products. Samples products in triplicate from each variety Bergad juice (BJ1, BJ2, BJ3), Miya juice (MJ1, MJ2, MJ3), Chali juice (CJ1, CJ2, CJ3), Bergad sauce (BS1, BS2, BS3), Miya sauce (MS1, MS2, MS3), and Chali sauce (CS1, CS2, CS3) were prepared and analyzed for their physicochemical characteristics. They were determined following standard methods. Texture was analyzed according to TA-plus NEXYGEN manual. Color was determined by LOVIBOND 3000 color comparator. Titration methods by 0.1N sodium hydroxide and phenolphthalein indicator were used for the determination of acidity. Abbe type refractometer was used at a temperature of 23^0*C for TSS. The process parameters at Merti Agro-Processing plant were evaluated to test the suitability of improved varieties. The data obtained from the laboratory analysis were subjected to ANOVA using SPSS software. Bergad (Merti Variety) was used as a control. Means were then compared at 5% significance level. The results showed that Juices of improved varieties were not significantly different from the control in acidity and color. In fact, they registered high TSS than that of the control. The Flavor of Chali juice was preferred most and was not significantly different from the control. However there is a significant difference in NTSS, Miya and Chali scoring higher means but all sauces are not significantly different in acidity. Based on the findings a tomato juice manufacturing plant has been suggested that Miya variety can be used for both juice and sauce production, while Chali can be used only for sauce production.*

1. INTRODUCTION

1.1. Background

Tomato is a widely processed vegetable to be used as a vital ingredient in many products, soups, sauces and ketchups. Growth of fast foods such as pizzas, burgers and French fries, which are often served with tomato sauce and tomato salsa, has further given fresh impetus to the tomato processing industry. Grades of tomato juice are largely determined by its color, viscosity, flavor and soluble solids content (Barett, et al., 1998). Viscosity is undoubtedly an important quality attribute of tomato products arising from the retention of pectin and destruction of pectin methyl esterase and polygalactouronase during hot break treatment.

Tomato juice attained popularity not merely for its acceptable taste, but because of its vitamin value. Tomato juice retains the characteristic color and mild acid flavor of tomatoes. Citric acid is the major organic acid in tomato juice and account for 60 to 90% of the total acids. (Getinet, et al., 2001)

Tomato sauce is a thickened, well-flavored liquid which is used to enhance the flavor and appearance of the food it accompanies, provide a contrast in texture and flavor to a food, help bind ingredients together, add color to a dish and contribute to the nutritional value of the food. A sauce serves to complement an entrée, vegetable, or dessert (Magris and Creery, 2001).

For making juice, high quality tomatoes are used. Those which are green, over mature, partially rotted, or even slightly molded should be eliminated, as off-flavors originating there from can easily transfer into the juice. Generally flumes are used as conveyers to avoid injury due to excessive handling in some plants. The tomatoes are washed with cold water to eliminate dirt and other adhering materials after first sorting to eliminate those unfit for use in juice. The tomatoes are trimmed, cored, sorted, and washed again. The next step in the process varies in various plants. In some instance, the tomatoes are scalded by steam and then conveyed to an extractor. They may be mechanically chopped or crushed and then heated before extraction. Heating inactivate pectic and other enzymes and eliminates oxygen which is responsible for destroying ascorbic acid (vitamin C).

Cyclones may be used for extraction, but with this type of equipment it is essential that the tomatoes be first heated, as less oxygen is taken up under these conditions. The shorter the elapsed time from the tomato crushing to filling and sealing, the better. Tomato juice expressed from unheated fruits can be passed through special machines to break up cellulose and prevent settling out of solids in the finished product. The extracted juice is then screened, homogenized to produce a product with more stable suspension, and de-aerated. Sometimes the de-aeration process is applied immediately after extraction of the juice to minimize oxidative changes. The screened and de-aerated juice is heated to 71.1^{o}C and filled into plain or enameled tin cans or bottles and sealed. The sealed can or bottles are pasteurized at 96.1^{o}C to 98.8^{o}C. In some instance, tomato juice may be processed by heat pasteurization, either before or after filling into cans and sealing. When processed before sealing, the juice is pasteurized in continuous heat exchangers at a temperature 121.1^{o}C for 0.7min, and then cooled to a temperature 93.3^{o}C to 98.8^{o}C. Salt may be added to the juice before filling for improving the juice flavor and quality. A minor amount of tomato juice is seasoned to produce tomato juice cocktail. The seasonings used in addition to salt are sugar, pepper, celery salt, vinegar, lemon juice etc. (Getinet, et al., 2001).

Tomatoes are mostly are water (94%), a disadvantage when condensing the product to paste. They are reasonably a good source of vitamin C and A. In 1972 tomatoes provided 12.2% of the recommended daily allowance of vitamin C, and oranges and potatoes contribute more to the American diet (Senti and Rizek, 1975). Tomatoes provided 9.5% of the vitamin A, second only to carrots. When major fruits and vegetable crops were ranked on the basis of their content of 10 vitamins and minerals, the tomato occupies sixteenth place (Rick, 1978). However when the amount that is consumed is taken into consideration, the tomato places first in its nutritional contribution to the American diet. This is because the tomato is popular food, added to a wide variety of soup, meat, and pasta dishes.

Fresh tomatoes are the fifth most popular vegetable consumed in the United States (16.6 pounds per capital), after potatoes (48.8), lettuce (23.3), onions (17.9), and watermelon (17.4) (USDA, 2000). There is no data in our country about tomato consumption. Canned tomatoes are the most popular canned vegetable, at 74.2 pounds per capital in the United States. In the condiment category, salsa and ketchup are number one and two, respectively. (Smith and Hui, 2004)

Tomatoes vary in visible fruit characteristics important for fresh market and processing values. These include shape, size, color, flesh thickness, number of locules, blossom end shape and fruit quality (TSS%, pH, acidity, juice viscosity, juice volume, flavor, nutritive values etc.) the fruit may be globe shaped, oval or flattened and pear shaped, which differ in acceptability in the local market, quality, storability etc. Red skin tomatoes are the most preferred in the local market. High TSS% (4.5-6.0), which is responsible for high yield of processed products, intensive red color of both skin and flash, low acid are some of the attributes favored by processing industries. The sugar and acid ratio has important contribution to the flavor tomatoes. (Stevens, 1979)

Since 1969, about 300 tomato lines/cultivars of both short and tall set open pollinated genotypes and hybrids have been imported from international seed companies and from Asian vegetable Research Center (AVRDC). These lines of high yield and good quality fruits, resistant/tolerant lines to the diseases, insect pests and parasitic weeds complex for the different production belts.

The production of processing tomato has increased in the last decade. In advance varietal studies at Melkassa, Roma VF was the only recommended and widely produced variety for the industry. Currently it has declined in acceptability because of its low yield and low fruit quality susceptibility to disease complex. It resulted in uneven ripening which affect the color and subsequent acceptability of processed products mainly juice.

Recently selected genotypes were evaluated in multi-location trials Malkassa, Zwai and Merti in the central Rift Valley in order to produce better variety for the processing industry. In the overall fruit yield Melkashola (Red Peer) and Melkasalsa (Serio) produced 724q/ha and 665q/ha compared to 591q/ha of the control Roma VF, respectively. However, in Merti Agro-industry enterprise Melkasalsa was higher than Melkashola in yield potential. The cultivars have been found suitable and acceptable for processing (Lemma, 2002).

In Ethiopia, one of the major tomato processing industries is Merti Agro-processing. It has the capacity to produce 5000 tones per year. However, such amount of production is insufficient as compared with existing homeland consumer needs (about 6224tones). Thus, a considerable amount of tomato products were imported. According to the data obtained from Ethiopian Customs Authority (from 2005 up to December 2009), there was a rapid increase of the amount imported in each year (Table 1). On the other side, basic data and assessment of quality control of imported tomato products seem to be until yet not established (MoI, 2006).

Table1. Tomato juice and sauce import (in kg)

Year	Tomato Juice	Tomato sauce
2005	5787	2553
2006	1167	9480
2007	2420	12398
2008	2160	22543
2009	2370	29040

1.2. Statement of the problem

In addition to fresh fruits and vegetables, Ethiopia exports some processed products. Currently, the horticultural crops that are produced in Ethiopia are mainly orange and tomato. The orange is canned and bottled in the form of juice and tomato is produced as ketchup, paste etc. According to CSA, the production of orange juice Marmalade and tomato paste were 71,214 and 3,276 tons respectively in the year 2008. The processing of horticultural crops is still inadequate and irregular. However, there are some that are exporting various products to some countries including Germany, Italy, and Netherlands. The participation of private investor has been low in the past.

The most important fruit and vegetable exports from Ethiopia, however, are the high value fresh produce sold primarily to Europe, mainly to Germany, Netherlands and Italy. The major exports are green beans, tomatoes, mangoes and papayas. With the variety of altitudes and agro climates, and the long growing season and accessible irrigation sources in Ethiopia, any thing can grow well here. In fact, nearly every fruit and vegetable is already available locally. Nevertheless, fresh fruit and vegetable processing is very little.

The favorable climatic condition, the vast irrigation sources, the abundant labor and other factors of Ethiopia are viable for the production and processing of fruits and vegetables. Currently, different varieties and diversified of horticultural crops are grown in Ethiopia. Fruits and vegetables produced locally include papaya, citrus, banana, mango, Avocado, Guava, grapes, tomato egg plant, passion fruit, apple, potato, onion, water melon, sweet melon, carrot, green bean, cut flowers, lime, and several others (MoI, 2006).

The composition of tomato is affected by the variety, state of ripeness, year, climatic growing conditions, light, temperature, soil, fertilization, and irrigation. Tomato total solids vary from 5 to 10% (Davies and Hobson, 1981), with 6% being average. Approximately half of the solids are reducing sugars, with slightly more fructose than glucose. Sucrose concentration is unimportant in tomatoes and rarely exceeds 0.1%. A quarter of the total solids consist of citric, malic, and dicarboxylic amino acids, lipids and minerals. The remaining quarter, which can be separated as alcohol-insoluble solids, contains proteins, pectic substances, cellulose, and hemicellulose.

The red carotenoid in tomatoes, lycopene, does not have any vitamin activity, but it may act as an antioxidant when consumed (Stahl and Sies, 1992). A review of epidemiological studies found that evidence for tomato products was strongest for the prevention of prostate, lung, and stomach cancer, with possible prevention of pancreatic, colon and rectal, esophageal, oral cavity, breast, and cervical cancer (Giovannucci, 1999). The consumption of fresh tomatoes, tomato sauce, and pizza has been found to be significantly related to a lower incidence of prostate cancer, with tomato sauce having the strongest correlation (Giovannucci, et al., 1995). Since anticancer correlations are typically stronger to processed tomatoes than to fresh tomatoes, several studies have looked at the effect of processing on lycopene. Tomato juice and paste have more bio-available (absorbed into the blood) lycopene than fresh tomato when both are consumed with corn oil (Gartner, et al., 1997; Stahl and Sies, 1992). This may be because thermally induced rupture of cell walls and weakening of lycopene-protein complexes releases the lycopene, or because of improved extraction of lycopene into the lipophilic corn oil. (Smith and Hui, 2004)

1.3 OBJECTIVES

1.3.1 General Objective

To develop juice and sauce from improved local tomato varieties.

1.3.2 Specific Objectives:

- to test the suitability of two improved tomato varieties for juice and sauce production at lab level
- to evaluate the existing process (Merti Agro-processing Enterprise)
- to select and develop tomato juice and sauce from the improved varieties.

2. LITERATURE REVIEW

2.1 General description

On a global scale, the annual production of fresh tomatoes accounts for approximately 100 million tonnes. In comparison, 3 times more potatoes and 6 times more rice are grown around the world (FAO, 2002). However, more than a quarter of those 100 million tonnes are grown for the processing industry, which makes tomatoes the world's leading vegetable for processing. More than 27 million tonnes of tomatoes are processed every year in factories belonging to the greatest labels of the global food industry. The main production regions are located in temperate zones, close to the 40th parallels North and South, as illustrated on the following map. However, most of this production is based in the Northern hemisphere, where an average of 91 % of the world's crop is processed between the months of July and December. The remaining 9 % are processed in the Southern hemisphere between January and June. Brazil is an exception, being the only country of the Southern hemisphere to process more than one million tones per year at the same time as the Northern hemisphere (Apaiah and Barringer, 2004).

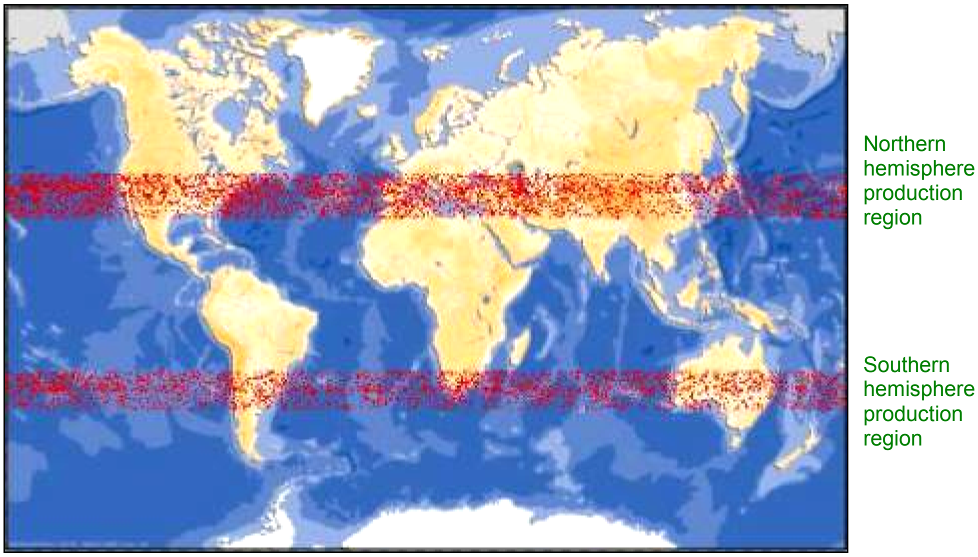

Figure 1: Global tomato processing regions

Despite the fact that many countries have a tomato processing industry, this production is strongly concentrated and the 8 largest producing countries account for some 84 % of the world's yearly production. Average figures for these countries between 1999 and 2003 were:

Table2. Global Largest Tomato processing countries

Countries	**Production capacity**
California	9.33million metric tones
Italy	4.87million tones
China	1.74million tones
Spain	1.52million tones
Turkey	1.5million tones
Brazil	1.17million tones
Greece	1.01million tones
Portugal	950 000 tones

In commercial terms, exchange volumes and commercial results also position the tomato processing sector among the main players of the global food industry. It can be said that in the 1999/2000 financial year, the four main production and exchange regions (the EU, China, the USA and Chile) exported approximately 1.1 million tones of finished products in the two leading tomato categories: paste and whole peeled tomatoes. Paste is the main tomato product, both in production volume and in commercial results: annual exports of tomato paste generate more than USD 510 million (EUR 500 million) of the USD 630 million (EUR 619 million) generated by this market (Apaiah and Barringer, 2004).

The undeniable importance of the tomato producing industry is also rooted in the regular growth in consumption observed over the past twenty years. Mainly a trait of nations with a high standard of living, the highest overall consumptions of tomato products are found in Europe with 19 kg per year and in the USA with 30 kg per year. Results from other countries (23 kg per capita per year in Canada) confirm the importance of the role played by tomato products in the eating habits of a wide variety of countries.

Throughout these areas, the increase in tomato consumption has been steady for several years, albeit at different rates. This has led to the appearance of new producing countries on the market. Some of them, like China, have dedicated heavy capital investment to this branch of the food industry. In only a few years, they have become able to threaten the dominant position of the two main producers, the USA and Italy.

The international tomato processing industry is organized around two main professional federations that together account for about 91 % of the world's production: the AMITOM and the WPTC.

In the Mediterranean region, the industry is organized within the AMITOM. The AMITOM is an association gathering professional organizations of tomato processors in the Mediterranean region. For the last twenty years, this international association has been collecting and storing technical and economic data and information on processing tomatoes, from research to final sale. To that effect, the AMITOM works in a variety of areas, and regular meetings bring together delegations from the member states, making up the executive committee. The AMITOM currently includes eleven member states – 5 European Union countries: France, Greece, Italy, Portugal and **Spain**, 6 non-EU countries: Algeria, Israel, Jordan, Morocco, Tunisia, Turkey, and three associate members: Malta, Syria and the United Arab Emirates.

The World Processing Tomato Council (WPTC) was created in 1998. It gathers professional growers and/or processors' organizations representing their respective production areas. Professional organizations from the following countries were the founding members of the Council: AMITOM countries, Argentina, Australia, Brazil, Canada, Chile, USA (California). They have since been joined up by Algeria, Jordan and more recently by Morocco, as well as Japan and South Africa. Brazil is no longer a member of the WPTC (Apaiah and Barringer, 2004).

2.2 Ethiopian Agro Industry

The existing agro processing factories in Ethiopia are very few. One of the major industries is Merti Agro-processing. It has the capacity to produce 5,000 tones per year. It utilizes raw materials produced by its mother company, Upper Awash Farming. It exports some of the processed food. The factory has the UREGAP certificate in green been products. ELFORA one of the oldest agro-processing factories in the country produce various types and sizes of tomato squash, tomato ripped off and green beans. The factory has also the capacity to produce vegetable sauce, tomato juice, as well as cereal foods. It out-sources agricultural product from its own farms as well as vicinities. The factory is constantly upgrading its capacity to meet the export demand and introducing several types of new exportable products. Above all, it is playing a significant role in saving foreign currency, replacing import trading of similar products.

Among the major factories is the recent establishment, called Sebeta Agro-processing. While its main business is the production and sale of dairy and dairy products, it is also producing processed fruits. In 2003, it sold 285,512 liters of apple, Mango and orange juice. The industry, which is currently selling various products to domestic market, is likely to export to the Sudan, Somalia, Djibouti and other neighboring countries. Green Stare Food Company, which is included in agro-industry, is now engaged in exporting canned carrot and tomato to the Middle East.

Although most of Ethiopia's fruits and vegetables are grown for local consumption, there are three categories of exports as well. Some amount of fruits and vegetables grown on small private farms in Eastern Ethiopia are exported directly to Djibouti through Dire Dawa by train. The export fruits include Oranges, Mangoes, Lemons, Guava, Papaya, Grape fruit, Pineapple and Banana. Local vegetables exported to Djibouti include Beans, Asparagus, Sweet pepper, Okra, Garlic, Avocado, and Green chilly. Ethiopia also sells some processed fruits and vegetables to Yemen, Saudi Arabia and other Middle East countries. The two most important products are oranges (as canned and bottled orange juice) and tomatoes (as ketchup, tomato paste, and tomato concentrate). The inadequate and irregular supply of imported packaging materials has been a major constraint in this area.

In recent years however, many commercial farmers are emerging to exploit untapped resource of the sub-sector. Among the investment licensees issued for commercial farming in the last five or six years, some are related to fruits and vegetable production. Investment in the agro-processing of fruits and vegetables is very encouraging in Ethiopia. The availability of various kinds of crops, the transportation services given by the Ethiopian Air Lines and Shipping Lines, the new investment code which creates conducive environment for agro-investment and cheap labor force in the country are some of the major factors for the development of this sector. Therefore, private, growers and producers of processed fruits and vegetables are highly encouraged to engage in the business (MoI, 2006).

2.3 Production Process

2.3.1 Juice production process

2.3.1.1 Raw Materials Preparation

After harvesting, tomatoes are transported to the processing plant as soon as possible. Once at the plant, they should be processed immediately, or at least stored in the shade. Fruit quality deteriorates rapidly while waiting to be processed. To unload, either tomatoes are off-loaded onto an inclined belt, or the gondolas are filled with water from overhead nozzles. If water is used, gates along the sides or undersides of the gondolas are opened, allowing the tomatoes to flow out into water flumes.

Mere rinsing of tomatoes in water is not enough, because of mold filaments and other micro-organisms found in their cracks, wrinkles, folds and stem cavities are not easily dislodged. For thorough cleaning they should be washed in running water. For large scale, rotary washers are used.

2.3.1.2 Grading

The first step the tomatoes go through is grading, to determine the price paid to the farmer. This is done at the processing facility or at the centralized station before going to the processing facility. Individual companies may set their own grading standards, use the voluntary USDA grading standards, or use local determined standards, such as those of the processing tomato Board in California. The farmer is paid based on the percentage of tomatoes in each category. Typically, companies hire USDA graders or hold an annual grading school to train their graders.

The USDA divides tomatoes for processing into categories A, B, C, and culls (USDA 1983). Grading is done on the basis of color and percentage of defects. Color can be determined visually by estimation of what percentage of the surface is red, or with an electronic colorimeter on a composite raw juice sample. Defects include worms, worm damage, freeze damage, stems, mechanical damage, anthracnose, mold, and decay. The allowable percentage of extraneous matter may also be specified. Extraneous matter includes stems, vines, dirt, stones, and trash.

Tomatoes for canning whole, sliced, or diced are graded on the basis of color, firmness, defects, and size. Solids content is unimportant, unlike in tomatoes for juice or paste. Graders must be trained to evaluate and score color and firmness. Color should be a uniform red across the entire surface of the tomato. Color is graded using USDA issued plastic color comparators, the Munsell colorimeter or the Agtron colorimeter, or the tomato is ground into juice and used in a colorimeter with a correlation equation to convert it to the Munsell scale. Firmness, or character, is important to be sure the tomato will survive canning. Soft, watery cultivars or cultivars processing large seed cavities give an unattractive appearance and therefore receive a lower grade. Size is not a grading characteristic per se, but all tomatoes must be above a minimum agreed upon size.

The Processing Tomato Advisory Board inspects all tomatoes for processing in California. Their standards are similar to those of USDA, but more geared for the paste industry. They inspect fruit for color, soluble solids, and damage (CDFA, 2001). A load of tomatoes may be rejected for any of the following reasons: >2% of fruit is affected by worm or inset damage, >8% is affected by mold, >4% is green, or >3% contains materials other than tomatoes, such as extraneous materials, dirt, and detached stems.

2.3.1.3 Washing

Washing is a critical control step in the processing tomato products with a low microbial count. A thorough washing removes dirt, mold, insects, Drosophila eggs, and other contaminants. The efficiency of the washing process will determine the microbial count in the final product (Heil, et al., 1984; Zacconi, et al., 1999). Several methods can be used to increase the efficiency of the washing step. Agitation increases the efficiency of soil removal. The warmer the water spray or dip, up to 90°C, the lower microbial count (Adsule, et al., 1982; Trandin, et al., 1982), although warm water is not typically used because of economical concerns. Lye or surfactants may be added to the water to improve the efficiency of dirt removal; however, surfactants have been shown to promote infiltration of some bacteria into the tomato fruit by reducing the surface tension at the pores (Bartz, 1999). The washing step also serves to cool the fruit. Since tomatoes are typically harvested on hot summer days, washing remove the field heat, slowing respiration and therefore quality loss.

Tomatoes are typically transported in a water flume to minimize damage to the fruit. Therefore, tomato washing can be a separate step in a water tank or it can be built into the flume system. A water tank also serves to separate stones from the fruit, since the stones settle to the bottom. The final rinse step uses pressurized spray nozzle at the end of the soaking process. Flume water may be either recirculated or used in a counter flow system, so that the final rinse is with fresh water, while the initial wash is done with used water. In either system, the first flume frequently inoculated rather than washes the tomatoes because all the dirt in the truck is washed into the flume water (Heil, et al., 1984). When the water is reused, high microbial counts on the fruit may result if careful controls are not kept.

Chlorine is frequently added to the water. Chlorine will not significantly reduce the spores on the tomato itself because the residence time is too short. However, chlorine is effective at keeping down the number of spores present in the flume water (Heil, et al., 1984). When there is a large number of organic material in the water, such as occurs in dirty water, chlorine is used up rapidly, so it must be continuously monitored. During fluming to the next step, upright stakes may be place at interval within the flume. Vines and leaves that have made it this far in the process are caught on the stakes. Periodically, workers remove the trapped vines.

2.3.1.4 Sorting

A series of sorters are used in a plant. The first sorter, especially in small plant, is an inclined belt. The tomatoes are off-loaded onto the belt. The round fruit rolls down the belt and into the water flume. The leaves, sticks, stones, and rotten tomatoes are carried up by the belt and dropped into a disposal bin.

Photoelectric color sorters are used in almost every plant to remove the green and to pink tomatoes. Those sorters work by allowing the tomatoes to fall between the conveyer belts in front of the sensor. Unacceptable tomatoes are ejected by a pneumatic finger. A small percentage of green tomatoes in tomato juice do not adversely affect the quality. Green tomatoes bring down the pH, but do not affect the color of the final product. In addition, less mature tomatoes result in a higher viscosity paste (Luh, et al., 1960; Whittenberger and Nutting, 1957). Pink or breaker tomatoes are the problem, however, because they decrease the redness of juice. Both pink and green tomatoes need to be removed from the whole peel or diced line. Size sorters remove excessively small tomatoes, which would be undesirable in the can. The small tomatoes are diverted to the juice or crushed tomato line.

The final sorting step is to go past human sorters, who are more sensitive than mechanical sorters. Employees remove extraneous materials and rotten tomatoes from sorting tables. Sorting conveyors should require employees to reach no more than 20 inches, move no more than 25feet/minute, and consist of roller conveyors that turn the tomatoes as they travel, exposing all sides to the inspectors (Denny, 1997).

2.3.1.5 Coring and Trimming

The trimming can be used for the preparation of tomato juice, puree or ketchup of fairly good quality. When tomato juice is made by the cold press method, the seeds are still good for raising tomato plants. The seeds can be separated from the skin after drying the material and utilized for the extraction of edible oil. Tomato seeds are also reported to be a good source of proteins and amino acids.

In the past, tomatoes were cored by machine or, more frequently, by hand, to remove the stem scar. Modern tomato varieties have been bred with very small cores so that this step is no longer needed. Trimming to remove rot or green portions is not practiced in United States due to the high cost of labor.

After trimming, tomatoes are cut into small pieces before boiling. Alternatively they may be crushed by means of wooden roller crusher.

Tomatoes can be pulped by the hot or cold process described below:-

Hot Pulping- the crushed tomatoes are boiled in their own juice in steam jacketed kettles or aluminum pans for 3-5min to facilitate pulping. The process has the following advantages:-

- The tendency of the juice to separate into liquid and pulp can be overcome if the natural pectin present in the seed and skin can be incorporated. During boiling pectin is released, and this thickens the pulp.
- Heating sterilizes the juice partly thereby checking to some extent the growth of living organisms which cause fermentation, etc.
- The yield of the juice is higher than in cold pulping.

Cold Pulping- the tomatoes are crushed and passed as such through a pulper. This process has the following defects:-

- As compared to hot processing, the extraction of the juice is somewhat difficult, the yield also smaller.
- Air gets incorporated in the juice in the process of extraction, and oxidizes vitamin C (Kalia, et al., 2004).

2.3.1.6 Break

The tomatoes are put through a break system to be chopped. Some break systems operate under vacuum to minimize oxidation. In an industrial plant operating under vacuum, no degradation of ascorbic acid occurs during break process (Trifiro, et al., 1998). When vacuum is not used, the higher the break temperature, the greater the loss of ascorbic acid (Fonseca and Luh, 1976).

Tomatoes can be processed into juice by either a hot break or cold break method. Most juice is made by hot break. In the hot break method tomatoes are chopped and heated rapidly to at least 80^{o}C to inactivate the pectolytic enzymes polygalacturonase (PG) and pectin metylesterase (PME). Inactivation of those enzymes helps to maintain the

maximum viscosity. Most juice is made by the hot break method, since most juice is concentrated to paste, and high viscosity is important in tomato paste used to make other products. Most hot break processes occur at 93-99^{o}C.
Inactivation of pectolytic enzymes by heat results in significantly higher values of serum and efflux viscosity (Hayes, et al., 1998). Tomato processors generally crush tomatoes, prior to hot breaking to realize higher juice yields. Crushing of tomatoes prior to hot breaking often leads to more serious fragmentation and disruption of cell walls, quick liberation of pectolytic enzymes as well as pectin from cell walls. This makes pectin more vulnerable to attack by pectolytic enzymes, resulting in rapid degradation of pectin. Under commercial practice too, 100% retention of pectic substances is never possible under best practical commercial conditions of rapid heating of crushed tomatoes (Miers, et al., 1967; Kaur, et al., 2007).

In the cold break process, tomatoes are chopped and then mildly heated to accelerated enzymatic activity and increase yield. Pectolytic enzymes activity is at a maximum at 60-66^{o}C. Cold break juice has less distraction of color and flavor but also has a lower viscosity because of the activity of the enzymes. This juice can be made into paste, but its lower activity is a special advantage in tomato juice and juice-based drinks. In practice, both hot and cold break paste with excellent color and high viscosity can be purchased.

The time gap that elapses between crushing and hot breaking is also a crucial factor determining the degree of pectin destruction. The lower the time gap, the higher the retention of pectin and the higher is the viscosity. Understanding the fact that minimizing cellular destruction of tomatoes prior to hot breaking can save losses to pectin (Kaur, et al., 2007).

2.3.1.7 Extraction

After the break system, the comminuted tomatoes are put through an extractor, or finisher to remove the seeds and skins. Juice is extracted with either a screw-type or paddle-type extractor. Screw-type extractors press the tomatoes between the screw and screen. The screw is continually expanding along its length, forcing the tomato pulp through the screen. Screw-type extractors incorporate very little air into the juice, unlike paddle-type extractors, which beat the tomato against the screw, incorporating the air. Air incorporation during extraction should be minimized because it oxidizes both lycopene and ascorbic acid. The screen size determines the finish, or particle size, which will affect viscosity and texture.

2.3.1.8 De-aeration

De-aeration to remove dissolved air incorporated during breaking or extraction is frequently the next step. The juice is de-aerated by pulling the vacuum as soon as possible, because oxidation occurs rapidly at high temperature. De-aeration also prevents foaming during concentration. If the product is not de-aerated, substantial loss of vitamin C will occur.

2.3.1.9 Homogenization

The juice is homogenized to increase product viscosity and minimize serum separation. The homogenizer is similar to that used for milk and other dairy products. The juice is forced through a narrow orifice at high pressure, shredding the suspended solids. The creation of a large particle surface area increase product viscosity.

The flowchart for processing tomatoes into juice, paste, whole, sliced, or diced tomatoes are shown in Fig2.

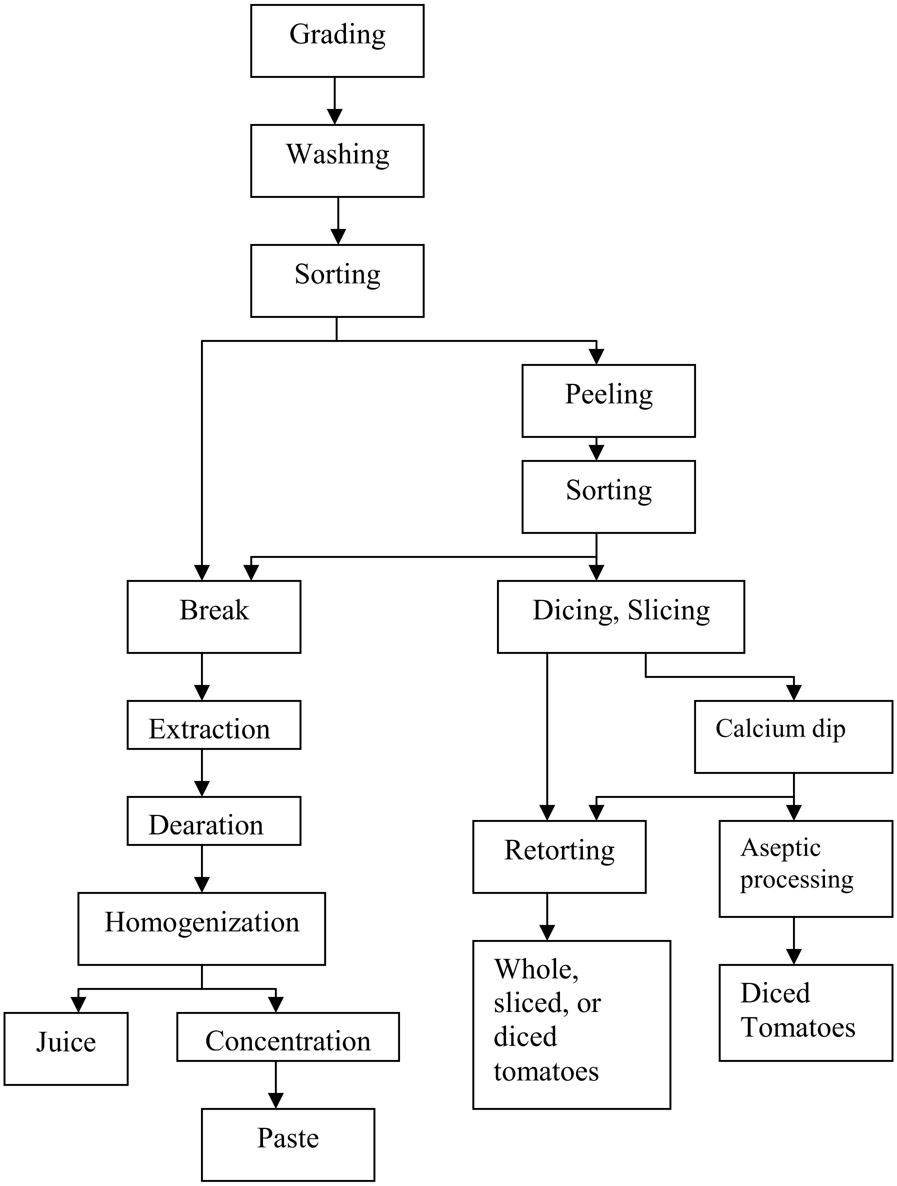

Figure 2: Tomatoes processing flowchart

2.3.1.10 Canning and Retorting

Because tomatoes are highly-acid food, they do not have to be sterilized. Tomato products can be hot filled and held, or can be processed in a retort as needed to minimize spoilage. Most tomato products undergo a retort process to ensure an adequate shelf life. Of the retorts, rotary retort is that most commonly used for tomato products. This retort provides agitation of the product and can handle large quantities in a process. Because tomatoes are high-acid food, the rotary may operate at boiling water temperature, 100°C. Rotary retorts set at 104°C for 30-40 minutes are also common. Exact processing conditions depend on the product being packed, the size of the can, and the type and brand of retort used. The key is for the internal temperature of the tomatoes to reach at least 88°C.

2.3.1.11 Cooling

After canning, the product must be cooled to 30-40°C to minimize quality loss. The product may be cooled by water or air. When cooling water is used, it should be chlorinated to 2-5ppm free chlorine to prevent contamination of the product while seals are soft (Downing, 1996). Even though the cans are sealed, spoilage rates increase when the water is chlorinated. The vacuum that forms as the contents cool must draw some microorganisms into the can. A rotary water cooler may be used in a continues process after a rotary retort. Water cooling is more efficient than air cooling; therefore, longer retort process times are recommended when water cooling is used than air cooling (Downing, 1996).

2.3.2 Sauce production process

Product description

According to United States Standards for Grades of Tomato Sauce published in October 18, 1994, by USDA, Tomato sauce is the concentrated product prepared from the liquid extracted from mature, sound, whole tomatoes; the sound residue from preparing such tomatoes for canning; the residue from partial extraction of juice; reconstituted or remanufactured tomato paste; or any combination of these ingredients to which is added salt and spices. One or more nutritive sweetening ingredients, vinegar or vinegars, onion, garlic, or other vegetable flavoring ingredients may be added. The food is preserved by heat sterilization (canning), refrigeration, or freezing. When sealed in a container to be held at ambient temperatures, it is so processed by heat, before or after sealing, as to prevent spoilage. The refractive index of the tomato sauce at 20 degrees Celsius is not less than 1.3455.

2.3.2.1 Preparation of raw materials

The selection process was carried out based on the criteria of good quality, fully ripe fruits, preferably plum varieties without infection mould or rot. The prepared fruit was blanched in hot water for 3-5 minutes until the skin loosened and then removes the skin. Finally the extract was pulped using a hand grinder.

2.3.2.2 Concentration into Paste

If the final product is not juice, the juice is next concentrated to paste. Concentration occurs in forced circulation, multiple effect, and vacuum evaporators. Typically, three or four-effect evaporators are used, and most modern equipment now uses four effects. The temperature is raised as the juice goes to each successive effect. A typical range is 48-82^{o}C. Vapor is collected from later effects and used to heat the product in the previous effects, conserving energy. The reduced pressure lowers the temperature, minimizing color and flavor loss. The paste is concentrated to a final solids content of at least 24% NTSS (natural tomato soluble solids) to meet the USDA definition of paste. Commercial paste is available in a range solids contents, finishes, and Bostwick consistencies. The larger the screen size, the coarse the particles and the larger the finish.

Concentration Technology

The traditional process for concentration of liquid foods are based on the principle of "boiling off" some of the constituent water under reduced pressure (the term evaporation is often synonymous to concentration in this case). The evaporation is carried out under partial vacuum to minimize heat damage to the many heat-sensitive food components and to reduce the energy needs to the process. The simplest production units, the single-effect evaporator, are relatively inexpensive to install, but the operating costs are high and productivity is low. The latent heat requirements for the evaporation are usually supplied by condensing steam (Ullmann, 1987).

For higher production economy, multiple-effect evaporators use the water vapor produced in one evaporation stage as the energy source in the next effect after appropriate evaporation to a higher energetic level by "thermo-compression" (enrichment with fresh steam) or, recently, by "mechanical compression" with a steam compression. The installation cost of multiple-effect evaporators increases with the number of stages, but the effectiveness and operation economy improve substantially. Often the vapors generated in the food concentration process carry various volatile compounds characteristic of the given food flavor; in some cases, the flavor volatiles are stripped from the vapor and returned to the finished product (Ullmann, 1987).

2.3.2.3 Manufacturing into Sauce

The majority of processed tomatoes are made into juice, which is condensed into paste. The paste is remanufactured into a wide variety of sauce products.

Manufacture of convenience meals by tomato paste and remanufacture it by mixing it with water, particulates, and spices to create the desired sauce. Some sauce is made directly from fresh tomatoes during tomatoes season, but this is less common. Sauce production from paste is more economical because it can be done during the off season using the equipment in tomato processing plants that would otherwise be unused. It is also cheaper to ship paste than sauce. (Smith and Hui, 2004)

The extracted juice was heated below boiling point in a pan with continuous stirring until the mixture has reduced to half the original volume. After that remove the spice bag and add sugar, salt and vinegar and then continue heating for 5-10 minutes. Finally the total soluble solids (10-12per cent solids) were check with a refractometer.

The sauce was hot-fill using pre-sterilized bottles or jars, at not less than 80°C and then closes the lids tightly. Finally the product cooled to room temperature. In this way the hot mixture will form a partial vacuum in the jar and help prevent re-contamination.

2.4 Quality change during processing

The type of process is important in determining how much quality loss occurs. For the same F(thermal death time) value, significantly more vitamin C is lost during thermal processing of whole peeled tomatoes in a rotary pressure cooker than in a high-temperature, short-time (HTST) process (Leonard, et al., 1986). Similarly, the texture is significantly firmer after the HTST processing (Leonard, et al. 1986). During canning, the nutrient content remains fairly stable. The already small lipid content decreases because of the removal of the skin. The calcium and sodium content increase because the processors add them to improve the firmness and flavor of the tomatoes. The vitamin A content is fairly constant, while the vitamin C content is reduced by 45%. Bioavailable lycopene content increases, because processing makes the carotenoid more available to the body (Gartner, et al., 1997; Stahl and Sies, 1992).

Color loss is accelerated by high temperature and exposure to oxygen during processing. The red color of tomatoes is mainly determined by the carotenoid lycopene, and the main cause of lycopene degradation is oxidation. Oxidation is complex and depends on many factors, including conditions, moisture, temperature, and the presence of pro- or antioxidants. Several processing steps are known to promote oxidation of lycopene. During hot break, the hotter the break temperature, the grater the loss of color, even when operating under a vacuum (Trifiro, et al., 1998). However in some varieties the break temperature affects color while in others it does not (Fonseca and Luh, 1977). The use of fine screen in juice extraction enhances oxidation because of the large surface area exposed to air and metal (Kattan, et al., 1956). Similarly, concentrating tomato juice to paste in the presence of oxygen degrades lycopene. It has been reported that heat concentration of tomato pulp can result in up to 57% loss of lycopene (Noble, 1975). However, other authors have reported that lycopene is very heat resistant and that no changes occur during heat treatment (Khachik, et al., 1992). With current operators it is likely very little destruction of lycopene occurs. Uptake of lycopene and its geometrical isomer is greater from heat-processed than from unprocessed tomato juice in human (Sies, et al., 1992).

Processing also affects color due to the formation of brown pigments. This is not necessarily detrimental, because a small amount of thermal damage resulting in a darker serum color increases the overall red appearance of tomato paste (Leonard, et al., 1986). Browning is caused by a number of reactions. Excessive heat treatments can cause browning due to caramelization of the sugars. However, during production of tomato paste the maillard reaction still of minor importance (Eichner, et al., 1996). Degradation of ascorbic acid has been suggested to be the major cause of browning (Mudahar, et al., 1986). Processing and storage at lower temperatures, decreasing the pH to 2.5, and the addition of sulfites can decrease browning (Danziger, et al., 1970).

2.5 Total Solids, Degrees Brix, NTSS, and Sugar Content

Tomato solids are important because they affect the yield and consistency of the finished product. Due to the time required to make total solids measurements, soluble solids are more frequently measured. Soluble solids are measured with a refractometer that measures the refractive index of the solution. The refractive index is depending on the concentration and temperature of solute in the solution; therefore, many referactometers are temperature controlled. The majority of soluble solids are sugar, so referactometers are calibrated directly in percentage sugar, or degree Brix. Natural tomato soluble solids (NTSS) are the same as degree Brix, minus any added salt. The sugar content reaches a peak in tomatoes when the fruit fully ripe (Hobson and Gierson, 1993). Light probably has a more profound effect on sugar concentration in tomatoes than any other environmental factor (Davies and Hobson, 1981). The seasonal trends in the sugar content of greenhouse grown tomatoes have been found to roughly follow the pattern of solar direction (Winsor and Adams, 1976). Even the minor shading that is provided by the foliage reduces the total sugar content by up to 13% (McCollum, 1946).

Many of the volatile responsible for the fresh tomato flavor are lost during processing, especially cis-3-hexenal and hexenal (Buttery, et al., 1990). Cis-3-hexenal, an important component of fresh tomato flavor, is rapidly transformed into the more stable trans-2-hexenal; therefore, it is not present in heat-processed products (Kazeniac and Hall, 1970). The amount of 2-isobutylthiazole, responsible for a tomato leaf green aroma, diminishes during manufacture of tomato puree and paste (Chung, et al., 1983).

Other volatiles are created. Breakdown of sugars and carotenoids produce compounds responsible for the cooked odor. Dimethyl sulfide is a major contributor to the aroma of heated tomato products (Buttery, et al., 1990; Guadagni, et al., 1986; Thakur, et al., 1996). Its contribution to the characteristic flavor of canned tomato juice is more than 50% (Guadagni, et al., 1968). Linalool (Buttery, et al., 1971), dimethyl, tri-sulfide, 1-octen-3-one (Buttery et al., 1990), acetaldehyde, and geranyiacetone (Kazeniac and Hall, 1970) may also contribute to the cooked aroma. Pyrrolidone carboxylic acid, which is formed during heat treatment, has been blamed for an off flavor that occasionally appears (Mahdi, et al., 1961). This compound, formed by crystallization of glutamine, arises as early as the break process (Eichner, et al., 1996).

Processing conditions further affect the pH and the acidity of processed tomato products. During processing, the pH decrease and total acid content may increase (Hamdy and Gould, 1962; Miladi, et al., 1969), although the citric acid content may increase (Miladi, et al., 1969) or decrease (Hamdy and Gould, 1962). Hot break juice has a lower titratable acidity (Gancedo and Luh, 1986) and higher pH than cold break juice (Fonseca and Luh, 1976; Luh and Daoud, 1971). The difference is caused by breakdown of pectin by pectolytic enzymes that are still present in the cold break juice (Stadtman, et al., 1977).

Factors that affect the quality and quantity of the solids determine the degree of serum separation that occurs. The higher temperature during the break process, the less serum separation occurs (Trifiro, et al., 1998). Hot break juice has less serum separation than the cold beak juice. This may be due to greater retention of intact pectin in the hot break juice (Luh and Daoud, 1971), although Robinson, et al. (1956) found that the total amount of pectin did not affect the degree of settling in tomato juice. The cellulose fiber may be more important in preventing serum separation than the pectin (Robinson, et al., 1956; Shomer, et al., 1984). Addition of pectinases degrades the pectin, increasing the dispersal of cellulose from the cell walls. The extraction of this cellulose minimizes serum separation (Shomer, et al., 1984).

Homogenization is commonly used to shred the cells, increasing the number of particles in the solution and creating cells with ragged edges that reduce serum separation the result is particles that will not efficiently pack and settle. Of these two effects, changing the shape of the particles is more important than changing in size (Shomer, et al., 1984). Evaporator temperature during concentration has little effect on serum separation (Trifiro, et al., 1998).

Canning significantly softens the fruit, so calcium is frequently added to increase the firmness. Varieties have been bred to be firm to withstand machine harvesting, which has also increase the firmness of canned tomatoes. Condition during processing such as temperature, screen size, and blade speed will affect the final viscosity of the juice. Hot break juice typically has a higher viscosity than cold break juice due to inactivation of the enzymes that degrade pectin. At very high temperatures, such as 100^{o}C, the structure collapses and the viscosity decreases again (Trifiro, et al., 1998), although this effect is not always observed (Luh and Daoud, 1971). The screen size and blade speed during extraction are also important factors. The effect of screen size is not a simple relationship. A higher viscosity is produced using a screen size of 1.0mm than either 0.5 or 1.5mm (Robinson et al., 1956). Other studies have been found on effect of finisher size on the final viscosity (Trifiro, et al., 1998). The faster the blade is, the higher the viscosity. The higher the evaporation temperature is, the greater the loss of viscosity (Trifiro, et al., 1998).

The flavor of tomatoes is determined by the variety used, the stage of ripeness, and the condition of processing. Typically, varieties have not bred for optimal flavor, although some work has focused on breeding tomatoes with improved flavor. Processing tomatoes are picked fully ripen; therefore, the concern that tomatoes that are picked mature but unripe have less flavor is not important. Processing generally causes a loss of flavor.

Processes are not optimized for the best flavor retention, but practices that maximize color usually also maximize flavor retention.

Heating causes degradation of some flavor volatiles and inactivates lipoxygenase and associated enzymes that are responsible for producing some of the characteristic fresh tomato flavor (Goodman, et al., 2002). However, some authors (Fonseca and Luh, 1977) have found that hot break processes a better flavor. While others (Goodman, et al., 2002) have found that it produces a less fresh flavor. Within one study, the flavor of one variety may be rated better as cold break juice than as hot break juice, and another variety the reverse (Fonseca and Luh, 1976; 1977). This may in part be because some panelists prefer the flavor of heat-treated tomato juice to fresh juice (Guadagni, et al., 1968).

3. MATERIALS AND METHODS

3.1 Materials

3.1.1 Improved tomato varieties

The basic raw materials are tomatoes (Bergad, Miya and Chali), and also spices are used in small amount.

3.1.2 Reagents and Solutions

- Sodium thiosulphate
- Hydrochloric acid
- Ether
- Thiosulphate solution
- Hydrochloric acid
- Sodium hydroxide
- Potassium hydroxide, etc.
- 1.25 % sulfuric acid (13 g conc. H_2SO_4 weighed and made up to 1litre)
- 1% H_2SO_4
- 1%NaOH
- 28%KOH
- Water free acetone
- Potassium iodide
- Sodium catalyst
- Boric Acid
- Standard ammonium chloride

3.1.3 Instrumentation

- Abbe Refractometer
- Flasks, measuring apparatuses, Test tubes
- Beaker, watch glass, stirrer
- Sintered glass crucible
- Vacuum pump

- Oven
- Muffle Furnace
- Pyknometer
- Digestion apparatus (aluminum block, tubes, etc)

- Soxhlet extraction apparatus
- Extraction flask, extraction thimble
- Electric hot plate
- Texture Analyzer
- Fruit/vegetable grinder
- Weighing and measuring equipment
- Stainless steel pan
- Heat source
- Thermometer
- Refractometer etc.

3.2 Methods

3.2.1 Sample preparation

The Control tomato variety (Bergad) was obtained from Merti Agro-Processing Share Company farm and the improved varieties (Miya and Chali) were obtained from Melkasa Agricultural Research Center (MARC). Three samples from each category were used for the analysis. Fruit samples were coded as BF for Bergad; MF for Miya and CF for Chali and kept refrigerated at 3^{o}C till analysis has started.

Sampling was carried out in such a way that the increments represent all the characteristics of the lot. After isolation of the damaged portions of the lot, separate samples were taken from the sound and from damaged portion (ISI 874-1980).

3.2.2 Juice and Sauce development

The tomatoes are washed with cold water to eliminate dirt and other adhering materials. The tomatoes are trimmed, cored, sorted, and washed again. They are chopped and then heated to 82°C for 5min. Then it is crushed and extracted to remove the skin, seed and other debries. The extracted juice is mix with 0.4% salt, screened, and homogenized to produce a product with more stable suspension and de-aerated. The juice is pasteurized at a temperature of 121°C for 0.7min (42sec). The juice is cooled to 93°C and filled in to the plastic bottles and sealed. The sealed bottles are pasteurized again at 96°C.

In order to produce tomato sauce, the prepared tomatoes are washed, trimmed, cored, sorted and chopped in the same process as tomato juice. The chopped tomatoes are heated to 82°C for 5min to facilitate extraction. Then it is crushed, extracted and screened. The juice is the boiled with spices until 45% by mass decreased. Finally sugar, salt and vinegar add and boil for 10min. The sauce is cooled to 93°C and filled in the bottle. The sealed bottles are pasteurized again at 96°C.

3.2.3 Analytical methods

3.2.3.1 Physicochemical analysis

Texture

Texture was analyzed according to TA-plus NEXYGEN (2007) procedure. The Fruit Texture Analyzer (FTA) measures fruit firmness at the push of a button and captures the results to a PC. Tests are conducted by taking 10samples from each variety at standard depths and speeds of penetration, ensuring accurate and repeatable results.

Color

Color was determined by LOVIBOND 3000 color comparator (1986) procedure. 50ml of sample is taken and filtered through 10micro filter paper. 30ml of the filtrate was transferred to sample cuvatte then determine the color.

Acidity

Titration methods by 0.1N sodium hydroxide and phenolphthalein indicator were used for the determination of acidity expressed as milligrams of citric acid per gram of sample, as indicated in Egan, et al. (1981).

$$\text{Acidity} = \frac{Titre * NormalityofAlkali * 64Volumemadeup * 100}{mloffiltratetakenfortitration * Wtofsampletaken * 100}$$

Total Soluble Solids

The refractive index of the sample was measured at 2060.5°C using Abbe type refractometer for TSS. The refractive index was correlated with the amount of soluble solids (expressed as sucrose concentration) using table 9.

pH

Measurement of pH: The pH of samples was measured using omega HP digital pH meter. Standardization of the meter was done using buffer solution of pH 4 and 9.

Viscosity

Viscosity determined using SV-10 VIBRO Viscometer (2001) procedure. Pour the sample into the cup until its surface reaches between the level gauges. The level gauge indicates between 35 and 45ml. Attach the cup on the table along the guides. Gently lower the sensor plates above the sample surface and measure the viscosity.

3.2.3.2 Juice and Sauce composition

The developed tomato juice and sauce composition were analyzed.

Moisture

The amount of water present in a sample is considered to be equal to the loss of weight after drying the sample to constant weight at a temperature of 100°C according to Method AOAC (1984),

Formula

$$\% \text{ Moisture} = \frac{w2 \times 100}{w1}$$

$$\% \text{ Total solids} = \frac{w3 \times 100}{w1}$$

Where: w1, w2, and w3 in wet base.

w1 = weight of wet sample

w2 = loss of weight

w3 = weight of dry sample

Note: w1, w2, and w3 are in wet base.

Crude Fiber

According to Method AOAC (1984), a fat-free or low fat content sample is treated with boiling sulfuric acid and subsequently with boiling potassium hydroxide or sodium hydroxide, the residue after subtraction of the ash is regarded as fiber.

Formula:

$$\text{Crude fiber g/100g} = \frac{(w1-w2)\,(100-M)}{w3}$$

Where: w1 = Crucible weight before drying

w2 = Crucible weight after drying

w3 = Sample dry weigh

M = % moisture content of the sample

Crude Protein

According to Method AOAC (1984), all nitrogen is converted to ammonia by digestion with a mixture of concentrated sulfuric acid and concentrated orthophosphoric acid containing potassium sulfate as a boiling point raising agent and selenium as a catalyst. The ammonia released after alkalinization with sodium hydroxide is steam distilled into boric acid and titrated with sulfuric acid.

Formula:

$$\text{mg nitrogen in the sample} = V * N * 14$$

$$\text{g nitrogen/100g sample} = \frac{\text{mg of nitrogen} * 100}{\text{mg sample}}$$

$$\text{Total nitrogen (\%)} = \frac{V * N * 1.4}{W}$$

$$\text{Crude Protein} = \text{total nitrogen (\%)} * 6.25$$

Where: V = volume of sulfuric acid consumed

N = normality of the acid

14 = Eq. wt of nitrogen

W = wt. of the sample

Fat

According to Method AOAC (1984), fat is extracted with ether (peroxide free) from dried samples in a soxhlet apparatus, and the other is evaporated from the extraction flask. The amount of fat is calculated from the difference in weight of the extraction flask before and after extraction.

Formula:

$W = W_2 - W_1$

$$\text{Fat g/100g fresh sample} = \frac{W * (100 - \%\ \text{moisture})}{W_D}$$

Where: W weight of fat

W_2 = weight of e.f after extraction

W_1 = weight of e.f before extraction

W_D = weight of dried sample

Ash

Organic matter is burned off at as low a temperature as possible and the inorganic materials remaining is cooled and weight. Heating is carried out in stages, first to derive the water, then to char the product thoroughly and finally to ash at 550°C in a muffle furnace. (AOAC, 1984)

Formula:

$$\%\ \text{Ash} = \frac{W2 * 100}{W1}$$

Where: W1 = weight of sample

W2 = weight if ash

Carbohydrates

Carbohydrate is measured using percentage difference from hundred.

Formula:

$C = 100 - P - F - Fi - A - W$

Where: P – percentage of protein

F – Percentage of fat
Fi – Percentage of fiber
A – Percentage of ash
W – Percentage of water.

3.2.3.3 Sensory Analysis

Using Difference-from-control test method, sensory was evaluated for each tomato juice and sauce. Present to each panel a control sample plus one or more test samples. Ask panel to rate the size of the difference between each sample and the control and provided a scale for this purpose. Sensory evaluation was carried out by eight trained panelists comprised of students of the Food engineering stream and lab assistants. Sensory attributes evaluated was taste, using a score scale of 1 to 6 where 1 indicates no difference and as it goes up to 6 indicates extremely different.

3.2.3.4 Microbial Analysis

Using Pour Plate Method, a 25g of sample taken and serially diluted to 1:10, 1:100 and 1:1000. For yeast and mold and total plate count, one ml diluents taken from each and put on sterile Petridis, pour potato dextrea agar and mix with the sample, then incubated at 35°C for 48hr finally count the colony (APHA, 1976).

For coli form count, from each serious one ml of diluents being inoculated into a separate tube of an all-purpose broth medium. Incubated for 48hr at 35°C and after incubation, the pattern of positive and negative tubes is noted, and a standardized MPN Table 10 is consulted to determine the most probable number of organisms (causing the positive results) per unit volume of the original sample using Most Probable Number Method (MPN) (APHA, 2001).

3.3 Experimental design and data analysis

Laboratory based experimental study was carried out using Bergad, Miya and Chali tomato samples in triplicate, under completely randomized design (CRD).

The data obtained from the experiment were subjected to analysis using statistical software, SPSS (Statistical Package for Social Sciences) version 13.0. A Bergad variety was used as a reference (control). Accordingly, Analysis of Variance (ANOVA), mean comparison and significance were set at 5% level. The process parameters from Merti Agro-processing Share Company and their effects on the final product were evaluated with reference to the Bergad tomato variety.

4. RESULTS AND DISCUSSION

Physicochemical characteristics such as TSS, color, viscosity, flavor of all tomato varieties Bergad juice (BJ1, BJ2, BJ3), Miya juice (MJ1, MJ2, MJ3), Chali juice (CJ1, CJ2, CJ3), Bergad sauce (BS1, BS2, BS3), Miya sauce (MS1, MS2, MS3), and Chali sauce (CS1, CS2, CS3) and also process evaluation were carried out. The obtained results are tabulated and discussed hereunder:

4.1. Results of the physicochemical analysis

The results of physicochemical analysis conducted were shown in Tables 2, 3, 4, and 5.

Table 3: Some physicochemical characteristics of Tomato juices (Mean ± SD)

Parameters	Bergad	Miya	Chali
Fruit firmness (N/mm)	4.1060.01	5.0560.92	4.1060.02
TSS	5.21760.062	6.73360.125	6.14360.049
Viscosity (mPa.s)	9.1460.314	10.5061.156	4.91560.161
Color of fruit	9.7760.139	9.8660.173	9.8760.096
Juice Color	8.78460.173	8.65660.086	9.19260.077
Titratable acidity (g/100ml)	0.47560.011	0.47160.010	0.45060.016
Moisture content (%)	94.0760.045	92.35860.121	93.19360.012
Ash (%)	0.81060.007	0.66560.003	0.76260.005
Crude Fiber (%)	0.35660.002	0.39460.003	0.30660.035
[a] Carbohydrate (%)	3.54160.045	5.0260.127	4.59560.038
Fat (%)	0.18560.001	0.36460.009	0.15560.001
Protein (%)	1.03360.001	1.19860.003	0.99460.002

[a] Obtained by subtraction of total from 100.

The control (Bergad) tomato variety was found to have mean fruit firmness value of 4.106, TSS values 5.217 and 9.146mPa.s viscosity. Viscosity is undoubtedly an important quality attribute of tomato products arising from the retention of pectin and destruction of pectin methyl esterase and polygalactouronase during hot break treatment (Hayes, et al., 1998). Kaur, et al., (2007) indicated that viscosity decreased from hot to cold break. The cold break process can be used to produce a premium flavored tomato juice. The color of the fruit was 9.776 while that of the juice was reduced to 8.784 during processing. Trifiro, et al., (1998) indicated that processes are not optimized for the best flavor retention, but practices that maximize color usually maximize flavor retention. Total titratable acidity mean value was 0.475g/100ml, while the ISO standard is between 0.34 and 1.0, as the product should have mild acidic flavor indicated in the tomato juice specification. Stadtman, et al., (1976) indicated that there is less titratable acidity in tomato juice that has been processed by a "hot-break" procedure to inactivate pectolytic enzymes than in juice of tomatoes from the same lot of fruit that has been extracted cold.

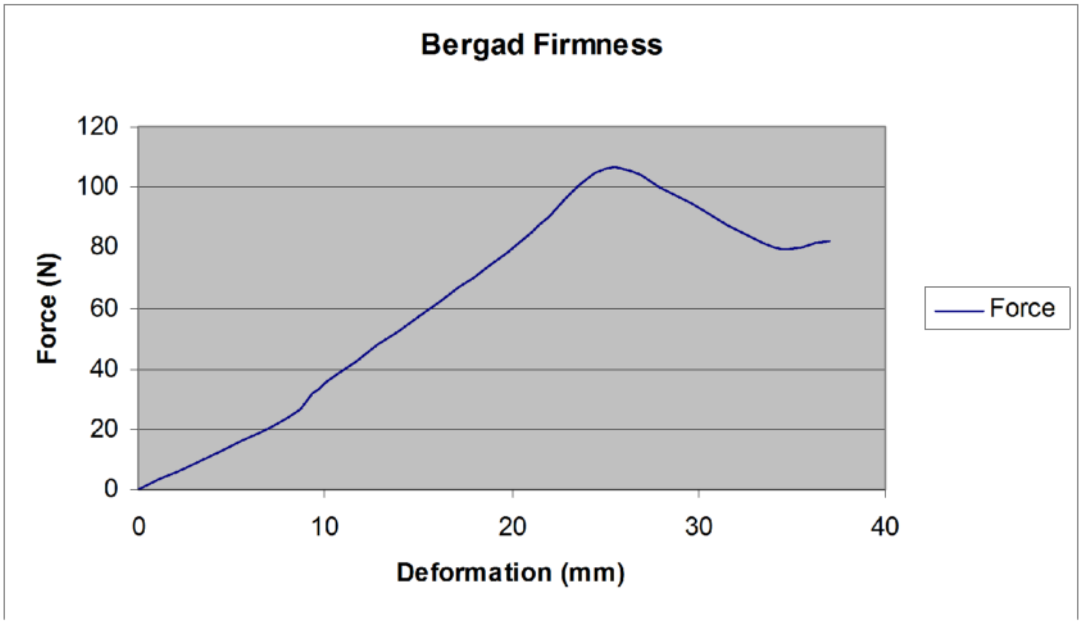

Figure 3: Texture for fruit firmness of Bergad variety

In Miya Tomato Juice, the obtained fruit firmness 5.05 was above the control. TSS of 6.733 and viscosity of 10.50mPa.s were also found to be above the control. Fruit color mean value was 9.86 while the juice color reduced to 8.656. Acidity of 0.471g/100ml below the control, however it is still within the ISO range.

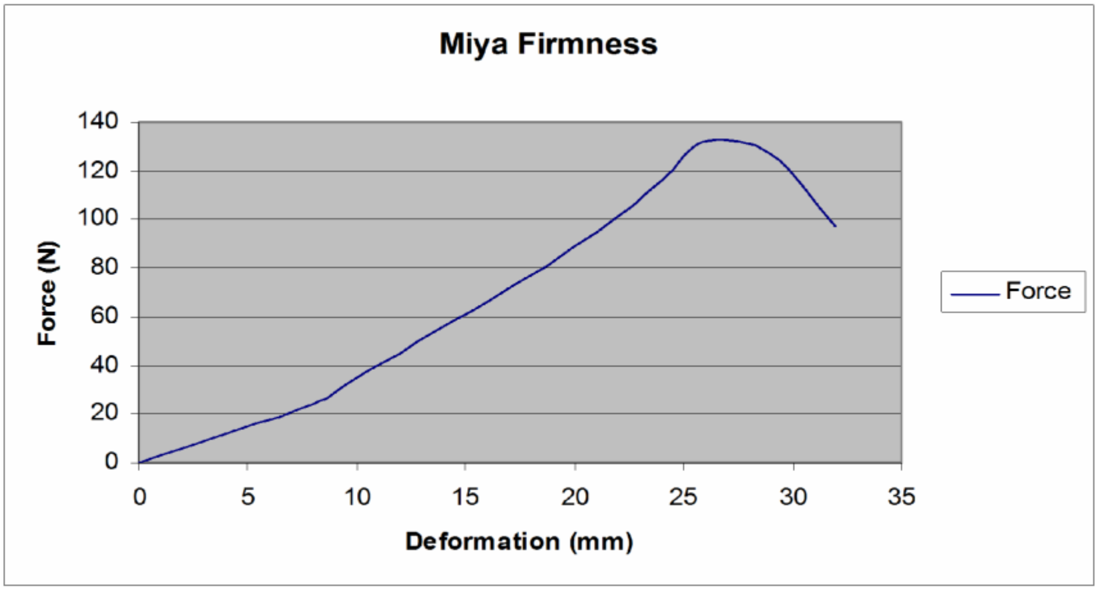

Figure 4: Texture for fruit firmness of Miya variety

In the case of Chali juice, fruit firmness mean value was almost equal to the control variety 4.10. TSS mean value 6.143 is above the control; however viscosity mean of 4.915 as far below the control variety. The color mean of 9.87 has decreases to 9.192 during processing to juice. The obtained acidity of 0.450g/100ml is within the ISO range even though it is below the control, and the 93.193 moisture was below the control as indicated in Table2.

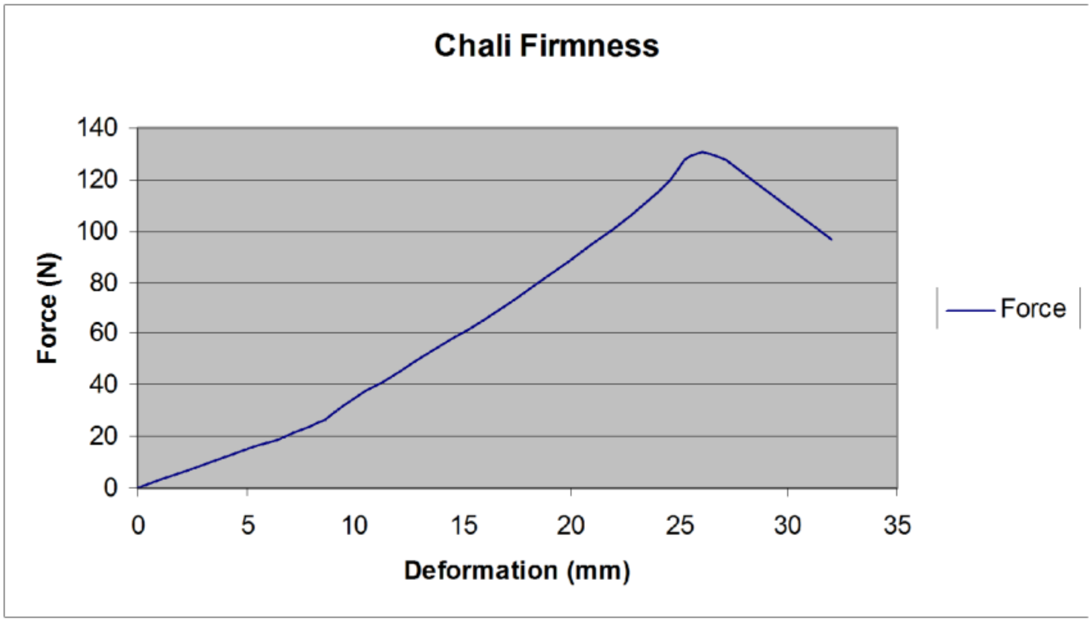

Figure 5: Texture for fruit firmness of Chali variety

The control (Bergad) variety sauce was found to have a TSS mean of 12.20 and 13.345mPa.s viscosity. Titarable acidity gave 0.612 for Bergad while the moisture content on dry basis was 76.231%.

Improved variety Miya sauce has a TSS value of 13.237. The viscosity mean value was higher than that of the control variety 14.337. Titratable acidity was higher for Miya as compared to control 0.648g/100ml, while the moisture content was found to be 69.543 as shown in Table 3.

The TSS value of Chali variety sauce was 13.509, which is that of above Bergad. However a viscosity of 9.175 was well below from control (13.346mPa.s). Taitrable acidity of Chali variety sauce of 0.588 was also below as compared to the control (0.612). Mean value of the moisture is found 70.68 on dry base (Table 3).

Table 4: Some physicochemical characteristics of tomato sauces (Mean ± SD)

Parameters	BS	MS	CS
TSS	12.2060.225	13.23760.284	13.50960.172
Viscosity (mPa.s)	13.34660.346	14.33760.343	9.17560.247
Titratable Acidity (g/100ml)	0.61260.177	0.64860.234	0.58860.184
Moisture content (%)	76.23160.013	69.54360.287	70.68060.355
Ash (%)	4.27960.007	5.76560.004	4.94360.066
Crude Fiber (%)	0.53560.010	0.55560.002	0.49460.005
Carbohydrate (%)	17.19260.02	21.73760.005	20.795 ± 0.104
Fat (%)	0.26560.001	0.25060.010	0.15460.014
Protein (%)	1.49760.002	2.05260.002	1.81360.109

The grade of tomato juice is largely determined by its color, viscosity, flavor, and soluble solids content (Barett, et al., 1998).

According to codex standard for tomato juice, the soluble tomato solids content of tomato juice, exclusive of added salt, shall be not less than 4.5% m/m determined by refractometer at 20^{o}C, uncorrected for acidity. Total soluble solids of Bergad, Miya and

Chali juices were 5.217, 6.701, 6.143 and titrable acidity 4.753, 4.717, 4.49 respectively (Table 4).

Viscosity of each variety was 9.146 for Bergad, 10.506 for Miya, and 4.916mPas.s for Chali. The juices were produced using 1.0mm screen at high speed as Robinson, et al., (1956) indicated that a higher viscosity is produced using a screen size of 1.0mm.

Flavor of tomato juice is a function of sugar:acid ratio with high-quality tomato juice having a ratio neither less than 10:1 nor more than 18:1 (Gould, 1978). The results obtained for all varieties are within the USDA standard range and also the flavor of the Miya varieties has been better than that of the control, while Chali is less than the control.

Table 5: Comparison of some physicochemical characteristics of Tomato juices (Mean ± SD)

Parameters	**Bergad**	**Miya**	**Chali**
TSS	5.21760.062a	6.73360.125a	6.14360.049a
Titratable Acidity (g/100ml)	0.47360.02a	0.46960.025a	0.45360.035a
Color of fruit	9.7760.139a	9.8660.173a	9.8760.096a
Juice Color	8.78460.173a	8.65660.086a	9.19260.077a
Viscosity (mPa.s)	9.14660.314a	10.50661.156b	4.91660.161c
Flavor (sugar/acid)	11.0360.05a	14.3660.065b	13.5660.041b

* Means bearing the same letters in a row are not significantly different from each other at P=0.05.

In terms of acidity and color there were no significant difference between Bergad and Miya juice. Miya juice was most preferred with a significant difference with respect to control based on TSS, Viscosity, and Flavor. Overall acceptability analysis showed that Miya juice had higher acceptance.

In the case of Chali juice, there was no significant difference detected with respect to color and Acidity. Regarding, TSS and Flavor, Chali juice was most preferred with higher significant difference with respect to Bergad. However there exists a higher significant difference in viscosity with lower value as compared to the control. Overall acceptability analysis showed that Chali juice had lower acceptance.

Mexican style tomato sauce retail specification and nutrition facts indicate that minimum NTSS value is 8.7% (Bhatia, 1994). According to UDA (1994), the refractive index of the tomato sauce at 20 degrees Celsius is not less than 1.3455 (NTSS = 8.9%). The improved varieties have NTSS above the control and also all of them are above both limits.

Viscosity of Miya sauce obtained in this study was 14.337mPa.s. However, Viscosity of Chali decreases as compared to control (Table 5). The stusdy conducted by Valencia, et al., (2002) indicated that the evolution of the viscoelastic characteristics of these products is mainly related to their mean volume diameter and tomato paste water insoluble solids content (WIS). This solid content is mainly controlled by tomato variety and tomato paste processing conditions. In this study all varieties are processed under the same condition and hence the difference in viscosity came from variety difference.

Titratable acidity of Bergad variety as determined in this study was 0.648g/100ml. While Titratable acidity of Chali was 0.588g/100ml (Table 5). The slight difference could be due to the difference in variety of samples used for the different analysis.

Table 6: Comparison of some physicochemical characteristics of the Tomato sauces

Parameters	**BS**	**MS**	**CS**
NTSS	9.48660.124a	12.24260.205a	11.16960.084a
Viscosity (mPa.s)	13.34560.346a	14.33760.343a	9.17560.247b
Titratable Acidity (g/100ml)	0.61160.177a	0.64860.234a	0.58860.184a
Flavor (sugar/acid)	15.50960.346a	18.87460.341b	18.97760.076b

* Means bearing the same letters in a row are not significantly different from each other at P=0.05.
* Flavor was obtained from sugar: acid ratio.

The comparison of Miya sauce with respect to the control indicated that there exists a significant difference in physical properties of natural tomato soluble solids, viscosity and flavor. However, there was no significant difference in acidity. Overall acceptability analysis showed that Miya sauce has the highest acceptance.

The result of the NTSS and flavor analysis indicated that there exists a significant difference between the control and Chali sauce. Besides, there was no significant difference in Acidity. However there exists a significant difference in viscosity as was rated lower than the control. Overall acceptability assessment showed that Chali sauce has the highest acceptance.

4.2. Sensory Analysis Results

The low sensory score for the samples implied higher performance. In terms of taste, there was no significant difference between juices. Regarding to taste, Chali juice was most preferred with no significant difference between the varieties. However, there exists a significant difference in Miya juice flavor as was rated higher than the control, while Bergad and Chali have no significant difference between them. Besides, there was no significant difference in the sauce taste with respect to taste in all varieties. Miya sauce has been found significantly different from other. However, there was no significant difference between Bergad and Chali sauce.

Table 7: Sensory scores of tomato juice and sauce for taste and flavor

Variety		Bergad	Miya	Chali
Juice	Taste	1.51a	1.65a	1.42a
	Flavor	1.47a	2.43a	1.65a
Sauce	Taste	2.60a	3.00a	2.80a
	Flavor	2.90a	3.70b	2.30a

* Means within a row followed by the same letter are not significantly different at P=0.05.

4.3. Microbial Data Analysis Results

Total plate count result of Chali was above the limit, while others ware below the acceptable limit. Coliform count and Yeast and Mold count for all varieties were under the specified limit and Salmonella was not detected in all.

Table 8: Microbial examination results of tomato juices

Organism	Result			Acceptable limit
	Bergad	**Miya**	**Chali**	
Total plate count	<1*10^1cfu/g	<1*10^1cfu/g	<30*10^4cfu/g	<10^4cfu/g
Coliform count	<3mpn/g	<3mpn/g	<9mpn/g	<10mpn/g
Yeast and Mold count	<1*10^1cfu/g	<1*10^1cfu/gm	<3*10^1cfu/g	<10^4cfu/g
Salmonella	Absent	Absent	Absent	Absent

Coliform count and Yeast and Mold count ware found to be below the acceptable limit. Bergad and Miya Total plate count were under the limit while Chali was above the limit though there was no significant difference between them (Table8).

Table 9: Microbial analysis result of tomato sauces

Organism	Result			Acceptable limit
	Bergad	**Miya**	**Chali**	
Total plate count	<1*10^1cfu/g	<1*10^1cfu/g	<10*10^4cfu/g	<10^4cfu/g
Coliform count	<3mpn/g	<3mpn/g	<6mpn/g	<10mpn/g
Yeast and Mold count	<1*10^1cfu/g	<1*10^1cfu/g	<3*10^1cfu/g	<10^4cfu/g
Salmonella	Not isolated	Not detected	Not detected	Absent

4.4. Process evaluation

Awash Fruit Processing Plant uses a continuous process for the production of juice and sauce. For making juice, high quality tomatoes, which are red, fully ripen and sound fruitsare collect from farm. Flumes are used as conveyers to avoid injury due to excessive handling and transportation. The tomatoes are washed with cold water to eliminate dirt and other adhering materials after manually sorting to eliminate those unfit for use in juice. The next step in the process is crushing and then heating to 82°C before extraction then conveyed to paddle extractor. The juice is extracted and screened continuously and pumps to juice collecting tank. 4% salt added to the juice and mix for improving the juice flavor and quality. Tomato juice from juice tank passes through special machines (homogenizer) to break up cellulose and prevent settling out of solids in the finished product. Before homogenization, de-aeration process is applied to minimize oxidative changes. The homogenized juice is pasteurized in continuous heat exchangers at a temperature of 121^{o}C for 0.7min, and then cooled to a temperature 93^{o}C to 98^{o}C before filling into cans and then filled and sealing into enameled tin cans and sealed. The sealed can are pasteurized at 96^{o}C to 98^{o}C.

For production of sauce, the extracted juice from juice tank pumps to double effect rising film evaporator. In the first effect, the juice is concentrated from 4.5Brix to 10Brix under vacuum (500-600mmHg pressure) at 65^{o}C temperature. Partly concentrated juice from the first effect is pumped to second effect evaporate; the juice is again concentrated to 24Brix under vacuum between 400-460mmHg pressure and at 45^{o}C temperature. The concentrated paste is transferred to pasteurizing and filling units.

All process parameters of juicing in Merti Agro-processing share company is consistent with the conventional method indicated in literatures, but this method of processing results in high exposure to oxygen during extraction. Therefore the current practice at Merti Agro-processing Share Company has to reduce exposure to air. Reduction of exposure to air can be achieved by using screw type extractor.

The main reaction conditions are temperature for juice and temperature, pressure and concentration for sauce. Evaporation process greatly affects the flavor. The study further found that the filling system is old and has low efficiency. It required to be substituted.

5. SUGGESTED DESIGN OF TOMATO JUICE MANUFACTURING PLANT

5.1. Production of tomato juice using screw type extractor

Extraction of tomato juice may be accomplished by two main types of commercially available extractors: the screw type extractor and the paddle type.

Screw-type extractors press the tomatoes between the screws and screen (Lopez, 1969). The pressing action of the juice extractor consists of an expanding helix inside a tomato juice screen, in which tomato pulp is forced against the screen at continuing and increasing pressures (Tressler and Joslyn, 1971). The holes in the screen vary but usually are about 0.02-0.03in in diameter (Gould, 1971; Lopez, 1969). This pressing action does not churn the product; therefore, very little air is incorporated into the expressed juice (Tressler and Joslyn, 1971). Some installations are equipped with a shaker screen ahead of the extractor where green areas, along with the stems, cores, and other foreign material, can be removed. When shaker screens are used, some canners employ a higher temperature hot break and a tighter setting of the extractor. Moyer et al. (1959) observed that the yield of the tomato juice extracted from fresh tomatoes ranged from 29.4-91.5%, depending on the type of the instrument used. They found that the pressing action of a screw-type juice extractor gave an average yield of 78.9%, whereas the beating action of a paddle pulper and a paddle finisher gave an average yield of 82.4%. Either of these types of extractors may be present to deliver either a high or relatively low percentage of juice extraction. A high extraction would yield 3% skins and seeds and 97% juice. It is, however, commercially feasible to extract only 70 to 80% juice, a procedure that yield a very moist residual containing useful tomato materials, which can be re-extracted for use in the other tomato products. In some cases, this low extraction yield (70%) is desirable because the extracted juice will have a high percentage of soluble solid components, which improve flavor, and at the same time a lower percentage of insoluble solids, which tend to reduce the quality of the finished juice (Tressler and Joslyn, 1971).

5.2. Manufacturing

Screw Press consists of a long spiral screw which presses the tomato against a tapered screen of fine mash having 25holes per linear inch, each with a diameter of 20/1000 of an inch. The juice passes through the screen while the skin and seeds are expelled at the other end of the machine. When the machines are operated at a speed of about 250 revolutions per minute, there is little or no incorporation of air in the juice. The tomato passing though the hopper should have a jet of steam spraying on them to prevent oxidation and distraction of vitamins. Pressing is controlled by a discharge cone that provides easy adjustment of moisture content. Stainless steel construction is standard.

Screw-type extractor (Continuous spiral press) has the following advantages:

- There is little or no incorporation of air in the juice
- Extracted juice will have a high percentage of soluble solid components, which improve flavor, and at the same time a lower percentage of insoluble solids, (Tressler and Joslyn, 1971).
- Oxidation and distraction of vitamin c is very low.

5.2.1. Raw materials

Table 10: Tomato Juice and Tomato Sauce Recipe

Products	**Ingredients**	**Composition (W/W)**
Tomato Juice	Tomato pulp	99.6
	Table salt	0.4
Tomato Sauce	Tomatoes	86.486
	Sugar	6.486
	Onions	1.946, finely chopped
	Salt	1.427
	Vinegar	3.459
	Mice	0.015
	Cinnamon	0.039
	Ground ginger	0.022
	Cumin	0.049
	Ground paper	0.070

Processing conditions for tomato juice

- Juice tomatoes should have high solids and good color
- Processing pH below 4.5, if not citric acid or lemon juice is often added to compensate for the acidity reduction
- Under no circumstances should damaged, over ripen or immature tomatoes be juiced
- Washing followed by careful inspection and grading is essential to eliminate damage
- A very rapid acting pectin enzyme system will break down the pectin under juicing, thus reduce viscosity
- Tomatoes are coarsely chopped and immediately heated to 80°C to inactivate these enzymes (primarily polygalacturonases and pectin methylesterases)
- Prior to thermal processing, the juice should be checked and adjusted below 4.5

- Rapid processing can retain over 90percent, whereas poor practices destroy all vitamin C.

5.2.2. Process flow sheets

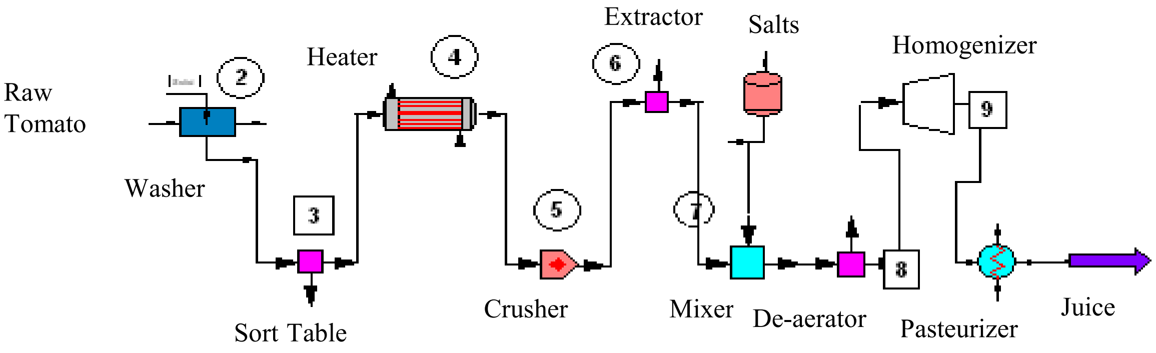

Figure 6: Suggested flow sheet of juice production

Process description for tomato sauce

- Tomato fruits are initially washed, sorted and then prepared for extraction.
- The fruits chopped and heated to 82°C to increase the extraction of pectic substances.
- Extraction is accomplished using screw press which expresses juice and produces dry pulp pumice.
- Remove dissolved air incorporated during breaking or extraction using vacuum pump.
- Homogenize the de-aerated juice to increase product viscosity and minimize serum separation using a narrow orifice at high pressure.
- The juice is pasteurized in continuous heat exchangers at a temperature 121.1°C for 0.7min, and then cooled to a temperature 93.3°C to 98.8°C.
- Tomato juice filled in the can at 93°C and then processed in a retort at boiling water temperature, 100°C.
- Finally cooled to 30-40°C to minimize quality loss using 2-5ppm chlorinated water.

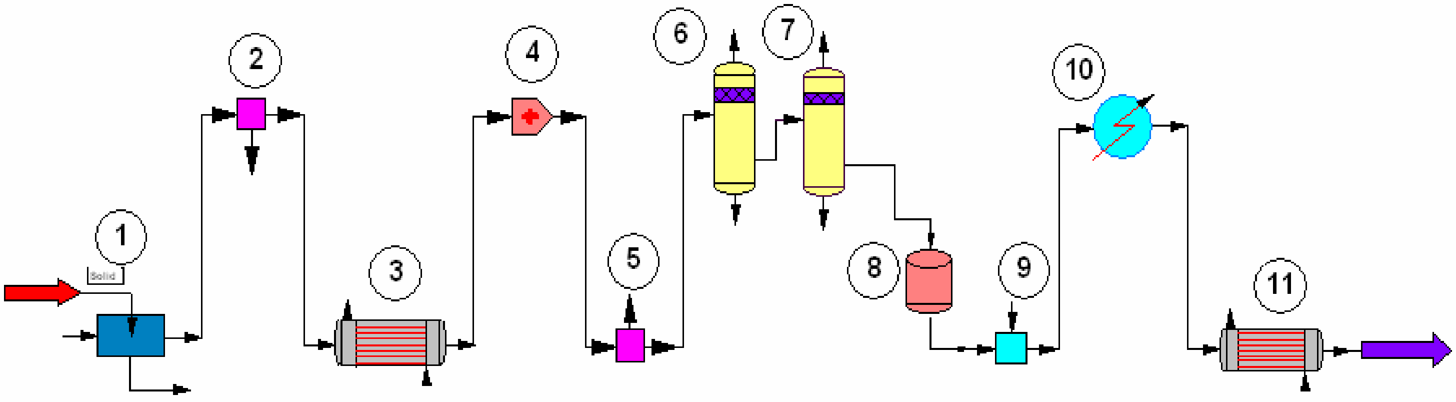

Figure 7: Suggested flow sheet of sauce production

Process units

1. Washer
2. Sorting table
3. Pre-heater
4. Crusher
5. Extractor
6. I-effect evaporator
7. II-effect evaporator
8. Holding Tank
9. Mixer
10. Boiling tank

11 Pasteurizer

Process description

1. Washing, sorting, Pre-heating, crushing and extraction is the same as juice process
2. The extracted juice is concentrated in first effect at 45°C temperature and 430mmHg pressure and in the second effect at 65°C and 550mmHg pressure until the concentration become 23°Bx.
3. The concentrated paste is mix with spices at the given recipe
4. The mixture is boiled from 5-10min at 100°C.
5. The sauce is pasteurized at 121°C for 42sec.
6. Cooled to 93°C and filled in the container as required.

5.2.3. Location and capacity of the plant

Since the major raw materials are tomato and must be processed within short time after harvesting, the plant should be located around the farm.

5.2.4. Material and Energy Balance

5.2.4.1. Material Balance

Only plant ripened red fruits feed to the washing section with about 3% defects (according to the data obtained from MAPSc.). All green, blamished and over-ripened fruits were rejected at sorting table.

Material balance on juice processing

Heated, crushed and pulped tomato juice was extracted with about 20% pumice removed, and then 0.4% by weight salt is added to juice.

Therefore the materials required to produce 3,000,000kg per year juice will be obtained as follows:

Juice total production = 3,000,000kg/year

Lets take the production is 300days per year and 24hrs per day, but only 200days out of 300 days to produced juice.

Juice required = 625kg/hr

The juice before salt = 622.5 kg/hr

The salt required will be = 2.5kg/hr

Juice obtained from extractor is about 80%

Thus, the tomato pulp (crushed) required will be = 778.13kg/hr

At sorting table, about 3% defect removed

Initial tomato requirement = 802.19kg/hr

Therefore in order to produce 625 kg/hr juice, 802.2 kg/hr tomato fruits and 2.5 kg/hr salt are required.

Table 11: Materials balance summery on juice processing unit

Processing Units	**Input (kg/hr)**	**Output (kg/hr)**
Sorting Table	802.2	778.1
Extractor	778.1	622.5
Mixing tank	622.5 + 2.5	625

Material balance on sauce processing

The materials required to produce 2,000,000 kg per 100 days sauce will be obtained as follows:

Sauce total production = 20,000kg/days

The production is 300days per year and 24hrs per day, only 100days for sauce

Final required Sauce flow rate = 833.3kg/hr

The sauce contains about 15.4% spices.

The tomato concentrate before adding spices = 705kg/hr

The tomato juice is concentrated from 5^{o}Bx to 23^{o}Bx or 45% volume reduced

The tomato pulp (crushed) required will be = 1281.82kg/hr

Note: - the density of the juice is approximately 1.

The extraction amount is 80%, therefore tomato fruits required before extraction

= 1602.3kg/hr

At sorting table, about 3% defect removed

Initial tomato requirement = 1650.4kg/hr

Therefore in order to produce 833.33kg/hr sauce, 1650.4kg/hr tomato fruits and 128kg/hr spices are required.

Table 12: Materials balance summery on sauce processing unit

Processing Units	**Input (kg/hr)**	**Output (kg/hr)**
Sorting Table	1650.4	1602.3
Extractor	1602.3	1281.8
I-effect evaporator	1281.8	945.3
II-effect evaporator	945.3	705
Mixing tank	705 + 128.3	833.3

Therefore the total amount of tomato fruits required for both juice and sauce is 2454kg/hr.

5.2.4.2. Energy Balance

Energy balances are made to determine the energy requirements of the process: the heating, cooling and power required. In plant operation, an energy balance (energy audit) on the plant will show the pattern of energy usage, and suggest areas for conservation and savings (Coulson, 1993).

Energy balance on juice processing unit

Tomato pulp properties

Heat Capacity at $27^{o}C = 4.092kJ/kg$

Inlet temperature = $27^{o}C$

Hot extraction Temperature = $83^{o}C$

The crushed tomato is heated to $83^{o}C$ to facilitate extraction.

The energy required will be

$Q_p = Cp\ \Delta T\ M_p$

$Q_p = 361338J/hr$

During extraction and salting, the temperature is decreased to about $53^{o}C$, and homogenization takes place at about $70^{o}C$.

Therefore the energy required will be

$Q_h = 56886.9kJ/hr$

The juice is pasteurized at $121^{o}C$.

$Qs = 172967.6kJ/hr$

Then the juice is cooled to $93^{o}C$ and filled in the can.

The energy removed will be

$Qc = -94187.5 kJ/hr$

After filling, retort in the can at $104^{o}C$

$Qr = 37112.7 kJ/hr$

Then the juice is immediately cooled to $35^{o}C$

$Qi = -229671 kJ/hr$

The total energy required will be

$Q_{total} = Qp + Qh + Qs + Qc + Qr + Qi$

$Q_{total} = 304446.7 kJ/hr.$

Energy balance on sauce processing

The crushed tomato is heated to 83°C to facilitate extraction.

The energy required will be

Q_p = 361330.7kJ/hr

Energy required to concentrate the juice from 5Bx to 23Bx will be

Qv = 1465383kJ/hr

The paste is mix with spices and boiled at 100°C

Qb = 57967.68kJ/hr

The sauce is pasteurized at 121°C.

Qs = 72344.7kJ/hr

Qtotal = 1889283kJ/hr

5.2.5 Design of basic equipments

5.2.5.1 Evaporators Design

The tomato juice has 4.5°Brix, and it is required to be concentrated to 24°Brix on average. We use double effect evaporator with rising film shall and tube heat exchanger. The steam is supplied at 4bar pressure and the product output has 833.3kg per hour flow rate. The boiling of juice inside the first effect takes place under vacuum 550mmHg at 65°C and boiling of partially concentrated juice in the second effect takes place under vacuum 430mmHg at 45°C. The feed has 40°C temperature and concentrated product has 65°C.

Specification

1st effect evaporator

Steam at 4bar pressure has 132°C (Singh, 2001) steam table.

Feed temperature $T_f = 40^oC$

Outlet temperature T_o of = 65°C

Mean temperature Tm = 52.5°C

Specific heat (Cp)

$$Cp = Cp_cX_c + Cp_fX_f + Cp_pX_p + Cp_fX_{fi} + Cp_aX_a + Cp_wX_w \tag{5.1}$$

Where – X_i is mass fraction of the i component

Cp_i is specific heat capacity of i component

Specific Heat capacity of the each substance as a function of temperature is

$$Cp = a + bT + cT^2 \tag{5.2}$$

Where: a, b, and c are constants for each substances and tabulated in the table 13.

Table 13: Constants for each food substances

Constants	a	b	c
Protein	2.0082	1.2089	-1.3129
Fat	1.9842	1.4733	-4.8008
Carbohydrate	1.5488	1.9625	-5.9399
Fiber	1.8459	1.8306	-4.6509
Ash	1.0926	1.8896	-3.6817
Water	4.1762	-9.0864	5.4731

At Tm = 52.5^{o}C

Cp_p = 2.06751 kJ/kgoC, Cpf = 2.04783 kJ/kgoC, Cpc = 1.6669 kJ/kgoC,

Cp_{fi} = 1.95366 kJ/kgoC, Cpa = 1.1809 kJ/kgoC, and Cpw = 4.18627 kJ/kgoC.

From laboratory analysis the composition of protein 1.17%, fat 0.14%, carbohydrate 3.94%, fiber 0.33%, ash 0.69% and moisture 93.73%.

Therefore using eq. (5.1)

Cp = 4.0688 kJ/kg^{o}C at 55^{o}C.

Table 14: Temperature and Specific heat of tomato paste

Tomato Paste	**Unit**	**outlet**	**mean**	**inlet**
Temperature (T)	^{o}C	65	52.5	40
Specific heat (Cp)	kJ/kg^{o}C	4.012	4.069	3.997

Overall heat-transfer coefficient U_1 in the first effect 800 W/(m^2 ^{o}C) and overall heat-transfer coefficient U_2 in the second effect 950 W/(m^2 ^{o}C) (Singh, 2001).

The enthalpy values of steam and vapor obtained from steam table (Singh, 2001).

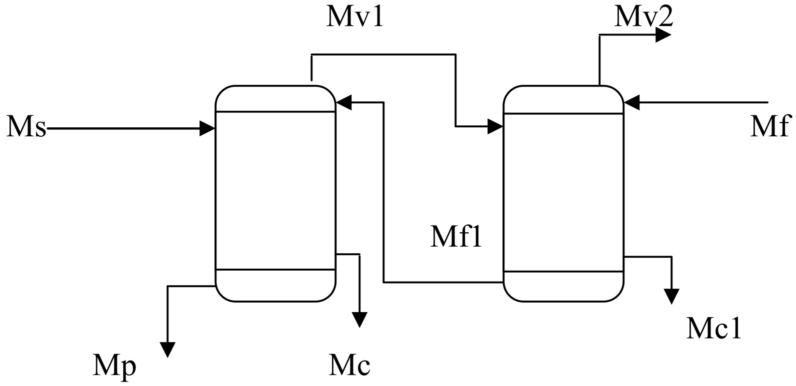

Figure 8: Double effect evaporator

Where Ms – mass of the steam supply to the evaporator from the boiler

Mc – mass of the condensed steam from the boiler

Mp – mass of the concentrated paste at the out let

Mv1 – mass of the steam generated in the first effect evaporator

Mv2 – mass of the steam generated in the second effect evaporator

Mc1 – mass of the condensed steam from the second effect

Mf – mass of the fresh juice supply

Mf – mass of the partly concentrated juice from first effect

Overall mass balance on both effects

$$Mf = Mp + Mv1 + Mv2 \tag{5.3}$$

Mass balance on solid mater

$$Mf\ Xf = Mp\ Xp \tag{5.4}$$

From the laboratory analysis total solids fraction in the feed (Xf) is 5.0 and in the final product (Xp) is 23.77m/m (Table4).

From steam table at 65^{o}C Hc1 = 272kJ/kg, Hv1 = 2618.3kJ/kg and at 132^{o}C steam supply temperature, Hvs = 2723.4kJ/kg, Hcs = 562.1kJ/kg.

From Eq. (5.4)

$$Mf = 4066.5\text{kg/hr} = 0.356\text{kg/s}$$

Thus, the total amount of water evaporated using Eq. (5.3)

$$Mv1 + Mv2 = 0.1602\text{kg/s}$$

The amount of heat transfer at each effect

$$Q1 = U1A1\ (Ts - T1) \tag{5.5}$$

$$Q2 = U2A2\ (T1 - T2) \tag{5.6}$$

Where: T1 is temperature in the first effect and T2 in the second effect.

The enthalpy equation around each effect

$$Q1 = Ms\ Hvs - Ms\ Hcs \tag{5.7}$$

$$Q2 = Mv1\ Hv1 - Mv2\ Hc1 \tag{5.8}$$

The area of heat transfer in the second effect is twice of the first effect.

Thus, from Eqs. (5.5) and (5.6)

$$\frac{Q1}{U1(Ts-T1)} = \frac{2Q2}{U2(T1-T2)} \tag{5.9}$$

And also from Eqs. (5.7), (5.8) and (5.9)

$$\frac{MsHvs - MsHcs}{U1(Ts-T1)} = \frac{Mv1Hv1 - Mv1Hc1}{U2(T1-T2)} \tag{5.10}$$

Enthalpies of the products are calculated from specific heat.

$$Hp = Cp\ (Tp - T) \quad (5.11)$$

Using Eq. (5.11)

$Hf = 160.48$ kJ/kg

$Hf1 = 179.55$ kJ/kg

$Hp = 254.8$ kJ/kg

In addition, from steam table

At $T1 = 65^{o}C$, $Hv1 = 2618$kJ/kg

$Hc1 = 272$ kJ/kg

At $T2 = 45^{o}C$, $Hv2 = 2583.2$ kJ/kg

$Hc2 = 188.45$ kJ/kg

At $Ts = 132^{o}C$, $Hvs = 2734.4$ kJ/kg

$Hsc = 562.1$ kJ/kg

Thus, substituting values in Eq. (5.9) and (5.10)

$$Ms = 1.4897\ Mv1$$

Enthalpy Balance around each effect

$$Ms\ Hvs + Mf1\ Hf1 = Mp\ Hp + Ms\ Hcs + Mv1\ Hv1 \quad (5.12)$$

$$Mv1\ Hvf2 + Mf\ Hf = Mf1\ Hf1 + Mv2\ Hf1v + Mv2\ Hv1 \quad (5.13)$$

Thus, substituting values in Eq. (5.12) and (5.13)

$$2172Ms = 58.98 + 2618Mv1 - 179.55Mf1$$

$$2346Mv1 = 179.55Mf1 + 2583.2Mv2 - 57.147$$

Let us assemble all the equation representing mass flow rates of product, feed, vapor, and steam.

$Mp = 0.2315$kg/s

$Mv1 + Mv2 = 0.1958$kg/s

$Ms = 1.4897\ Mv1$

$2172Ms = 58.98 + 2618Mv1 – 179.55Mf1$

$2346Mv1 = 179.55Mf1 + 2583.2Mv2 – 57.147$

We have five equations with five unknowns, namely Mp, Mv1, Mv2, Ms, and Mf1. we will solve those equations using a spreadsheet procedure to solve simultaneous equations.

Mp = 0.232kg/s, Ms = 0.0646kg/s, Mv1 = 0.0434kg/s, Mv2 = 0.0812kg/s and Mf1 = 0.179kg/s

Heat capacity of juice = 4.005 kJ/kg^{o}C

$$Q = MCp(T1 – T2) \tag{5.14}$$

Heat Load from Eq. (5.14)

Ql = 90.5kW

At 132^{o}C, Hc = 556kJ/kg

Hv = 2723.4kJ/kg

Heat of evaporation

Qev = 1174.73kW

Total heat load Qt

Qt = 1265.24kW

Use on shell pass and one tube pass

$$\Delta Tm = \frac{(Tsi - Tjo) - (Tso - Tji)}{\ln \frac{(Tsi - Tjo)}{(Tso - Tji)}} \tag{5.15}$$

Where: *Tsi*- Temperature of inlet Steam

Tjo- Temperature of outlet Juice

Tso- Temperature of outlet steam

Tji- Temperature of inlet juice

From Eq. (5.15)

ΔTm = 76.6^{o}C

Singh, 2001, the overall heat transfer coefficients

U1 = 750 W/m^2 ^{o}C and

U2 = 850 W/m^2 ^{o}C

Provisional area from Eq. (5.5)

A1 = 22.033m^2

Choose 19.03 mm o.d., 14.83 mm i.d., 4.88-m-long tubes, and stainless steel.

Area of one tube = (4.83) (19.03*10^{-3}) π = 0.287m^2

Number of tubes = 77

As the shell-side fluid is relatively clean use 1.25 triangular pitch.

Bundle diameter = $do\left(\frac{Nt}{K1}\right)^{1/n1}$ (5.16)

From Table 12.4 (Coulson and Richardson)

K1 = 0.319 and N1 = 2.142

From Eq. (5.16)

Db = 276mm

From Figure 12.10 (Coulson and Richardson), bundle diametrical clearance = 88 mm,

Shell diameter, Ds = 276 + 88 = 364 mm.

Tube-side coefficient

Mean water temperature = 55°C

Tube cross-sectional area = 172.6mm^2

Total flow area = 0.013m^2

Juice mass velocity = 85.2kg/sm^2

Density of juice = 1020kg/m^3

Juice linear velocity = 0.084m/s

Thermal conductivity = 1.53w/m°C

$$\text{Re} = \frac{\rho utdi}{\mu} \tag{5.17}$$

$$\text{Pr} = \frac{Cp\mu}{kf} \tag{5.18}$$

$$\frac{hidi}{kf} = jh\,\text{Re}\,\text{Pr}^{0.33}\left(\frac{\mu}{\mu w}\right)^{0.14} \tag{5.19}$$

From Eq. (5.17) and (5.18)

Re = 13514, Pr = 24.475

Neglecting $\left(\frac{\mu}{\mu w}\right)$

$$\left(\frac{L}{di}\right) = 324$$

From figure 12.19 (Coulson and Richardson)

jh = 0.025

Internal coefficient, from Eq. (5.19)

hi = 988

Shell-side coefficient

The convective heat-transfer coefficient on the steam side is very large and can be neglected.

Overall coefficient

Thermal conductivity of stainless steel = 16w/m^{o}C.

$$\frac{1}{Uo} = \frac{1}{ho} + \frac{do \ln\left(\frac{do}{di}\right)}{2kw} + \frac{do}{di} * \frac{1}{hi} \qquad (5.20)$$

Uo overall coefficient based on the outside area of the tube, W/m^2 ^{o}C, ho outside fluid film coefficient, W/m^2 ^{o}C, hi inside fluid film coefficient, W/m^2 ^{o}C, kw thermal conductivity of the tube wall material, W/m ^{o}C, di tube inside diameter, m, do tube outside diameter, m.

From Eq. (5.20)

Uo = 793 W/m^2 ^{o}C.

Well above the initial estimate of 750 Wm^{2o}C, so design has adequate area for the duty required.

Thus the area required for this purpose will be 22m^2.

The steam requirements are 0.0646 kg/s

The steam economy can be computed as

$$= \frac{\text{Mv1} + \text{Mv2}}{\text{Ms}}$$

Thus, 2.48 kg water evaporates per kg of steam.

5.2.5.2 Screw Type Extractor Design

Screw Press consists of a long spiral screw which presses the tomato against a tapered screen. After crushing the tomato fruit, the juice is extracted using screw having 6cm screw diameter, 17.6568^{o} helix angle, 2cm screw depth and 0.5cm screw edge flight Width.

Basic fluid flow rate equation in the screw

$$Qs = \pi^2 N h D_B (D_B - h) \sin \Phi_B \cos \Phi_B \frac{W}{W+e} \quad (5.21)$$

$$h = \frac{DB - Ds}{2} \quad (5.22)$$

$$D = D_B - 2h \quad (5.23)$$

$$\Phi = \tan^{-1} L/\pi D \quad (5.24)$$

$$\Phi_B = \tan^{-1} L/\pi D_B \quad (5.25)$$

$$\Phi_S = \tan^{-1} L/\pi Ds \quad (5.26)$$

$$W = L\cos\Phi - e \quad (5.27)$$

$$W_B = L\cos\Phi_B - e \quad (5.28)$$

$$Ws = L\cos\Phi s - e \quad (5.29)$$

Where N is number of revolution, D_B barrel diameter, Ds screw diameter, W average width of channel, b screw flight edge width in axial direction, e width of the screw edge flight perpendicular to the flight, h screw depth, δ clearance between the screw flight edge and the barrel, Φ helix angle, Φ_B helix angle at the outside diameter (at the barrel) Φs helix angle at the screw, Ws width of channel at the screw diameter, W_B width of channel at the outside diameter (at the barrel).

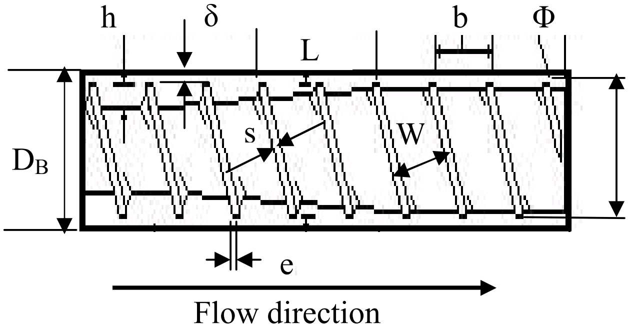

Figure 9: Screw Extractor detail figure

From American National Screw and Thread standard

Ds	6	cm
e	0.5	cm
h	2	cm

The standard helix angle (Φ) for most injection and extrusion screws is 17.6568°.

The most common screen holes sizes vary from 0.5 to 1.5mm. Therefore we can take the average holes size as the clearance between screw and screen.

Then $\delta = (0.5 + 1.5)/2$

$\delta = 1\text{mm}$

From Eq. (5.22)

$D_B = 10\text{cm}$

From Eq. (5.23)

$D = 8\text{cm}$

From Eq. (5.24)

$L = 7.992\text{cm}$

From Eq. (5.27), (5.28), and (5.29)

$W = 7.116\text{ cm}$

$WB = 6.599\text{cm}$

$Ws = 7.196\text{cm}$

From Eq. (5.21)

$Qs/N = 570.56\text{cm}^3$

In let-flow Rate will be <u>570.56 cm^3</u>

At the outlet, the diameter of the screw increase and depth decrease, while e constant.

$Ds = 9\text{cm}$

$h = 0.33\text{cm}$

Then, using Eq. (5.22), (5.23) and (5.24)

$D_B = 9.66\text{ cm}$

$D = 9.33\text{cm}$

$L = 9.32\text{cm}$

Angles determine using Eq. (5.25) and (5.26)

$\Phi_B = 18.25^o$

$\Phi s = 27.1^o$

From Eq. (5.27), (5.28) and (5.29)

W = 8.38

WB = 8.41

Ws = 8.35

From Eq. (5.21)

$Qs/N = 115.747cm^3$

Outlet Flow Rate $115.747cm^3$

Extraction Rate = (Inlet -Outlet) / Inlet

Extraction Rate = 0.797

Juice Flow rate from mass balance

Annual production	5,000,000kg
To Sauce line	1281.8kg/hr
To Juice line	778.2kg/hr
Total required	2060kg/hr
Density	$1.02g/cm^3$
Production flow rate	$2019600cm^3/hr$
	$561cm^3/s$
Screw Capacity	$454.81cm^3$ per revolution

Let the screw has one revolution per second

This implies that it extract $454.8cm^3$ per second.

Then

561 / 454.8

=1.234

It is about 1 and 1/4 times the required flow rate.

Therefore the screw should have 1.25 revolutions per second.

Most common screw designs have screw length to diameter ratio 20 (American National Standard)

$L/Ds = 20$

$L = 20 * 6$

$L = 120\text{cm}$

About 120cm long screw required.

The power requirement

$$P = 0.00053\ Cp\ T_f\ Q_{total} \tag{5.30}$$

$$Q_{total} = Fd\ \alpha\ N - Fp \tag{5.31}$$

$$\alpha = \pi^2\ D^2\ h\ \{(1\text{-}e)/L\}\sin^2 \Phi \tag{5.32}$$

From figure Fd = 0.43 and Fp = 0.52 (Griskey, 1995)

Where: Cp is specific heat of the feed.

From Eq. (5.32)

$$\alpha = 44.2$$

From Eq. (5.31)

$$Q_{total} = 28.3$$

Thus, power from Eq. (5.30)

$$P = (0.053)(\ 4.0688)(83)(28.3)$$

The power required is 501W

5.3. Market evaluation and research

Market research is the process of investigating a market in order to find out the sales prospects for a product and how to achieve success. It is the set of activities necessary to obtain the information required about the market (Coulson, 1993).

5.4. Quality control

Quality assurance is an important and necessary function in any manufacturing company. It provides the necessary know-how to the plants so they can deliver finished products within the highest standards. The quality control department in a plant provides important services by maintaining a high standard of product quality and by giving proper training to the plant personnel. Today's market is highly competitive. Any company is likely to lose business if it does not possess the capability of supplying customers with high-quality product at a competitive price. Therefore, more than ever before, it is important that the personnel in the processing plant be well-informed of the techniques of tomato processing, manufacturing, quality, and cost management (Delamarre and Batt, 1999).

5.4.1. Key elements of good quality control

As in all other areas of management, quality management requires a well-defined set of objectives. Examples of such objectives are as follows:

- quality standards;
- product standards;
- process-operation standards;
- training program for process personnel to understand the principles behind process operation and quality management; and
- training program for the maintenance personnel on routine and preventive maintenance.

Some examples of quality objectives for juice processing plant are listed below:

- 100% compliance with the finished-product standards;
- Total compliance with the process-operating standards;
- Zero defects on all products;

- Zero customer refusal for noncompliance with quality; and
- In-process or finished-product reprocessing less than 2% of total plant production.

To produce finished products with zero defects, the incoming raw materials must meet all specifications. Poor quality tomato fruit prevents the production of the best-quality finished product at a low cost. Poor-quality tomato fruit also reduces the viscosity of the final product.

Process operating standards are critical in order to obtain the product with the proper physical properties. Some of this information may be available in the public domain; some may be developed by individual companies and retained as proprietary information within the company (Cussler and Moggridge, 2001). In any case, the process conditions are typically related to the following:

- operating temperature;
- operating pressure (vacuum in deodorizing);
- retention time
- juice-flow rate in a continuous process;
- water-washing parameters;
- pasteurization condition and
- Packaging.

Quality standards on any product are established on the basis of the following:

- the specific product and its application;
- the quality requirement of specific customers;
- the shelf-life stability of the product; and
- the competitive edge of the product over its competition.

5.5. Product specification (Ethiopian standard)

This standard applies to tomato juice prepared from fully plant ripen tomato fruits. The soluble tomato solids content of tomato juice exclusive of added salt shall be not less then

4.5%m/m when determined by refractometer at 20^{o}C in accordance with ESISO 2173, uncorrected for acidity.

Organoleptic properties

The product shall have the characteristic color, aroma and flavor of tomato juice.

pH value

The pH of the sample shall not be more than 4.5.

Coloring mater

Artificial coloring material shall not be added.

Label

Record the product name, date of manufacture, content, brand name and name of manufacturer.

Table 15: Limits for microorganism

Organism	**Requirement**	**Test method**
Total plat count, max	2/ml	ESISO 4833
Coliform count	Nil/ml	ESISO 7251
Yeast and mold count, max	1/ml	ESISO 7954

5.6. Packaging and Storage Requirement

Packaging

The container should be well filled with the product which should occupy not less than 90% (minus any necessary head space according to good manufacturing practices) of the water capacity of the container. The water capacity of the container is the volume of distilled water at 20^{o}C which the sealed container will hold when completely filled.

Storage

If adequately packed and stored in a cool place, the sauce can be stored for up to a year with out any loss of flavor or taste. However, it should be stored out of direct sunlight to avoid any discoloration.

5.7. Building, equipment and manpower requirements

5.7.1. Plant parameters

Capacity, tons per year	5000
Number of shifts /day	3
Working days/year	300
Land area/ covered, m^2	1000

5.7.2. Building requirement

Several structures are required for different purposes like production area, packaging area, laboratories, stores, etc. The total area required for these structures is 1000 m^2 and from the current construction costs an average of 1000 Birr per m^2 of the area for the buildings which will be equal to 1,000,000 birr for this project.

5.7.3. Machinery and equipment requirements

Table16: Machinery and equipment requirements

Item	Quantity	Price, birr
Fruit washer	1	68,435
Pre-heater	1	95,273
Crusher and Pulper	1	120,000
Screw extractor	1	210,000
Mixing tank	1	43,672
De-aerator	1	56,752
Homogenizer	1	64,000
Pasteurizer	1	120,000
Filling Machine	1	168,000
Boiler	1	199,780
Total	10	1,145,912

5.7.4. Manpower requirement

Table 17: Manpower requirement

Human Resource	Number	Monthly average salary, birr	Total monthly salary, birr	Total yearly salary, birr
Managerial	2	2000	4,000	48,000
Skilled	15	1100	16,500	198,000
Unskilled	36	400	14,400	172,800
Total	53	3200	34,900	418,800

5.8. Cost estimation

5.8.1. Cost of raw materials

Table 18: Raw material costs for juice

Item	Quantity (kg)	Unit price, birr	Total price, birr
Tomato	3850560	5.00	19,252,800
Salt(refined)	12000	6.00	72,000
Total			19,324,800

Table 19: Raw material costs for sauce

Item	Quantity (kg)	Unit price, birr	Total price, birr
Tomato	3171600	5.00	15,858,000
Salt	28540	6.00	171,240
Onions	38920	6.00	233,520
Sugar	129720	10.00	1,297,200
Vinegar	69180	24.00	1,660,320
Total			19,220,280

5.8.2. Cost of utilities

Table 20: Cost of utilities

Item	Quantity	Unit price, birr	Total price, birr
Power	65kwh/ton*3000 ton =195,000kwh	0.57	126,750
Fuel	42 l/ton*3000ton =126,000lit	8.5	1,071,000
Packaging material	12,100,000 packs	1.55	18,118,000
Water	34,000 lit	2.5	85,000
Total			19,401,217

5.8.3. Fixed capital cost estimation

Table 21: Fixed capital cost estimation

Item		Description / factor	Total Cost, birr
I. Direct cost	A. Material + labor	estimated	38963080
	a. Equipment	“	1,145,912
	b. Installation	0.35*1,145,912	401,069.20
	c. Instrumentation	0.10*1,145,912	114591.20
	d. Piping	0.3*1,145,912	343,774.00
	e. Electrical	0.25*1,145,912	286,478.00
	B. Building +auxiliary	Direct estimate	1,000,000
	C. Service facilities	0.4*1,145,912	458,364.80
	D. Land	0.06*1,145,912	68,754.72
	Total direct cost	A+B+C+D	42380955
II. Indirect Costs	A. Engineering& supervision	0.1*42,380,955	4,238,095.5
	B. Construction +contractor fee	0.1*42,380,955	4,238,095.5
	C. Contingency	0.06*42,380,955	2542857
	Total indirect cost	A+B+C	11,019,048.2
III. Fixed capital investment		Direct + Indirect	53,400,003.2
IV. Working capital		0.15*53400003.2	8,010,000.5
V. Total capital investment		III +IV	61,410,003.7

5.8.4. Estimation of total product cost

Table 22: Estimation of total product cost

Item		**Description/factor**	**Total cost, birr**
I. Manufacturing cost	A. Fixed Charges		
	a. Depreciation	0.1*mach +0.02*buil.	134591.2
	b. Local taxes	0.02*FCI	1068000
	c. Insurance	0.006* FCI	320400
	Total of A		1,522,991
	B. Direct production cost		
	Total product cost (TPC)	Total fixed charge/0.15	10,153,273
	a. Raw material	Already estimated	38,963,080
	b. Utilities	“	19,401,217
	c. Operating labor (OL)	0.1*TPC	1,015,327.3
	d. Supervisory	0.1*OL	101,532.73
	e. Maintenance	0.05*FCI	2,670,000
	f. Lab charges	0.12*OL	121839.3
	Total of B		72,426,269
	C. Plant overheads	0.1*TPC	1,015,327.3
	Total manufacturing cost	A+B+C	74,964,587
II. General Expenses	a. Administrative cost	0.05*TPC	507663.7
	b. Distribution	0.1*TPC	1015327.3
	c. R&D	0.05*TPC	507663.7
	d. Interest	0.05*TPC	507663.7
	Total general expenses		1167626.3
III. Total Product Cost		I +II	76,132,213
Total product cost/kg margarine		$\frac{76132213}{5,000,000.}$ =15.226birr/kg	

5.8.5. Gross earnings

Whole selling price of 1kg of tomato juice =24.39birr

Whole selling price of 1kg of tomato sauce =28.60birr

Expecting all produced juice and sauce will be sold

Total income = 24.39*3,000,000 + 28.57*2,000,000 = 130313589

Gross income = total income-total product cost

= 130313589-76,132,213 = 54,181,375birr

Let the tax rate be 35% (income tax of Ethiopia)

Taxes = 0.35*36,096,283.16 birr = 18,963,481birr

Net profit = gross income – tax

= 54,181,375birr - 18,963,481birr = 35,217,894birr

Rate of return

ROI = $\frac{netprofit}{totalcapitalinvestment} \times 100 = \frac{35,217,894}{61,410,003.7} \times 100$ = 57.35%

Pay out period = $\frac{FCI}{NP + Depre} = \frac{53,400,003.2}{35,217,894 + 134,591.2}$ = 1.5 years

Tomato juice and sauce production using screw extractor is profitable as it is clearly observed from the above cost estimation. The project can fully be implemented after detailed feasibility study. From the literature survey, screw extractor reduces exposure to air and provides good flavor, nutritional quality and cost-efficient alternative to paddle extractor. The process gives a more natural product and can easily be implemented in existing factories for continuous operation. As no chemicals are used and the operating system is simple, production of a large variety of end-products will be possible environmentally friendly.

6. CONCLUSION AND RECOMMENDATIONS

There are a lots of tomato products available in the market including juice and sauce. This study indicates that tomato juice and sauce demand in the market of Ethiopia are high.

In Ethiopia, there are some tomato processing industries, like Merti Agro-processing. However, the amount of production is insufficient as compared with existing homeland consumer needs. Thus, a considerable amount of tomato products were imported from different countries, such as China, United Arab Emirates, Saudi Arabia, Oman, Yemen and others. On the other side, basic data and assessment of quality control of imported tomato products seem to be until yet not well established.

According to the data obtained from Ethiopian Customs Authority, there was a rapid increase of the amount of tomato juice and sauce imported in each year. For instance, it was about 135 tons in 2005 and increased to about 205 tons in 2008.

The favorable climatic condition, the vast irrigation sources, the abundant labor and other factors of Ethiopia are viable for the production and processing of fruits and vegetables. Currently, different improved tomato varieties and diversified of horticultural crops are grown in Ethiopia.

It requires great effort and motivation as well as legal background for the participation of private investor. The participation of private investor has been low in the past.

Production of juice and sauce using screw type extractor reveals that it is possible to develop products with the desired quality. As indicated in the current study, it is possible to produce tomato products at reasonable price locally and substitute the imported products. Based on the findings a tomato juice manufacturing plant has been suggested that Miya variety can be used for both juice and sauce production, while Chali can be used only for sauce production. The present study also encompasses process opportunities to get better quality of the products. In view of different improved tomato varieties, the following recommendations are forwarded:

- At the industry, it is necessary to use improved varieties which are obtained from local agricultural research center and to look into optional methods for better production.
- Concerned bodies especially Quality and Standard Authority and Ministry of Health should start the control work by establishing appropriate laboratories and legal framework for local and imported products.
- Awareness should be created with regard to local and foreign market for investors by the Ministry of Trade and Industry.
- Further studies are recommended on:
  - Optimization of evaporator conditions
  - Modifying the existing production process
  - Detailed feasibility study for improved varieties

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8. Annex

Table 23: Some physicochemical characteristics of Bergad Sauce (BS1, BS2 and BS3) (Mean ± SD)

Parameters	BS1	BS2	BS3
TSS	12.50260.0624	11.96260.106	12.14160.048
Viscosity	13.83560.180	13.11460.36	13.08760.170
Total Acidity	6.15560.045	5.87560.0368	6.30260.02
Moisture content (%)	76.24560.061	76.21360.073	76.23660.073
Ash (%)	4.27760.016	4.28960.0175	4.27260.0175
Crude Fiber (%)	0.53860.023	0.52260.026	0.54560.026
Carbohydrate (%)	17.1760.082	17.21760.098	17.18660.098
Fat (%)	0.26660.005	0.26660.004	0.26460.004
Protein (%)	1.49960.011	1.49460.014	1.49860.0135

Table 24: Some physicochemical characteristics of Miya Sauce (MS1, MS2 and MS3) (Mean ± SD)

Parameters	MS1	MS2	MS3
TSS	13.1560.062	13.6260.106	12.9460.048
Viscosity	14.3560.18	13.9160.36	14.7560.170
Total Acidity	6.5160.025	6.7560.035	6.1860.02
Moisture content (%)	69.1660.08	69.85060.096	69.6260.063
Ash (%)	5.76260.014	5.76360.017	5.77060.010
Crude Fiber (%)	0.55360.009	0.55460.011	0.55860.006
Carbohydrate (%)	21.7360.032	21.7460.038	21.7460.036
Fat (%)	0.24560.026	0.24160.032	0.26360.009
Protein (%)	2.05260.003	2.05460.002	2.05060.002

Table 25: Some physicochemical characteristics of Chali Sauce

(Mean ± SD)

Parameters	**CS1**	**CS2**	**CS3**
TSS	13.75160.024	13.36260.106	13.41660.048
Viscosity	8.93560.180	9.51460.36	9.07660.170
Total Acidity	5.61560.015	5.98560.048	6.02460.023
Moisture content (%)	70.1960.070	70.8360.065	71.0260.038
Ash (%)	4.87260.046	4.92760.073	5.03160.031
Crude Fiber (%)	0.48960.032	0.49360.051	0.50160.016
Carbohydrate (%)	20.7860.029	20.92860.035	20.67560.046
Fat (%)	0.17260.021	0.13760.007	0.1526.024
Protein (%)	1.80560.003	1.68460.002	1.95060.002

Table 26: Sensory table

Difference-from-control test

Name:_____________ Date:________ Test: ________

Type of sample: ______________________________

____

Introduction

1. Taste the sample method "Control" test
2. Taste the sample method with the three digit code
3. Assess the overall sensory difference between the two samples using the scale below.
4. Mark the scale to indicate the size of the overall difference.

	Scale	Mark to indicate difference
No difference	1	_____________
	2	_____________
	3	_____________
	4	_____________
	5	_____________
Extremely difference	6	_____________

Remember that a duplicate control is the sample some time.

Comments: ____

____

Table 27: Refractive versus TSS table

Refractive index	**TSS**
1.3376	3.2
1.3381	3.5
1.3385	3.8
1.3388	4.0
1.3391	4.2
1.3395	4.5
1.3399	4.7
1.3400	4.8
1.3403	5.0

Table 28: MPN table

No. of Tubes Positive in			**MPN in the inoculums of the middle set of rubes**
First set	**Meddle set**	**Last set**	
0	0	0	<0.03
0	0	1	0.03
0	0	2	0.06
0	0	3	0.09
0	1	0	0.03
0	1	1	0.061
0	1	2	0.092
0	1	3	0.12
0	2	0	0.062
0	2	1	0.093
0	2	2	0.12
0	2	3	0.16

0	3	0	0.094
0	3	1	0.13
0	3	2	0.16
0	3	3	0.19
1	0	0	0.036
1	0	1	0.072
1	0	2	0.11
1	0	3	0.15
1	1	0	0.073
1	1	1	0.11
1	1	2	0.15
1	1	3	0.19
1	2	0	0.11
1	2	1	0.15
1	2	2	0.20
1	2	3	0.24
1	3	0	0.16
1	3	1	0.20
1	3	2	0.24
1	3	3	0.29
2	0	0	0.091
2	0	1	0.14
2	0	2	0.20
2	0	3	0.26
2	1	0	0.15
2	1	1	0.20
2	1	2	0.27
2	1	3	0.34

Table 29: Tomato paste physical property table

Refractive Index at 25^{o}C	**Salt free solids**	**Total Solids**
1.3676	23.6	24.0
1.3677	23.7	24.1
1.3678	23.8	24.2
1.3679	23.8	24.2
1.3680	23.9	24.3
1.3681	23.9	24.3
1.3682	24.0	24.4
1.3683	24.1	24.5
1.3684	24.1	24.5
1.3685	24.2	24.6
1.3686	24.2	24.6
1.3687	24.3	24.7
1.3688	24.4	24.8
1.3689	24.4	24.8
1.3690	24.5	24.9
1.3691	24.5	24.9
1.3692	24.6	25.0
1.3693	24.6	25.0
1.3694	24.7	25.1
1.3695	24.8	25.2

Declaration

I, the undersigned, declare that this thesis is my original work and has not been presented for a degree in any other University, and that all sources of materials used for the thesis have been duly acknowledged.

Name: ________________________

Signature: ________________________

Place: Addis Ababa, Ethiopia

Date of submission: ________________________

This thesis has been submitted for the examination with our approval as university advisor

Name: ________________________

Signature: ________________________

Name: ________________________

Signature: ________________________