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Effect of Tomato Varieties, lemon juice concentration and storage temperature on the physico-chemical, sensory and microbial properties of Tomato Paste

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FACULTY OF CHEMICAL AND FOOD ENGINEERING

MASTER OF SCIENCE PROGRAM IN FOOD SAFETY &QUALITY

MSc. Thesis on

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Advisor: Tadle Andargie (Assistant Professor)

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Approval of Thesis for defense

I hereby certify that I have supervised, read, and evaluated this Thesis entitled **"Effect of Tomato Varieties, lemon juice concentration and storage temperature on the physico-chemical, sensory and microbial properties of Tomato Paste"** prepared by Mezgebu Muche under my guidance. I recommend the Thesis to be submitted for oral defense.

Tadele A. (Asst. Professor)		20/3/2024
Name of advisor	Signature	date

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Approval of thesis for defense result

I hereby confirm that the changes required by the examiners have been carried out and incorporated in the final thesis.

Name of Student **Mezgebu Muche** Signature ________ Date Apr 19/2024 As members of the board of examiners, we examined this thesis entitled "Effect of Tomato Varieties, lemon juice concentration and storage temperature on the physico-chemical, sensory and microbial properties of Tomato Paste" by Mezgebu Muche Reta. We here by certify that the thesis is accepted for fulfilling the requirements for the award of the degree of Masters of Science in "Food Safety and Quality".

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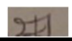
Declaration

This is to certify that the thesis entitled **"Effect of Tomato Varieties, lemon juice concentration and storage temperature on the physico-chemical, sensory and microbial properties of Tomato Paste"** in partial fulfillment of the requirements for the degree of Master program in Food Safety and Quality under Chemical and Food Engineering Faculty, Bahir Dar Institute of Technology. It is a record of my original work that has never been submitted to this or any other institution for any other degree or certificate. I am humbled by the help and assistance I received during this investigation. All sources of materials used for this thesis have been acknowledged.

Mezgebu Muche		**19/4/2024**
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LIST OF ABBREVIATION

AA	Ascorbic Acid
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
CCPs	Critical Control Points
CFU	Colony forming unit
CSA	Central Statistically Agency
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistical Databases
GAP	Good Agricultural Practices
GDP	Good Distribution Practices
GDP	Gross Domestic Products
GHP	Good Hygienic Practices
GMP	Good Manufacturing Practices
HACCP	Hazard Analysis Critical Control Points
HIPEF	High-intensity pulsed electric field
HP	High-pressure
LSD	least significant difference
MC	Moisture Content
NTSS	Natural tomato soluble solids
PEF	pulsed electric field
QA	Quality Assurance
SNV	Netherlands Development Organization
SSC	Soluble solids content
TA	Titrable Acidity
TSS	Total soluble solids
US	Ultrasonic
USA	United States of America
USDA	United States Department of Agriculture
WHO	World Health Organization

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Abstract

Tomato (Lycopersicon esculentum Mill.). is an important fruit and an excellent source of nutrients, including vitamin C and dietary fiber. Quality characteristics of tomato varieties and related products have been studied in almost all major tomato-producing countries around the world. Tomato paste is commonly produced by the hot-break processing method: a rapid deactivation of pectolytic enzymes during the hot-break process is considered essential to prevent demethylation and breakdown of pectin molecules. This, study was initiated to determine the effect of varieties, lemon juice and storage temperature on the physicochemical, sensory evaluation, and microbial load of tomato paste in Ethiopia. The treatments consisted of three varieties of tomato (Galilea, Gabby & Anna) two lemon juice concentration (5&10) % and three storage temperatures (4, 14, and 24 °C). The experiment was laid out a completely randomized design in factorial arrangements (3x2x3) with control (3) samples=21 treatments) with triplicates. The result revealed the physical properties of the three fully ripened tomato varieties. Tomato variety, lemon juice and storage temperature had a highly significant effect (P<0.01) on the physicochemical properties of tomato paste (i.e., total soluble Solid (°Brix), titratable Acidity, pH and vitamin C ranges with treament was (28.00 -22.30 %) (V1L1T1-C1), (1.24- 0.70) (V1L1T3-C3),(4.46-3.36(V1T1T3-C1) (25.10-16.26) g/100g)V1L1T1-C3)). In addition, V1L1T1 tomato paste that was treated at 5 % lemon juice concentration was mostly preferred by the panelists. From the total bacteria, yeast and mold growth in each treatment, the tomato paste was microbiologically safe for one and half months at room temperature storage. The most preferred paste by the panelists was produced from Galilea and Gaby tomato with the treatment of lemon juice 5 % & at 4°C. Generally, this study concluded that V1L1T1 and V2L1T1 separately could be recommended in the production of Tomato paste.

Keywords: Hot break, tomato paste, tomato varieties, quality, and sensory evaluation.

CHAPTER ONE

1. Introduction

1.1 Background

Tomato (*Lycopersicon esculentum Mill.*) is one of the major horticultural crops, with an estimated total world production of 182.30 million tons worth about $88.34 billion (A. Kumar et al., 2020). Ethiopia is endowed with favorable environmental conditions, adequate water, and fertile soils that are suitable for tomato cultivation (Ashinie & Tefera, 2019).

In Ethiopia, there is no exact information as to when tomatoes were first introduced; however, the crop is cultivated in different major growing areas of the country. In the 2015 cropping calendar, tomato production in Ethiopia was about 22,788 tones from a harvested area of 3,677 ha (Gemechu & Beyene, 2019).

Tomatoes are popularly used for both commercial and home-use purposes. The fresh produce is sliced and used as salad. It is also cooked for making local saucer ('watt'). The processed products like tomato paste, tomato juice, tomato catch-up, and whole peel-tomato are produced in the country for local markets and export. It was recognized as a quality product for both local and export markets, providing a route out of poverty for small-scale producers who live in developing countries in general and in Ethiopia in particular (Desalegn *et al*., 2016).

The tomato is one of the most perishable fruits, and it changes continuously after harvesting. Depending on the humidity and temperature, it ripens very soon, ultimately resulting in poor quality as the fruit becomes soft and unacceptable (Arthur, 2014). Hence, it must be harvested at the right time because overripe tomatoes are more susceptible to physical injury than ripe and pink ones (Arthur, 2014). After harvest, ripening continues, and tomatoes can become overripe very rapidly. In season, the price and demand of tomatoes are very low, which causes economic loss for the farmer. On the other hand, during the end period of the harvesting season, the tomato price becomes 2–3 times higher. Hence, short-term preservation like making tomato juice, tomato puree, cocktails, paste, ketchup, sauce, jelly, soups, powdered tomato chutneys, etc. will help the grower by reducing economic loss.

Tomato paste is commonly produced by the hot breaking system a rapid deactivation of pectolytic enzymes during the hot-break process is considered essential to prevent demethylation and breakdown of pectin molecules (Hassen *et al*., 2019). The consistency of the product also depends on the bio-availability of various compounds, such as pectin and other hydrocolloids (e.g., hemicelluloses). If the initial product is rich in these hydro-colloids, and subsequently evaporated to produce tomato paste, it results in a high consistency tomato paste. However promoting concentrated tomato paste in tomato juice and other tomato products, the physiochemical characteristics and sensory profiles of different tomato varieties are important quality indicators. The quality characteristics of tomato varieties and relative products have been studied in almost all major tomato-producing countries around the world. However, in Ethiopia, information is lacking on the quality of tomato varieties and processing technologies for the production of tomato paste (ABDU, 2016).

1.2 Statement of the problem

In Ethiopia, different tomato varieties are cultivated both from imported seeds and those released nationally by agricultural researchers. However, the local tomato varieties are less acceptable to use as input raw materials at the industrial level for the processing of tomato products due to factors such as Post-Harvest Handling Challenges, low yield, inconsistent quality, susceptibility to diseases, and compatibility with processing methods (Adhikari *et al*., 2017). . Therefore, studies of the effects of tomato varieties, lemon juice concentration, and storage temperature on the nutritional quality and safety of tomato paste production in terms of physicochemical qualities, microbial properties, and sensory evaluation are needed to see their differences. Due to their innate biological nature, fruit and vegetables mature quickly and degrade with extremely high losses after harvest.

In impoverished nations, postharvest losses of fruits and vegetables range from 20 to 50% (Bantayehu *et al*., 2017).

Different tomato varieties can have varying levels of nutrients such as vitamins, minerals, and antioxidants. Some varieties may have higher levels of certain nutrients compared to others. Factors like soil quality, growing conditions, and ripeness at harvest also affect the nutritional content of tomatoes. Therefore, the choice of tomato variety can have a significant impact on the nutritional quality of tomato paste.

Lemon juice is often added to tomato products like paste as a natural acidifier and flavor enhancer. The concentration of lemon juice added can affect the taste, acidity, and overall nutritional profile of the tomato paste. Lemon juice contains vitamin C and other antioxidants which can contribute to the nutritional value of the final product. However, excessive amounts of lemon juice might alter the taste and texture of the paste, affecting its acceptability.

The storage temperature of tomato paste can impact its nutritional quality over time. Storing tomato paste at higher temperatures can accelerate chemical reactions such as oxidation, leading to nutrient degradation. Vitamin C, for example, is sensitive to heat and can degrade over time when exposed to high temperatures. Additionally, improper storage conditions can promote microbial growth, potentially leading to spoilage and loss of nutrients.

Consumers need tomatoes for different purposes, both fresh and processed. However, local tomato varieties have low disease resistance, yield, and qualities to manufacture tomato paste products for domestic markets or export at the commercial level. Nowadays, the available packed tomato paste products on the market are also very expensive. So the aim of the study was to determine the effect of tomato varieties, lemon juice concentration, and storage conditions on the quality, safety, shelf life of tomato paste and maintain or enhance the nutritional value of the final product at the factory level to meet the demands of domestic markets and others.

1.3 Objectives

1.3.1 General objective

The main objective of this study is to investigate the effect of tomato variety, lemon juice concentration, and storage temperature on the physico-chemical, sensory and microbial properties of tomato paste.

1.3.2The specific objectives

- o To evaluate the effect of tomato variety, lemon juice concentrations and storage temperatures on the physico-chemical properties of tomato paste.
- o To evaluate the effect of tomato variety, lemon juice concentrations and storage temperatures sensory qualities of tomato paste.
- o To evaluate the effect of tomato variety, lemon juice concentrations, and storage temperature on the microbial properties of tomato paste.

1.4 Significance of the study

Even though it is hardly known in Ethiopia, tomato paste products may have great potential for many reasons, such as vast areas of fertile land, a diverse climate, and a large labor pool for tomato and tomato paste production. The tomato paste processing industry in Ethiopia is very limited despite the substantial amount of tomato fruit that is grown in the country. There is an increasing local demand for tomato paste in Ethiopia. However, the Merti tomato paste processing factory is the only industry that is available for the processing of tomato paste with zero additives or chemical preservatives.

In Ethiopia, the demand for tomato paste and juice is mainly a function of urbanization, income, and changes in the consumption habits of the population. Urban population growth in Ethiopia is about 4%, while GDP has been growing by more than 7% per year for the last few years. As income rises and urbanization grows, there is a shift towards more expensive but conveniently packed goods. Considering this situation, demand for tomato paste and tomato juice is forecast to grow by 5% per year.

In Ethiopia, the demand for tomato and tomato paste is mainly a function of industrialization, urbanization, income, and changes in the consumption habits of the population. This study will contribute to increasing the supply of a good variety of raw materials to the manufacturing plant for processing tomato products.

The study is believed to be significant in that it will:

- ✓ Reduce post-harvest loss of tomato in Ethiopia by processing the best quality tomato paste, prolonging tomato shelf life without loss of quality attributes.
- ✓ Provide basic information about tomato varieties and processing technology for the tomato paste manufacturing industry in Ethiopia.
- ✓ Replace or substitute the import of tomato paste in Ethiopia.

1.5 Scope

The study generally covers:

Determining the effect of tomato varieties, lemon juice concentration and storage conditions on the nutritional quality of the treatment on the physico chemical, microbial, and sensory attributes of tomato paste. This research could have implications for food processing techniques, product formulation, and storage practices aimed at maximizing the nutritional value and quality of tomato-based products like paste.

The preparation method and laboratory analysis of tomato paste, namely physicochemical analysis, sensory evaluation, microbial load analysis, and final recommendation of the best tomato variety, lemon juice concentration and storage conditions for tomato paste processing.

CHAPTER TWO

2. Literature Review

2.1 A Brief Description of Tomato

One of the most significant vegetables in the world is the tomato (*Lycopersicon esculentum L.*). About 152.9 million tons of fresh tomatoes were produced globally, with a market value of $74.1 billion(Abdu, 2016).The area under cultivation is expanding daily since it is a crop with a short growing season and a high yield that is enticing to businesses. A member of the Solanaceae family is the tomato. Other well-known species in this family include potatoes, tobacco, peppers, and eggplant (Nasir *et al*., 2015). Tomato (*Lycopersicon esculentum* L.) belongs to the Solanaceae family, and its origin is in the Andean zone, particularly Peru-Ecuador-Bolivian areas, but cultivated tomato originated in Mexico. One of the most popularly consumed vegetables and a significant source of vitamins and minerals is the tomato. It is one of the most widely consumed salad ingredients and is enjoyed greatly (Zahedi & Ansari, 2012).

A balanced, nutritious diet includes tomatoes. They are rich in essential minerals, vitamins, essential amino acids, and dietary fiber. Tomatoes are rich in iron, phosphorus, and vitamins B and C. It is possible to eat tomato fruits raw in salads or cooked in sauces, soups, and dishes with meat or fish. They are capable of being made into purées, sauces, and juices. Tomatoes, whether they are dry or canned, are economically important processed foods. In contrast to red tomatoes, yellow tomatoes have higher levels of lycopene, an antioxidant.

One of the main fruit and vegetable crops that is widely consumed around the world is the tomato (*Lycopersicon esculentum*). Both fresh and processed tomato products were consumed. The tomato is beneficial to health and is full of beneficial components. Additionally, it is thought to offer defense against or lower the chance of developing chronic degenerative disorders. Our diet's main source of lycopene is tomato. With a quenching rate constant on singlet oxygen approximately twice as high as that of carotene, it had been discovered to be a significant and powerful antioxidant. Tomato eating as part of a healthy diet may protect us from a variety of cardiovascular illnesses and epithelial malignancies.

Food product processors saw an opportunity to expand the tomato processing sector and create a market for pharmaceutical-grade products since customers are sensitive to their diet and health. As a result, tomato production gained value.

2.1. Overview of Fruits and Vegetables in the World

WHO and FAO recommend a minimum of 400 g of fruit and vegetables per day, excluding starchy root crops, for the prevention of chronic diseases such as heart disease, cancer, diabetes, and obesity and the prevention and alleviation of several micronutrient deficiencies, especially in less developed countries. Meeting the rising global demand for fruits and vegetables can create opportunities for poor farmers in developing countries, but improved supply chain efficiency, lower post-harvest losses, and investments in infrastructure will be necessary before farmers in many of these countries can reap the full benefits of cultivating these highly perishable crops (van Gogh et al., 2017).Even though many countries have a tomato processing industry, this production is strongly concentrated, making it the tenth largest producing country in the world's yearly production.

2.2. Current Status of Tomato Production in Ethiopia

One of the main vegetable crops grown in Ethiopia is the tomato, a crop with a short shelf life and a high rate of perishability. Due to its short lifespan, poor processing, and lack of preservation, it produces a glut during its short production season and becomes extremely rare and expensive during its off-season, costing farmers money. Although the United States is the world's second-largest tomato grower behind China, 89% of the tomatoes produced there in 2008 were processed, generating more than $2 billion in yearly farm revenue receipts (Adegbola *et al*., 2012)

Ethiopia's excellent climate, proximity to markets in Europe and the Middle East, and affordable labour give it a comparative advantage in several horticulture commodities. However, compared to the nation's food grain production, horticulture crop production is far less advanced.

Public and private commercial farms generate more than 2,399,566 tons of vegetables and fruits annually, which is more than 2% of all crops produced. According to the latest data from the Central Statistics Authority, there were around 12,576 hectares of fruits and vegetables planted in 2011. Less than one percent (0.11%) of the nation's total land area was cultivated in the same year for fruits and vegetables, which is negligible in comparison to food crops.

Large-scale tomato production takes place in the upper Awash Valley under irrigated and rain-fed conditions, whereas small-scale production for the fresh market is common practice in the areas of Koka, Ziway, Wondo-Genet, Guder, Bako, and many other regions (AGERNESH, 2023). Besides, tomatoes are the most widely cultivated and lucrative vegetables in the Amhara region. With the expansion of irrigated farming, market-oriented tomato production has been expanding in the last few years, enabling various actors, including growers, merchants, consumers, middlemen, and transporters, to take part and benefit from the value chain. In the 2018/19 Ethiopian Winter (meher) cropping season, tomato production was estimated at 4,322.31 ha with a total production of 23,583.75 tones (Endalew, 2020) (Table1). Similarly, in the 2018–2019 Amhara region, meher cropping season tomato production was estimated at 894.26 ha with a total production of 7,422.50 tonnes (Endalew, 2020).

In Ethiopia, demand for commercial hybrid vegetable seeds has been rising quickly. Following adaptation and confirmation, more than 90 hybrid vegetables have been certified and licensed for production in Ethiopia. Checking 20 natural hybrid tomato varieties in Ethiopia, tomatoes account for the majority of organic veggies (Binalfew *et al*., 2016). In Ethiopia, small-scale farmers under irrigation and rain-fed conditions and large-scale commercial vegetable growers cultivate the plant. Since the start of its commercialization, smallholders have been growing tomatoes for a long time because of their livelihood needs. However, the average yield of tomato in Ethiopia is low, at 8 tons/ha, c compared with world average yields of 34 tones/ha (Mohammed, 2020).

Table 2. 1 Area, production and yield of tomato for winter (meher season) in Ethiopia (2015-2019) (ABDU, 2016)

Production/years	Area in hectares	Production(ton)	Yield (Q/ha)
2014/2015	5,026.68	30,699.95	61.12
2015/2016	9,524.42	59,156.33	62.11
2016/2017	6,298.63	28,364.82	45.03
2017/2018	5,235.19	27,774.53	53.05
2018/2019	4,322.31	23,583.75	54.56

2.3 Post-harvest loss of tomato in Ethiopia

Despite its nutritional, economic, and health importance, the production of tomatoes is constrained by post-harvest losses, which limit the volume of good-quality produce reaching consumers. The perishable nature of produce, inferior technology, and lack of awareness among producers as well as market actors resulted in poor handling of the tomato(Mohammed, 2020). Although increasing production is one aspect of fulfilling food demand, failure to reduce post-harvest loss reduces the availability of food vegetables and the income that could be generated by selling the vegetables. The issue of post-harvest losses is of high importance in the efforts to combat hunger, raise revenue, and improve food security in the world's poorest countries, like Ethiopia. Roughly one-third of food produced for human consumption is lost or wasted globally, which amounts to about 1.3 billion tons per year (Gustavsson et al., 2011). In a study conducted on post-harvest loss and quality deterioration of horticultural crops in Dire Dawa Region, Ethiopia, the highest post-harvest loss (45.3%) was recorded for tomato(Kasso & Bekele, 2018).

Many researchers have stated that the reduction of post-harvest losses is reported as a critical component of ensuring future global food security (Mugao, 2023).Therefore, to devise alternative solutions for loss reduction, it is necessary to identify major causes of losses, critical loss points, and quantify the scale of these losses. To measure postharvest losses for fruits and vegetables, researchers have developed various methods, each focusing on different aspects of the value chain (Kitinoja & Kader, 2015).Among the post-harvest loss measurement approaches, commodity system assessment methodology has developed to identify the critical loss points and significant causes of losses and use local and low-cost technologies and techniques to solve or minimize the problem. It helps the operation within the context of the local, regional, or national commodity system.

2.4 Processing of tomato fruit in Ethiopia

Tomatoes are a source of basic raw materials required for fresh consumption and the local processing industry for the production of processed tomatoes like tomato paste, tomato juice, etc. by (Nardos, 2021). Tomatoes have very wide importance both as a source of food and as a source of health care, i.e., they contain vitamins like A and C, which play an important role in human health, and they are widely consumed in every household in different modes, including raw, as an ingredient in many dishes, sauces, salads, and drinks (Bezabeh *et al*., 2014).Studies revealed that fresh tomatoes and tomato products are of economic importance as a source of cash income for households as well as in creating employment opportunities and access for smallholder farmers to participate in the market (Bezabeh *et al*., 2014).

2.5 **processing of technology for tomato paste**

Fresh tomato is consumed in large quantities, not only due to its pleasant taste and versatile use in culinary practices worldwide but also due to its high nutritional value and functional properties. Despite these staggering production numbers and health benefits, tomatoes are a highly problematic agricultural commodity in terms of their short postharvest lives due to their high perishability (94% moisture). To overcome this issue, one-third of the total world production of tomatoes is processed into less perishable products, such as juice, puree, paste, ketchup, sauce, whole canned tomatoes, and powder(Etebu & Enaregha, 2013).

Thermal processing techniques, such as pasteurization, sterilization, and aseptic processing, are commonly used in the tomato processing industry. These processing techniques, however, often cause detrimental effects on the total quality and stability of tomato products (Jayathunge *et al*., 2015), & There is a growing demand for efficient, novel non-thermal processing technologies to overcome undesirable changes in organoleptic properties and retain higher quantities of bioactive compounds while maintaining the microbial stability of the product for the desired storage period (Jan *et* *al*., 2017). In the past decade, novel non-thermal technologies, such as high-pressure (HP), ultrasonic (US), and high-intensity pulsed electric field (HIPEF), have become established in the food industry; however, there are still many challenges to be tackled. Moreover, review papers related to the impact of novel thermal (microwave, radio frequency, ohmic heating, etc.) and non-thermal processing technologies (high pressure processing [HPP], ultra sonication, pulsed electric field [PEF], etc.) on various aspects of food commodities have been extensively published (Jayathunge *et al.*, 2019) have reviewed the impact of thermal pasteurization on ready-to-eat foods and vegetables, focusing on process design and effects on quality and the impact of non-thermal technologies on the microbial quality of juices, respectively.

2.6 Tomato paste processing

Tomato paste is a concentrated tomato juice or pulp without seeds or skin, containing not less than 25% tomato solids. Tomato ketchup is a thick paste-like product of tomatoes and tastes like sauce. Tomato concentrate and ketchup are potable foods used in hotels, restaurants, and homes. Tomato ketchup has a delicious taste, flavour, and bright red colour. It is liked by all people and is used widely with other foods to give it a very good taste and flavour. It has very good domestic use and is highly demanded in hotels and restaurants for the preparation of different dishes to serve customers (Deha, 2019). This makes tomato paste and ketchup production a very good business venture that can be considered by entrepreneurs. Fully matured fresh tomatoes, free from insect attack and mould infection, are harvested and transported to the plant, where they are cleaned by washing in water. Tomatoes infected with mould and other defects lead to quick deterioration and loss of quality in the products developed from them. Initial microbes present in the raw material are transferred to the finished product, resulting in poor-quality finished products. The washing is done using a specially designed machine responsible for washing the fruit to allow preservation of the fresh natural qualities of the fully ripe tomato (Lee *et al.*, 2018). Washed tomatoes are crushed into tomato pulp, which is strained and filtered. After preheating, a heat exchanger plant is used to concentrate the tomato pulp to a volume of about one-third of the initial volume. Concentration is then achieved in a very short time. Immediate concentration is necessary to reduce the oxidation reaction, which will otherwise give the product an undesirable dark-reddish color, as contrasted with the color of naturally grown tomato fruit. The tomato pulp concentrate is then homogenized, and thereafter, spices and flavoring ingredients such as sugar, salt, and vinegar are added to give it the characteristic sensory appeal associated with tomato sauce and tomato paste. The final products are then packaged (either bottled or canned) and later packed for storage or transportation.

2.7 Process description

Tomato paste is a processed product. Fresh tomatoes are usually consumed in many institutions, households, and restaurants. Tomato concentrates, typically tomato paste, are concentrated tomato juices produced from tomatoes that do not contain the tomato skin and seeds but rather contain more of the natural tomato soluble solids (NTSS). Unfortunately, most of the flavanols in tomatoes are known to be present in the skin (the chief source of lycopene) and a water-soluble fraction of the pulp disposed of during the processing of tomato paste (Toor & Savage, 2005).Tomato puree is a lower concentration of tomato paste made up of less than 24% (NTSS). Tomato serum is tomato juice filtered to remove all available solid material. Tomato syrup is a form of concentrated tomato serum. Tomato pulp is a suspended material in tomato juice, puree, or paste that could be separated. Tomato concentrates are a good source of lycopene, vitamin C, polyphenols, and small quantities of vitamin E (Giovanelli & Pagliarini, 2009).

2.8 Harvest and postharvest handling for processing

Harvesting at the right stage of maturity is critical for the intended use of tomatoes, i.e., whether for the fresh market or processing. At harvest time, tomatoes should be firm and free from bruising during handling, grading, and packing. Titratable acidity is lower in fruits harvested at the firm red stage, which decreases during storage (Brashlyanova et al., 2014). The best-flavoured tomatoes are those that have fully ripened on the plant. In many countries, tomatoes are harvested by hand. However, for tomatoes intended for processing, large-scale harvesters are commonly used. For efficient mechanical harvest, vine size is important due to its effect on the machine design, ease of vine pick-up, and effectiveness of fruit removal (Motamedzadegan & Tabarestani, 2011).

Raw tomatoes are handled using hampers, lug boxes, plastic boxes, or bulk containers (bulk boxes, water tanks, and bulk trailers) (Motamedzadegan & Tabarestani, 2018). Efficient bulk transport represents another step towards complete mechanization of harvest and handling. Once at the plant, they are processed immediately or stored in the shade. The relative storage life of fresh tomato fruit in air at near-optimum storage temperature and relative humidity (RH) is about 2–4 weeks, depending on the ripeness stage. The optimum storage temperature for ripe tomatoes is 45–50◦F (7.2–10◦C), with a RH of 85–96%. The mature green fruit can be stored at 55–60 °F (12.8–15.6 °C) for several days without significant quality loss (Motamedzadegan & Tabarestani, 2011).

Tomato respiration, transpiration, and ethylene production are major factors implicated in quality deterioration. Refrigeration is the most important technology for extending the shelf life of fresh tomatoes. A broader range of postharvest technologies is commonly used for extending the shelf life, e.g., edible coating, use of modified atmosphere storage, and innovative packaging.

2.9 Raw Material Availability

Ripe, fully developed tomatoes will be the most important raw ingredient. When two prerequisites are satisfied, tomato paste and sauce production can begin. These include the availability of a plentiful and consistent supply of fresh, high-quality tomatoes and water. There is a lot of emphasis placed on tomato growing because the quality of the tomato used as the raw material will greatly influence the quality of the paste that is produced.

2.10 Tomato Paste Manufacturing Process

2.10.1 Preparation of Raw Materials

Based on the requirements of good quality, completely ripe fruits preferably plum kinds free of infection, mold, or rot the selection procedure was carried out. Fruit and vegetables that are mature and ripe should be carefully selected to minimize other damage..

2.10.2 Washing

In a wash jar, washing is done using clean, potable water to get rid of contaminants on the surface like pesticide stains, insects, soil, dirt, etc. Truckloads of fresh tomatoes are unloaded into a collection channel (also known as a flume), a stainless steel into which a continuous flow of water that is three to five times more than the volume of unloaded tomato is pumped. For instance, a 10 tons/hour rate needs at least 30 m3 of water each hour. Washing is a crucial control step in the processing of tomato products with a low microbiological count, according to (ABDU, 2016). A thorough cleaning gets rid of pollutants including Drosophila eggs, mildew, insects, and dirt.

2.10.3 Chopping or Crushing

Tomatoes enter the chopper for crushing after sorting in order to obtain the juice. This implies that tomatoes are diced before boiling. Prior to heating or breaking, the tomatoes are typically cut to a thickness of 0.040 to 0.060 inch. They could also be crushed with a wooden roller crusher. If the tomatoes are solid and ripe, they can be crushed under pressure, but this is not very effective (El Mashad *et al*., 2019).

2.10.4. Pre-heating/Breaking

Tomatoes can be processed into juice by either a hot break or cold break method. Most juice is made by hot break. The term Hot Break means that the fresh tomato is chopped when heated, at temperatures ranging from 85 to 100°C, while Cold Break means that the fresh tomato is chopped at lower temperatures, ranging from 65 to 75°C.

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 and does not separate upon standing than in cold breaking. In Cold breaking 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 but this product has a more natural tomato color and it has a fresher tomato flavor.

The heated tomato pulp (fiber, juice, skin and seeds) is then conveyed via a special pump to an extraction unit composed of two operating stations: a pulper and a refiner, equipped with two sieves having different sized meshes. The first sieve processes solid pieces up to 1 mm, while the refiner processes solid pieces up to 0.6 mm, depending on the type of sieve fitted on the machine (the manufacturer can supply sieves with different sized holes if necessary). Two products therefore come out of the extraction unit: refined juice for concentration and waste for disposal.

2.10.5 Juice Extraction

The heated crushed tomatoes are subjected to a pressing or extraction process to separate the liquid juice from the solids. This can be done using various methods, including mechanical presses or decanters.

The extracted juice is separated from the solid components through filtration or centrifugation. This step helps remove any remaining solid particles and impurities from the juice by (Gao *et al*., 2021).

2.10.6 Evaporation

ABDU(2016) reported that situation of evaporation when juice was concentrated to paste. If the final product is not juice, the juice is next concentrated to paste. The extracted juice is then concentrated to increase its thickness and reduce its water content. This concentration step is crucial in the production of tomato paste. It 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 50- 90°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. According to the ABDU(2016) tomato 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.

The entire concentration process takes place under vacuum conditions and at low temperatures, significantly below 100°C. Product circulation inside the various concentric tubular exchangers is carried out by special stainless steel pumps which are designed to ensure that the product is conveyed inside the exchanger tubes at a speed of over 1.2 m/sec to avoid "flash evaporation" thus avoiding to get burnt. Evaporator output is measured in liters of evaporated water per hour while concentrating tomato juice with an initial 5°Brix concentration and producing tomato paste double concentrate at 30° Brix. All the tomato juice evaporators are designed according to these parameters. The evaporative capacity of tomato juice concentrators is greatly influenced by the viscosity level.

2.10.7 **Pasteurization**

The concentrate is sent from the evaporator directly inside the aseptic system tank. From here it is pumped at high pressure inside the aseptic pasteurizer-cooler and then to the aseptic filler, where it is filled into pre-sterilized aseptic bags housed in metal drums. The pasteurization temperature and the holding time vary according to the product's pH value. Generally speaking, a product with a pH value equal to or less than 4.2 could have a pasteurization temperature of 92- 94°C measured at the end of the holding section, and a holding time of at least 60-90 seconds. On the other hand, if the pH value is greater than 4.2, it is advisable to acidify the product in order to bring it to about 4.1, improving taste and final product quality, tank also to the reduced pasteurizing temperatures/time. The pasteurized tomato paste is cooled down to about 35-38°C before being piped into pre-sterilized aluminum bags housed in special metal or plastic bins via a special aseptic filler. The packaged concentrate can be kept up to 24 months depending on its pH value and ambient conditions. When storing for over 12 months, it is however advisable to conserve it in refrigerated cells, more to reduce oxidization, which could cause darkening than to protect the product's aseptic quality.

Pasteurization is a heat-treatment process used to kill or inactivate harmful microorganisms in food products. For tomato paste, pasteurization helps ensure safety by reducing the risk of bacterial contamination and spoilage. Here's a general overview of the pasteurization process for tomato paste

In the Preparation of Tomato Paste was Tomatoes are harvested and processed to obtain tomato puree. The puree is then concentrated to form tomato paste, which is a thicker and more concentrated product. And also the heat treatment of the tomato paste is heated to a specific temperature for a set period. The temperature and duration depend on the desired level of pasteurization and the specific requirements of the product.

Pasteurization Temperature and Time can be Typically, pasteurization temperatures range from 80°C to 100°C (176°F to 212°F), and the time can vary but is often around 2 to 5 minutes.

The goal is to reduce the number of microorganisms present in the tomato paste without significantly affecting its quality.

2.10.8 Cooling

The cooling processing stage which used to after the heating process, the tomato paste is rapidly cooled to stop the heat treatment and prevent overcooking or degradation of the product.

Pasteurized tomato paste can be stored for an extended period under appropriate conditions.(Koh *et al*., 2012).Refrigeration or aseptic packaging that be used to further extend shelf life. It's important to note that the specific parameters for pasteurization may vary depending on the regulations, industry standards, and the equipment used by the tomato processing facility. Always follow the guidelines provided by food safety authorities and adhere to industry best practices to ensure the production of safe and high-quality tomato paste by (Deteah, 2017).

2.10.9 Sterilization

Sterilization of tomato paste is a critical step in the production process to ensure that the final product is free from harmful microorganisms and has an extended shelf life. The sterilization process involves heating the tomato paste to a sufficiently high temperature for a specific duration to destroy or inactivate bacteria, yeasts, molds, and enzymes. Here's a general overview of the sterilization process for tomato paste.

Tomato paste is typically prepared through the extraction and concentration of tomato juice, as mentioned in the previous response.

The tomato paste is heated to a high temperature. The specific temperature and duration of heat treatment depend on the sterilization method used.

Sterilization methods are various methods for sterilizing tomato paste, and the choice of method may depend on factors such as the desired quality of the final product, production scale, and available equipment. Common sterilization methods include:

Hot Break Process: This involves heating the tomato paste to a temperature around 85-95°C (185-203°F) for a shorter duration.

Cold Break Process: This involves a milder heat treatment, usually around 60-75°C (140-167°F), for a longer duration.

Continuous or Batch Processing: The sterilization process can be carried out in a continuous or batch mode, depending on the production scale and facility setup.

Cooling was used to after the sterilization process; the tomato paste is rapidly cooled to stop the heat treatment. Cooling is essential to prevent overcooking and maintain the desired quality of the product.

Aseptic Packaging also can be used to further ensure the sterility of the tomato paste, some facilities use aseptic packaging. In this method, the sterilized tomato paste is packaged in a sterile environment to prevent recontamination.

Quality Control which measured throughout the sterilization process, quality control measures is implemented to ensure that the tomato paste meets safety and quality standards.

Storage is the main important for the sterilized tomato paste is then stored in suitable containers to maintain its quality and safety during transportation and storage.

It's important to note that the specific parameters for sterilization, such as temperature and duration, may vary based on the type of tomato paste and the equipment used. The sterilization process is a critical step in ensuring the safety and stability of the final product. Food safety regulations and industry standards should be followed during the entire production process.

2.10.10 Labeling

The legal requirements are that a label should contain the following information: Name and address of the producer, name of the product, list of ingredients (in descending order of weight), net weight of product in the package, a 'use-by' or 'sell-by' date, nutritional information, allergen information, date marking, batch or lot number, storage instruction, country of origin, manufacturer information and barcode.

2.10.11 Canning tomato paste

Canning tomato paste process involves preserving the product which can sealed container to provide increase the shelf life. The canning process typically includes the following steps: However the Preparation of Tomato Paste to produce tomato paste through the extraction, concentration, and sterilization processes mentioned earlier.

2.10.12 Sterilization of Cans

Ensure that all of the cans that are to be used for packaging are thoroughly cleaned and sterilized. This can be done through heat treatment, sterilization, or other approved methods.

2.10.13 Filling the Cans

Fill the sterilized cans with the prepared and sterilized tomato paste. The filling process should be conducted in a way that minimizes air pockets and ensures proper headspace to allow for expansion during heat treatment.

Seal the filled cans using a proper sealing method. This may involve placing lids on the cans and crimping or vacuum-sealing to create a hermetic seal.

2.10.14 Heat Treatment (Processing)

The sealed cans are then subjected to heat treatment to destroy or inactivate any microorganisms that could cause spoilage or pose health risks.

2.10.15 Cooling

After the heat treatment, the cans are rapidly cooled to stop the cooking process and ensure the quality and safety of the tomato paste.

2.10.16 Labeling

Labels are to be all of the cans that include information such as the product name, ingredients, net weight, nutritional information, date of production, and any other required details.

2.10.17 Quality Control

Conduct quality control checks to ensure that the canned tomato paste all of parameters are meets safety and quality standards. This may include checks for proper sealing, pH levels, and overall product integrity.

2.10.18 Storage

Store the canned tomato paste in a cool, dry place away from direct sunlight. Proper storage conditions are essential for maintaining the quality of the product throughout its shelf life.

It's important to note that the canning process should adhere to food safety regulations and guidelines specific to the country or region of production. Following Good Manufacturing Practices (GMP) and implementing a Hazard Analysis and Critical Control Points (HACCP) plan are common practices to ensure the safety of canned food products.

Additionally, be aware that the specific procedures and regulations can vary, and it's advisable for food processors to consult local health authorities and relevant regulatory agencies for the most up-to-date guidelines on canning tomato paste.

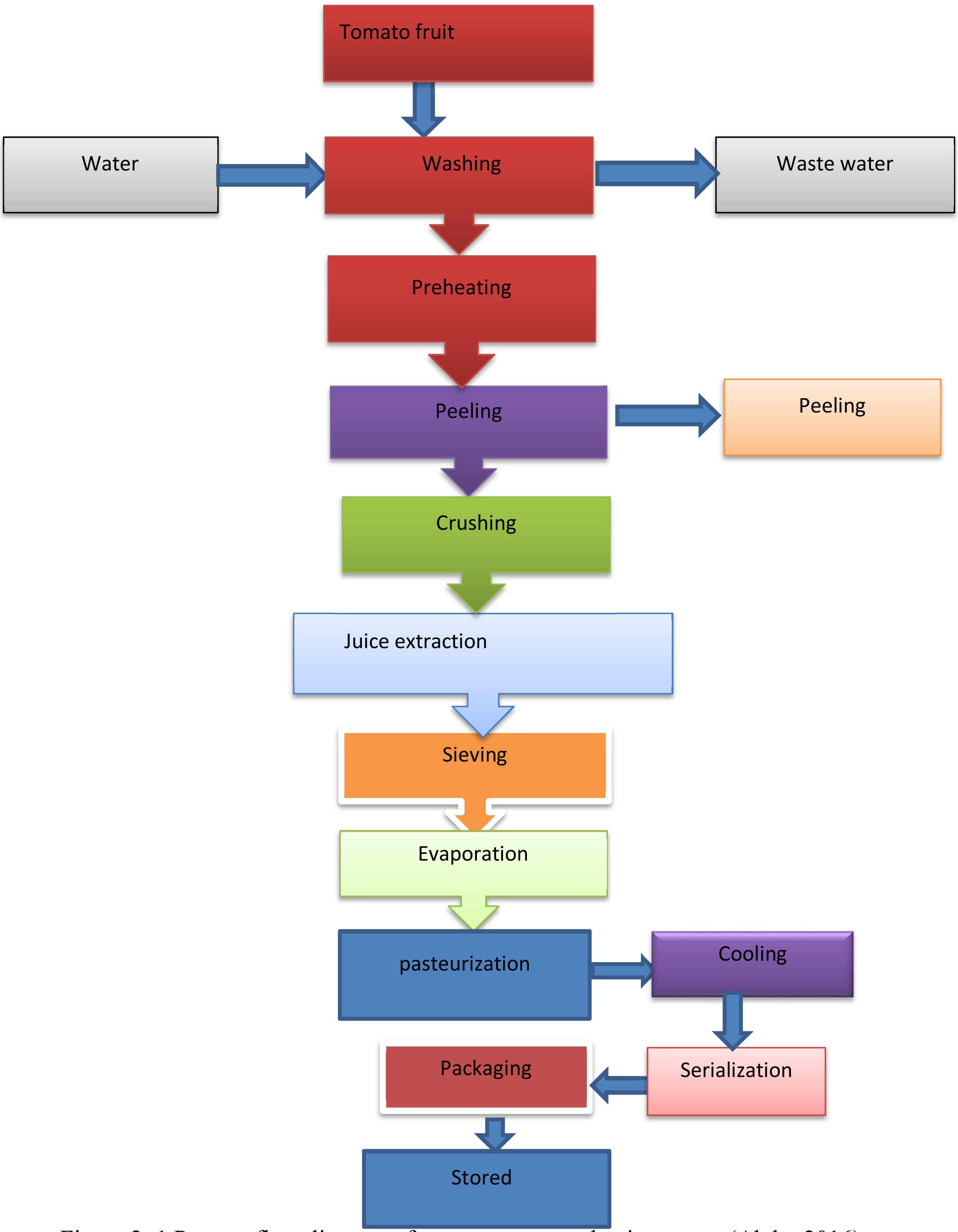

Figure 2. 1 Process flow diagram of tomato paste production source(Abdu, 2016)

2.9. Harvest maturity stage and cold storage period influence of the lemon fruit quality

Lemon (Lee *et al*., 2018) is commercially cultivated in all the citrus producing areas of the world. Globally, 17.35 million tons of lemon and lime fruit were produced from 1.08 million ha cultivated area, with the top producers being India, Mexico, China, Argentina, and Brazil, which collectively account for 61.32% of total production (Y. Sun *et al*., 2019) Lemon fruit is rich in nutrients and bioactive compounds like citric acid, vitamin C, minerals and flavonoids, therefore widely used in the preparation of refreshing drinks, cordials and to flavour as well as garnish the foods (Y. Sun *et al.*, 2019).The quality and storage life of lemon fruit depends upon various physiological and biochemical changes which occur during fruit growth, development and maturity (Mukhim *et al*., 2015).

The harvest maturity stage of citrus fruit is one of the critical factors which affect its quality parameters such as fruit colour (Y. Sun *et al*., 2019),total antioxidant capacity (de Moraes Barros *et al*., 2012), individual organic acid and storage life (X. Sun *et al*., 2013). A gradual reduction in ascorbic acid levels, titratable acidity (TA) and a rise in soluble solids content (SSC) have been noted with the advancement of the maturation process in sweet orange fruit (Y. Sun *et al*., 2019). (Y. Sun *et al*., 2019), was reported that with the extension of the harvest period slightly increase the juice percentage, SSC: TA, and pH value in the juice of Navel orange. Lemon fruit is usually strip or selectively harvested depending upon the fruit size at the yellow, green yellow or green stage, according to the market requirements. It has been reported that the fruit harvested at yellow stage could be stored for few weeks, whilst green-yellow stage for 6 weeks and green stage for 2–6 months before marketing at commercially acceptable state (Y. Sun *et al*., 2019).

Storage conditions and duration significantly influence the postharvest fruit quality parameters of lemon such as weight loss (Y. Sun *et al*., 2019), colour parameters and citric acid content. Physiological processes in the lemon fruit are influenced by the storage temperatures and durations. An extended storage at low temperatures induce physiological breakdown in the lemon fruit. Previously, he reported that 10 °C is suitable for long duration storage of lemon fruit. Lemon fruit is sensitive to cold temperature and when stored below 5°C it can develop chilling injury symptoms including discolouration, weight loss, and development of brown spot and pitting on the fruit surface (Y. Sun *et al.*, 2019). Apparently, the effects of the different harvest maturity stages (green, green-yellow and yellow stages) and cold storage periods on the fruit quality parameters have not yet been investigated. It was hypothesized that harvest maturity stages and cold storage duration will influence the postharvest quality of the lemon fruit. Therefore, the present investigation aimed at evaluating the effects of three different harvest maturity stages (green, green-yellow and yellow stages) and different cold storage periods (30, 60 and 90 days) on Eureka lemon fruit quality including weight loss, fruit colour, SSC, Titrable acidity, individual organic acids, vitamin C and total antioxidant capacity in the juice of the fruit.

2.9.1 Lemon juice concentration process description

Processing lemon juice involves several steps to extract the juice, concentrate it, and ensure its quality. Here's a general overview of the lemon juice concentration process:

2.9.2 Harvesting

Lemons are typically harvested when they are ripe. Harvesting at the right time ensures the best flavor and quality of the juice.

2.9.3 Washing

Wash the lemons thoroughly under running water to remove any dirt or surface impurities. Lemons are thoroughly cleaned to remove dirt and debris. They are then sorted based on size and quality.

2.9.4. Peeling

Use a zester, micro plane grater, or the fine side of a box grater to remove the outer zest of the lemon. Be careful to only remove the colored part of the peel and not the bitter white pith beneath.

2.9.5. Cutting

Cut the lemons in half crosswise. Use a sharp knife to make clean cuts.

2.9.6 Juicing

Juicing: The lemons are juiced to extract the liquid. This can be done using mechanical processes like squeezing or with industrial juicing machines.

There are various methods for juicing lemons:

- Manual Juicer: Use a handheld citrus juicer or reamer to extract the juice. Place the cut side of the lemon onto the juicer and twist to extract the juice.
- Citrus Squeezer: A citrus squeezer is a tool that allows you to press down on the lemon halves to extract the juice.
- Electric Juicer: If you have an electric juicer, you can use it to quickly and efficiently extract lemon juice.

2.9.7 Filtration

The extracted juice may contain pulp, seeds, or other solid particles. Filtration is done to remove these impurities, resulting in a smoother juice.

2.9.8 Pasteurization

The concentrated juice is pasteurized to destroy any harmful microorganisms, ensuring a longer shelf life.

2.9.9 Cooling

After pasteurization, the juice is cooled to a suitable temperature for packaging.

2.9.10 Quality Control

Throughout the process, quality control measures are implemented to ensure that the juice meets safety and quality standards. This includes testing for acidity, sweetness, and other relevant parameters.

Processing of the lemon juice is important to note that specific processing methods may vary depending on the scale of production, equipment used, and the desired characteristics of the final product. Additionally, some producers may add preservatives or adjust the acidity for consistency and flavor.

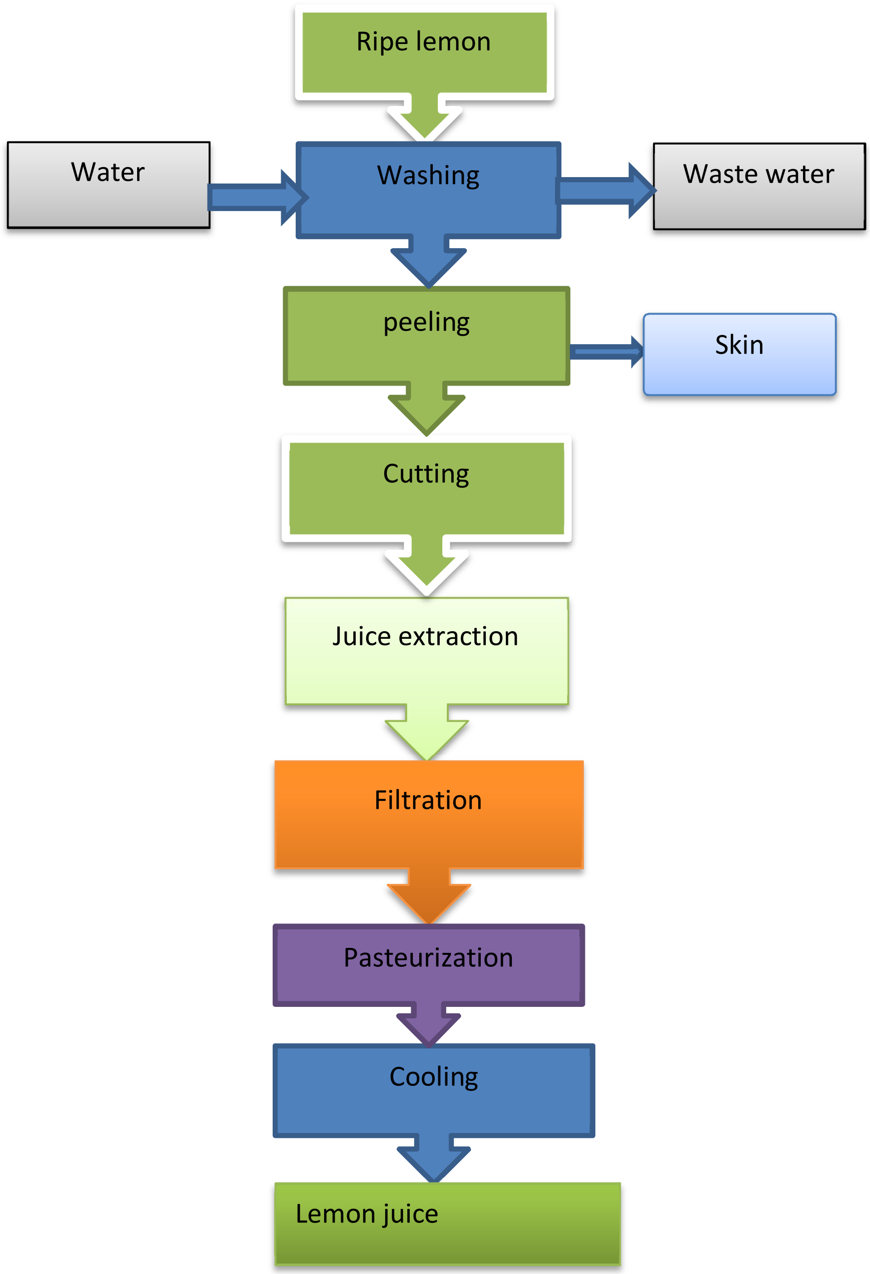

Figure 2. 2 Process flow diagram of lemon juice extraction concentration process source(Uçan *et al*., 2014)

2.9.8 Concentrated Tomato paste treated and lemon juice concentration preservation

When it comes to preserving food, thermal treatment and the addition of acidic ingredients like lemon juice can be complementary methods, each contributing to the preservation of the product. However, it's crucial to ensure that the combination is safe and effective. The overview of the thermal treatment and lemon juice concentration can be applied: either thermal treatment (heat processing) or lemon juice concentration. However, the main purpose of thermal treatment (heat processing) that involves subjecting the food product to high temperatures to kill or inactivate spoilage-causing microorganisms, enzymes, and pathogens. It is a common method used in canning and pasteurization. The process can be the tomato paste is typically heated to a specific temperature and held for a specific duration to ensure the destruction of harmful microorganisms and enzymes. However, the application for tomato paste, heat processing is often done during the canning process. The filled cans or jars are heated to a temperature that is sufficient to ensure product safety and stability.

In addition to this Lemon Juice Concentration adding to the tomato paste to provide the purpose of Lemon juice, or other acidic ingredients like citric acid, can be added to adjust the acidity of the product. This adjustment helps to create an environment that is inhospitable to the growth of harmful bacteria, particularly Clostridium botulinum. The process of Lemon juice concentration involves increasing the strength of the lemon juice by removing some of its water content. This concentrated lemon juice is then added to the tomato paste. It’s Application: Lemon juice is often used in canning recipes for its acidity, which contributes to both flavor enhancement and preservation.

2.9.9 Cooling, Packaging and Storage of tomato Concentrated paste

The purpose of Cooling is essential to halt the cooking process and prevent overcooking or changes in the quality of the tomato paste. It also helps in preparing the product for packaging. The Process of the hot tomato paste is rapidly cooled down to a temperature suitable for packaging. This can be achieved using cooling tanks, heat exchangers, or other cooling systems. However, the temperature: The specific cooling temperature may vary, but it is generally cooled to a temperature that is safe for handling and packaging.

Aluminum cans are also used for packaging tomato paste, and they offer several advantages similar to those of metal cans. Here are some reasons why aluminum cans are chosen for tomato paste packaging, light weight, recyclability, barrier properties, long shelf life, and resistance to corrosion, versatility in design, quick chilling and tamper evident packaging.

2.9.10 Physicochemical Characteristics of Tomato

Tomatoes exhibit a range of colors, with red being the most common. The color is influenced by pigments such as lycopene, carotenoids, and chlorophyll. The tomato properties will be determined those the physical characteristics of the processed paste quality are (pH, titratable acidity, soluble particles, viscosity, and color). Selected tomato varieties will exhibit significant differences in their morphological characteristics and paste quality. Color, consistency, viscosity, total soluble solids (Brix), acidity, water activity, lycopene and microbial stability. Analyzing these physicochemical properties helps in assessing the quality, acidity, taste, shelf life and nutritional content of tomatoes and tomato paste

2.9.11 Tomato Nutritional Composition

(Nasir et al., 2015), showed that the nutritional composition of tomato was described as below: Water content of tomato is quite high and is about 93-95%. Tomatoes contain between 5.5 and 9.5% of solid matter, of which roughly 1% is made up of seeds and peel (on a fresh weight basis). This wide range of solids % in tomato composition can be attributed to a number of factors, including variety, rainfall, soil properties, and irrigation. Lignin, cellulose, and pectin make up the majority of the 15-20% of total solids that are insoluble in tomato juice. The majority of soluble solids are made up of free sugars. The majority of the free sugars in tomatoes are lowering sugars. In tomatoes, sucrose is present in extremely small amounts no more than 0.1%. Glucose and fructose are the main reducing sugars that makeup 50-65% of tomato solids. The total sugar content of tomatoes varies from 2.19-3.55%. Tomato contains more fructose than glucose (54:46). Numerous polysaccharides, including xylan, pectin, cellulose, arabinoxylan, and arabinogalactan, are present in tomatoes. In tomato juice, these polysaccharides make up roughly 0.7%. The two most abundant polysaccharides are arabinogalactans and pectin, which together make up roughly half of the entire amount present. Cellulose and xylans make about 25 and 28% of the total amount of polysaccharides, respectively.

The predominant acid in tomatoes is citric acid as citric monohydrate. Other little amounts of acids like succinic, oxalic, and tartaric acid are also present in tomatoes. Tomatoes contain nineteen amino acids, according to their amino acid profile. Glutamic acid, which makes up about half of tomato juice's total amino acid composition, has the highest concentration of any amino acid. After glutamic acid, aspartic acid is the second most prevalent amino acid.

2.10 Behavior of Nutrients during Tomato Processing

(Nasir et al., 2015), reported that the behavior of nutrients during tomato processing is as follows:

2.10.1 Amino acids

Processing of tomato juice at a temperature above 100 °C for 20 minutes causes a remarkable rise in amino acid contents owing to partial hydrolysis and protein denaturation. The highest increase in the concentration was found in glutamic acid followed by aspartic acid, threonine, and alanine. Some amino acids like glutamine and asparagine are lost completely during processing due to their conversion into respective acids.

2.10.2 Vitamins

During the processing of tomatoes, ascorbic acid is primarily lost by oxidation. Ascorbic acid oxidation is influenced by a number of variables, including processing temperature, oxygen concentration, enzyme activity, and dissolved copper. Ascorbic acid is destroyed in direct relation to temperature and air, according to studies. Later research revealed that if the juice is not kept in the open air at a higher temperature for a long amount of time, the retention of ascorbic acid for both pre-heating techniques (hot and cold) is nearly the same. Retinol and other B vitamins are destroyed when tomato juice is heated for an extended period of time outside.

2.10.3 Acids

The acid content of tomato increases during its processing into juice. An increase in the concentration of acetic acid was observed up to 32.1%. There may be several reasons for this increase in acid content like the oxidation of alcohols, aldehyde, and some other compounds. It is considered that the breakdown of amino acids into their respective components is the major reason for the increased acid content in processed tomatoes. An increase in other acids like citric and malic was also observed in tomato juice. Researchers found that the acidity of hot break juice is less than that cold break juice and the pH of hot break juice was higher than cold break juice.

2.11 The effect of processing of tomato's on sensory properties

(Nasir *et al.*, 2015), investigates the effect of processing on the sensory properties of tomatoes as described below.

2.11.1 Color

During processing, the color of tomato paste may be slightly darkened due to the initiation of browning reactions. These reactions are not so important in terms of decreasing quality because they cause the red pigment formation that eventually adds up to the red color of tomato paste. Some reactions cause the browning of tomato paste like the Millard reaction and caramelization. Caramelization may occur due to high temperatures during processing. However, the Maillard reaction is not a major issue during the processing of tomato juice into the paste. Ascorbic acid is present in large quantities in tomatoes, and its breakdown during processing is thought to be the primary cause of the serum's darkening. However, browning can be reduced by lowering the pH and processing temperature.

2.11.2 Flavor

Processing alters completely the aroma of processed tomatoes from the fresh ones. It may be due to the loss of compounds that are volatile in nature due to high temperatures during processing or due to the formation of new compounds. Processing of tomato juice at higher temperatures in open air causes the production of terpenes due to the oxidation of carotenoids.

The Millard reaction during processing can also result in the production of certain sulfurous and carbonyl chemicals. Hexenal and cis-3-hexenal are crucial ingredients in the distinctive tomato flavor that is lost after processing. One significant element in the loss of tomato flavor is the conversion of cis-3-hexenal to trans-2-hexenal. The chemicals created by the decomposition of sugar and carotenoids may be a contributing factor in the cooked smell of processed tomatoes. The main component of heated tomato products' scent is dimethyl sulfide. During the heating process, the lipoxygenases that give tomatoes their characteristic flavor are broken down.

2.11.3 Firmness

A fruit's texture can alter as it ages, notably during ripening when it can quickly become softer. Crop texture may also be impacted by excessive moisture loss. The harvester may only need to gently crush the fruit in order to determine whether the crop can be harvested because these textural changes are detectable by touch. The texture of fruits and vegetables can now be measured with sophisticated tools, such as texture analyzers and pressure testers, which are currently offered in a variety of configurations. The fruit's surface is forced, which allows the penetrometer's or tetrameter's probe to pierce the fruit's flesh and measure its firmness.

2.11.4 Texture

(ABDU, 2016), noted that processing tomatoes altered the texture in the following ways: Tomatoes are distinctive fruits and vegetables made up of a variety of tissues that are essential to the feeling of texture. Products made from tomatoes are a growing element of the American diet and are a crucial source of antioxidants, potassium, and vitamin C. (primarily lycopene). Understanding the textural characteristics of processing tomatoes is essential for ensuring product acceptability. By measuring, controlling, and optimizing these characteristics through careful variety selection and management of unit operations, products that appeal to consumers can be produced. Both subjective and objective tests, which can be destructive or nondestructive in nature, can be used to gauge the texture of processing tomatoes.

2.11.5 Factors Affecting Tomato Texture

Production-related or tissue-specific factors can both have an impact on the textural characteristics of processing tomatoes. Cultivar or variety, maturity at harvest, degree of ripeness, cultural practices, such as fertilizer application, hormone application, amount of water, and sun exposure, as well as environmental stresses on the tomato plant prior to harvest, such as drought, salinization, water, chilling, and freezing stresses, are all production-related factors.

2.11.6 Effects of Variety and Maturity

The textural characteristics of processing tomatoes are greatly influenced by both tomato type and the maturity stage at which the fruit is selected. Tomato breeders had to create varieties that could endure the additional rough handling sustained during harvest as a result of the design of the automated tomato harvester in (Baur & Iles, 2022) To preserve the structural integrity of tomato fruit, thicker pericarp walls, more pericarp tissue, and fewer molecules were used. As a result, the insoluble solids content increased, leading to improvements in consistency.

Different tomato varieties can have varying levels of acidity, sweetness, and thickness, which can influence the taste, texture, and color of the resulting tomato paste.

Some varieties may have more intense flavors or higher concentrations of certain nutrients, which can affect the nutritional profile of the paste.

The choice of tomato variety can also impact the yield and consistency of the paste during processing.

2.11.7 Effect of lemon juice concentration tomato paste

Lemon juice is often added to tomato paste as a natural preservative due to its acidity, which helps inhibit the growth of microorganisms and prevents spoilage (Olaiya & Aremu, 2013).The concentration of lemon juice can affect the pH level of the paste, which in turn can influence its stability and shelf life(No *et al*., 2007).Higher concentrations of lemon juice may impart a more pronounced citrus flavor to the paste, which can alter its overall taste profile.

2.11.8. Effect of storage temperature on tomato paste

Lower temperatures inhibit the growth of microorganisms, including bacteria, yeast, and mold, which can spoil the tomato paste. Storing tomato paste at 4°C helps prevent microbial contamination and extends its shelf life(Fatima *et al*., 2015).also Enzymatic reactions that contribute to the degradation of color, flavor, and nutrients in tomato paste are slowed down at lower temperatures. Storing tomato paste at 4°C helps preserve its quality by minimizing enzymatic browning and flavor changes. Storing tomato paste at 4°C helps retain the nutritional content of vitamins, minerals, and antioxidants present in tomatoes. This ensures that consumers can benefit from the nutritional value of the paste over an extended period.

Overall, storing tomato paste at 4°C is beneficial for maintaining its quality, safety, and shelf life by inhibiting microbial growth, reducing enzymatic activity, preserving texture and color, and retaining nutritional content and flavor. However, it's essential to ensure proper packaging and handling practices to prevent moisture absorption and flavor contamination during storage.

2.12. Effects of Cultural Practices and Environmental Conditions

2.12.1Temperature

According to an excellent assessment of tomatoes (ABDU, 2016), environmental factors have a significant impact on how firm the tomato fruit is. At temperatures between 30 and 40°C, ethylene synthesis, polygalacturonase activity, lycopene synthesis, and carotenoid synthesis are all inhibited. Tomatoes are also sensitive to chilling temperatures (above -1°C and below 12.5°C) and freezing temperatures (-1°C). A water-soaked look, softening, and drying of the gelatinous molecular substance are signs of freezing injury. The temperature and length of exposure determine how severe a chilling injury is. Although symptoms are more obvious after being transferred to ripening temperatures, chilling is more likely to happen in green ripe tomatoes as opposed to red ones. Failure to ripen fruit, uneven fruit ripening, and freezing injury are all signs of chilling.

The three nutrients nitrogen, phosphorus, and potassium are crucial for tomato development and, consequently, for maintaining its textural integrity. Both the fruit's quality and harvest ripeness may be impacted by nitrogen. According to some reports, applying nitrogen at high rates may lead to lesser soluble solids, blotchier ripening, more yellow eye, and inferior machinability. By encouraging the growth of the roots, a strong stem, and healthy foliage, phosphorus influences the quality of the fruit. Acidity, color, and form of tomato fruit are all influenced by potassium. With potassium making almost 85% of the tomato's total composition, tomatoes' acidity rises as well as their color and form. Low potassium levels abbreviate the tomato fruit's growth cycle, resulting in smaller, less dense fruits.

2.11.2 Ripening Associated Softening

The cell turgor, cell anatomy (shape, size), the proportion of intercellular spaces, the chemical composition of the cell wall and middle lamella, as well as the unique arrangement of all the polymers constituent of the entire wall structure, all influence the textural characteristics of a given plant tissue. Numerous elements, including fruit type, ripening stage at harvest, agronomic procedures, and postharvest handling circumstances, have an impact on fruit texture. Fruit softening can result via turgor loss (as with dehydration), starch breakdown (like with banana fruit ripening), or degradation of polymer components of the cell wall.

2.11.3 Tomatoes and tomato products Nutritional Composition Health Benefits

For each nutrient, tomatoes are a good, very good, or outstanding source. Furthermore, due to their economic significance as well as their nutritional worth for the human diet and subsequent importance to human health, tomatoes have developed into a significant cash and industrial crop in many regions of the world (Ayandiji *et al*., 2011).The nutrients, minerals, lipids, vital amino acids, magnesium, dietary fibers, phosphorus, and vitamins B and C are all abundant in tomatoes(Ayandiji *et al*., 2011). So, after being consumed, it offers a source of these three nutrients. The table below lists 15 important nutrients and how much of each one you may get by eating 123 grams of mature tomatoes in Table 2.1(Yada *et al*., 2011**).**

Table 2. 2 Major nutrients derived from tomatoes

Nutrient	Amount
Calcium	1.2mg
Carbohydrate	4.4**g**
Copper	0.073mg
Dietary fiber	1.5g
Fat	0.25
Iron	0.33mg
Magnesium	1.4mg
Niacin	0.731mg
Pantothenic acid	0.109mg
Phosphorus	3mg
Potassium	292mg
Protein	1.0g
Thiamin	0.046g
Total sugars	3.23g
Vitamin C	16.9mg

The use of tomatoes can enhance well-being and reduce the risk of conditions including cancer, osteoporosis, and heart disease. Regular tomato eaters are at a lower risk of developing cancers such as lung, prostate, stomach, cervical, breast, oral, colorectal, esophageal, pancreatic, and many more types. According to numerous studies, tomatoes and garlic should be ingested together to prevent cancer (Yimenu, 2022). Alpha- and beta-carotene, lutein, and lycopene are the four main carotenoids that can be found in tomatoes. Although each of these carotenoids may have advantages, they also work well together as a whole (that is, they interact to provide health benefits). Lycopene is the name for the tomato-derived red pigment. This substance seems to function as an antioxidant, scavenging free radicals that could harm bodily cells.

All three of these potent antioxidants beta-carotene (which acts as vitamin A in the body), vitamin E, and vitamin C are present in tomatoes. Lycopene is a crucial antioxidant that aids in the battle against the development of malignant cells as well as various types of health issues and disorders. Lycopene is an essential antioxidant that can be used to flush out free radicals in the body. The tomato is so rich in this nutrient that it really gets its deep red color from it(Yimenu, 2022).

2.11.4 Market Study

Past Supply and Present Demand Processed and canned tomato paste and tomato juice are consumed by urban households, hotels, restaurants, hospitals and the like. These products are supplied both from domestic production and imports. The sole domestic producer of tomato paste and juice is Merti Agro Processing Industry under upper Awash Agro Industry Enterprise.

Table2. 3 Domestic Production of Tomato Paste and Import of Tomato Juice

Year	Domestic production of paste(tones)	import tomato juice(tones
1999/01	2,424	15.5
2000/01	1,730	10.0
2001/02	555	6.1
2002/03	2,878	16.8
2003/04	1,846	8.3
2004/05	1,846	5.3

*Source: CSA, statistical Abstract of Ethiopia Customs Authority, Annual External Trade statistic (2006).

2.11.5 Market Opportunities

The Processed Fruits and vegetables have a large domestic demand market in Ethiopia with a population of 90 million. There is a demand both in the local market and as well as the export opportunity to the neighboring countries and the Middle East. The availability of raw material is secured for wineries, tomato processing plants, and vegetable canning factories which require grapevine, tomato, and various types of vegetables for processing.

In Ethiopia, fruit processing is mainly to extraction of fresh juice which is sold on the local market. The Merti processing factory is producing fruit juice for the local market. At present, a range of fruit juices are imported into the country. The demand for fruit juices on the local market is high as indicated by the volume of imports. This is a strong indication of the existence of investment opportunities in fruit juice processing for the local market (ABDU, 2016).The most popular fruit juices imported into the country are shown below.

Table2. 4 The Volume and Value of Fruit Juice Imports in Ethiopia (2009).

Fruit juice	2009		2010		2011	
	Volume (Kg)	Value (Birr))	Volume (Kg)	Value (Birr)	Volume (Kg)	Value (Birr)
orange	22,110	114,938	60,741	743,751	50,529	961274
grape	5,689	179,980	3,971	66,311	31,001	413,495
others	1,090	16,584	300,425	3,947,090	416,970	10,029,261
Pineapple	294,757	3,462,641	531,439	6,576,537	1,060,958	16,774,035
tomato	951,920	9,022,271	1,509,352	20,671,644	1,558,240	22,283,409
Apple	430,398	6,004,336	381,461	6,964,263	586,445	10,125,950
Other	1,225	35,741	3,204	110,097	953,901	12,036,835
Mixture	339,039	3,759,322	980,419	10,250,038	1,237,883	17,106,937
Total	2,046,228	22,595,813	3,771,012	49,329,731	5,895,927	89,731,196

*Source: Ethiopian Customs Authority, 2015

*Note: Exchange rage 1 US$ = 20.36 Birr (as of March 9, 2015)

2.11.6 Quality and Safety Control

Determining the content and properties of food is frequently necessary for investigations in food science and technology, whether they are conducted by the food industry, governmental organizations, or academic institutions. As they labor to monitor food composition and assure the quality and safety of the food supply, food scientists face challenges from consumer trends and desires, the food industry, and national and international regulations. All food items must undergo analysis as part of a quality management program at all stages of development (including raw materials), manufacture, and distribution. Additionally, competitive items and issue samples are analyzed.

For regulatory purposes and common quality control, the features of foods (i.e., chemical composition, physical properties, and sensory properties) are employed to provide precise answers. Food firms must pay growing attention to government rules and guidelines, as well as to the policies and standards of international organizations, in order to efficiently offer safe, high-quality meals in a national and worldwide market place (Nielsen, 2010).

All parties participating in the food supply chain must agree that the primary responsibility for ensuring food quality and safety rests with those who produce, prepare, and trade food, and that the public control system should be based on scientific risk assessment. The operator's responsibilities cover every participant in the food supply and marketing chain, from primary production to final consumption, in both exporting and importing nations. GAP, GDP, GMP, and GHP (for example, HACCP) minimize possible risks associated with the produce along the production and distribution chain as well as operators' duties for food quality and safety as well as (ABDU, 2016)

The GMP regulations define requirements for acceptable sanitary operation in food plants and include the following relevant to food processing:

Ingredients, particularly any spices that can be contaminated with bacteria, the product's acidity or moisture level, and the quantity of any preservatives employed are some factors that need to be looked at. Any sources of contamination from structures or water sources should also be mentioned. Critical Control Points (CCPs) are the stages in a process where a mistake might compromise a product's safety, and these are the stages that require the most attention (Iaiani *et al*., 2021).

CHAPTER THREE

3. Material and Methods

3.1 Sample Collection

Tomato variety namely Galiliea, Gabi and Anna, most popular and most known tomatoes in Ethiopia, lemon var.ucr and (Galilea, Gabi and Anna) variety were (lemon var.ucr) , obtained from Woramit Horticulture agricultural research institute, and Netherlands Development Organization(SNV) in Bahirdar branch agricultural research center, respectively. The four samples were collected during the same 2015 E.C. season. All preventive measures were taken while collecting the ripe samples to avoid adventitious contamination including wearing gloves, using clean plastic jar. Galilea (12 kg), Gabby (12 kg), Anna (12 kg) and 5 kg lemon ripe were collected and prepared for the respective laboratory analysis and stored at around 4°C.

Selection criteria for three varieties included some physical properties, such as adaptability to the local climate of growing conditions, disease and pest resistance tolerance, storage and transportability, and market demand. Consumer preferences for tomato, with its comparative advantage, social acceptance and support by government policymakers, potential, and availability in different areas, ultimately contribute to food security, economic growth, and sustainable agriculture (DERSO & ZELEKE, 2015).

Analytical grade chemicals and reagents used for chemical analysis of the tomato paste were prepared in Bahir Dar Institute of Technology in Food processing laboratories (BiT). The laboratory-based experimental works were conducted at Bahir Dar Institute of Technology in Food processing laboratories.

Figure 3. 1 Raw materials used during the experiment

3.2 Experimental Site

The experiment was conducted at Bahir Dar Institute of Technology (BiT) (pH, TSS, titrable acidity, vitamins C, colour, moisture, water activity, and microbial analysis) at the Woramit Horticulture Agricultural Research Centre (lemon sample) on the availability of the laboratory facilities.

3.3 Experimental Design

The experiment was analyzed with two factors: variety (three types), lemon juice (two levels), and temperature (three levels) using a (3x2x3) full factorial experimental design comprising three variables of tomato varieties (Galilea, Gabi, and Anna) and three stored temperatures (4, 14, and 24 °C). The details of the treatment combinations can be found in Table 3 below. A control sample, prepared at room temperature, was included to compare with the controlled experimental runs.

Table 3. 1 Treatment combination of the experiment

Factor 1:variety	Factor2:Lemon juice concentration	Factor 3:Storage condition (Temperature)		
		T1	T2	T3
V1	L1	V1*L1*T1	V1*L1*T2	V1*L1*T3
V2	L2	V2*L1*T1	V2*L1*T2	V2*L1*T3
V3		V3*L1*T1	V3*L1*T2	V3*L1*T3
		V1*L2*T1	V1*L2*T2	V1*L2*T3
		V2*L2*T1	V2*L2*T2	V2*L2*T3
C1 C2	C3	V3*L2*T1	V3*L2*T2	V3*L2*T3

Where, F1 = tomato variety, V1= Galilea V2= Gabby and V3= Anna, F2= lemon juice concentration, L1=5%, L2= 10% F3 = storage temperature, T1 = 4 °C, T2=14°C and T3=24 °C, control (C1, C2 and C3) C1 = Galilea, C2= Gabby and C3= Anna

3.4 Experimental framework

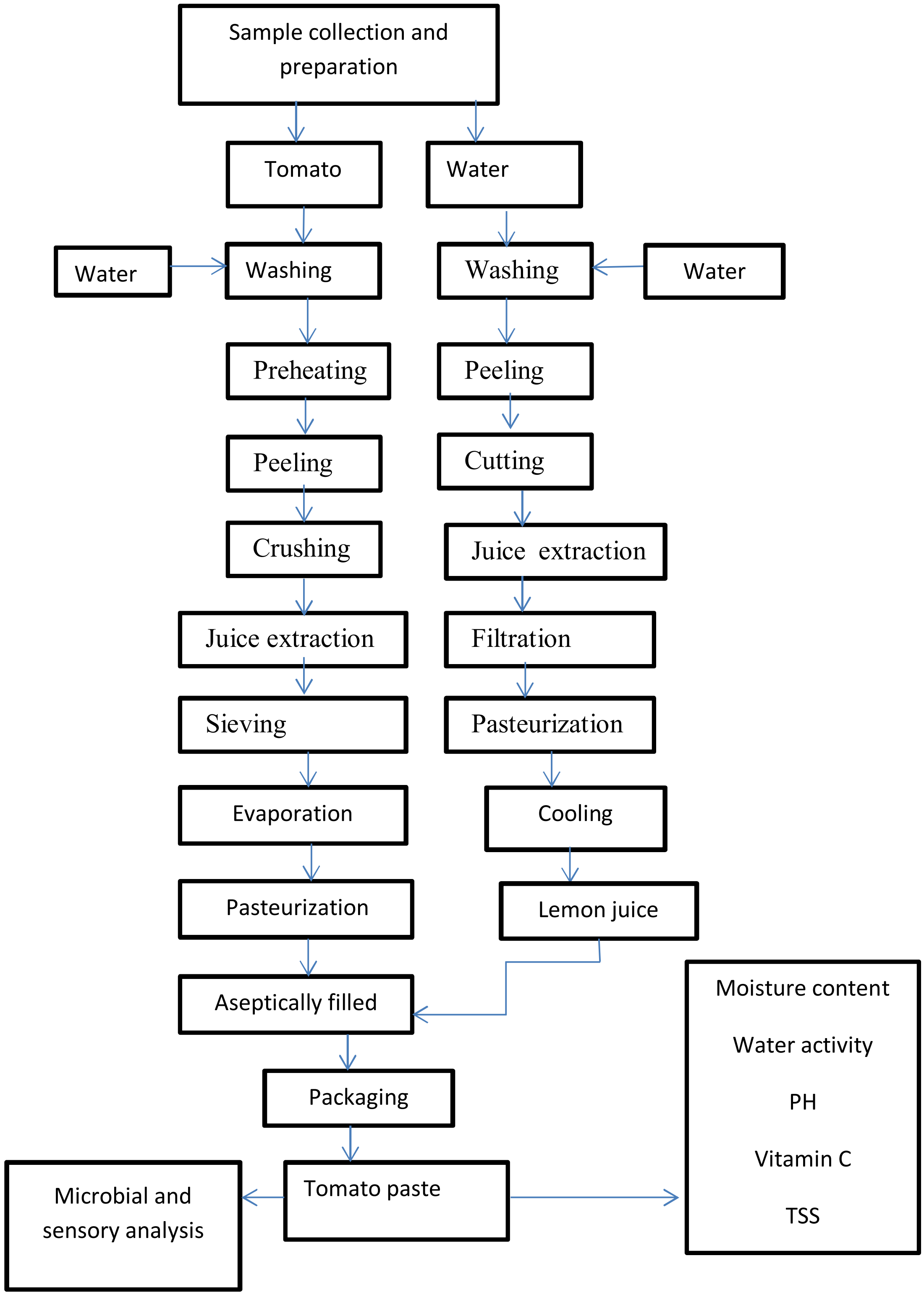

Figure 3. 2 Experimental frame work

3.4 Sample Preparation

Undamaged three tomato varieties of fruits were sorted for uniform shape, size, colour, and ripeness, free from disease and bruises. Tomato fruits were cleaned to remove dust from the surface, washed, and steam blanching was done at 90 °C for 7 minutes in an electrical thermostatic water bath (DK-98-IIA model, USA). The tomatoes were then easily peeled manually using the knife and cut into quarters or smaller pieces for easier blending. Then, transfer the crushed tomatoes to a blender or food processor. And also, blend the tomatoes until you achieve a smooth, paste consistency. Then Cooking Pour the tomato paste into a large pot and place it over medium heat. Bring the paste to a gentle stirring occasionally to prevent sticking or burning.

3.5 Experimental procedure

Generally, the tomato paste preparation process involves several steps, as described in Figure 3.3

Sorting and cleaning: The parameters used for tomato sorting are the colour and physical state of the fruits. Therefore, the ripe tomato fruits of uniform size were selected, and they have been sorted out to eliminate bruised, punctured, and damaged ones. Washing is a critical control step in the processing of tomato products with a low microbial count. The ripe tomato sample was washed with potable water to remove dirt, mould, insects, and other contaminants.

The sorted tomatoes were then washed in potable water. The cleaned tomatoes were individually cut into four quarters, and the seed and pulp were removed manually by using a clean knife. The seed and peel removed pulp further copped and crashed by fruit juices.

Breaking: The seed and peel were removed, the pulp was further copped and crushed by a household juicer, and then break temperatures were used as a normal break at 70°C and a hot break at 90°C for the action of natural enzymes for 7 minutes at all the breaking temperatures (Hassen et al., 2019).

Evaporation: After sorting and effective cleaning, the tomato paste entered the evaporation process. The tomato paste was evaporated at 80°C and 90°C to achieve

28°Brix of TSS concentration in conventional techniques by a kitchen saucepan at atmospheric pressure for 2 hours. This is done after the respected break.

Pasteurization: After evaporation, the tomato paste was filled in previously sterile screw sample jars and pasteurized in a water bath at 100°C for 14 minutes at atmospheric pressure.

The pasteurized tomato paste was cooled and stored at ambient temperatures. This process was done after concentration. The tomato paste was prepared as illustrated in Figure 3.3

Then tomato paste was filled in sterilized open-top sanitary (OTS) metal can containers with a net weight of 100 g and added to the lemon juice concentration (5 ml and 10 ml). Then the sealed product was pasteurized in a hot water bath at 100 ˚C for 14 min and cooled in running tap water. Finally, the products were labeled and kept at "room temperature" or normal storage conditions (recording with a data logger), which means storage in a dry, clean, well-ventilated area in the Food Research Laboratory, Department of Food Technology, Bahir Dar Institute of Technology, until used for further physicochemical, sensorial, and microbial analysis.

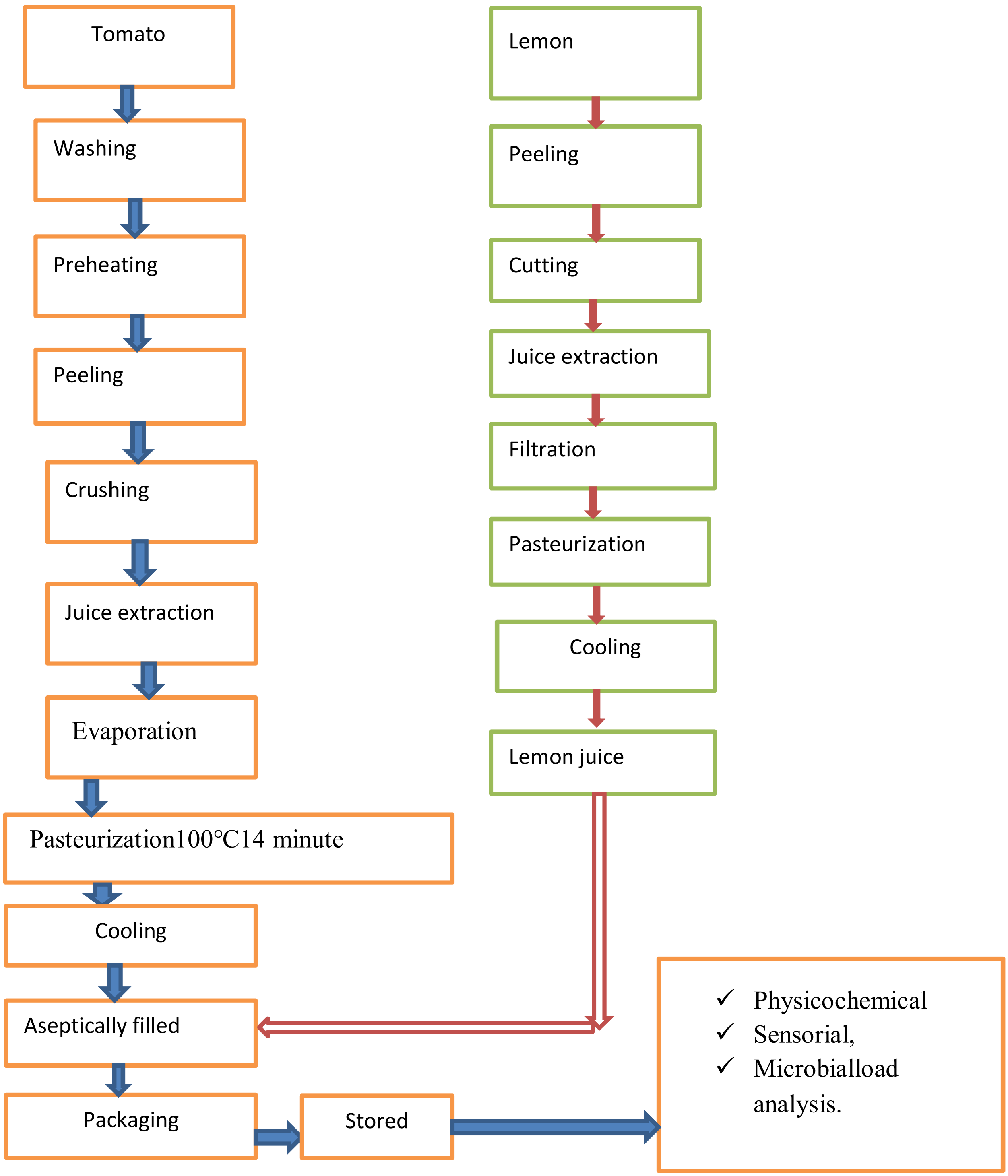

Figure 3. 3 Flow diagram of tomato paste production

3.6 Physico-Chemical Properties of Heat Treated Tomato Paste

3.6.1 Determination of Vitamin C (Total Ascorbic acid) Content

The vitamin C content of tomato paste was determined according to the AOAC method (Horwitz, 2010).Ten grams of sample were crushed, and 25 mL of metaphosphoric id-acetic a acid solution was added to a 50 mL volumetric flask. The mixture was shaken gently to homogenize the solution and was diluted to the mark with metaphosphoric acid and acetic acid. The mixture was then centrifuged at 4000 rpm for 15 min. An aliquot of 0.23 mL of 3% bromine water was added to 4 mL of collected supernatant to oxidize the ascorbic acid to dehydroascorbic acid. Then, 0.13 mL of 10% thiourea was added to the mixture to reduce the excess bromine. 1 mL of 2, 4-dinitrophenylhydrazine solution was then added to the mixture to form an osazone complex. The obtained solution was left at 37 °C for 3 hours in a water bath before refrigerating for 30 minutes. Finally, 5 mL of 85% H_2SO_4 was added to the mixture to obtain the coloured solution. The absorbance of the coloured solution was recorded at 521 nm (model: Shimadzu 1800, USA). The total vitamin C content in the sample was calculated based on the standard equation y = 0.01544x minus 0.22 (coefficient R2 = 0.977).

3.6.2 Total soluble solids

The total soluble solids (TSS) levels of the fruit and puree were determined according to the AOAC (2000) method by using a hand refractometer (RX 5000, Atago, and Tokyo, Japan) (Horwitz, 2010).An appropriate quantity of a sample of each product was placed on the prism plate of the refractometer, and the reading appearing on the screen was directly recorded as total soluble solids. Results were expressed in Brix°.

3.6.3. pH Value

The pH of tomato fruit tomato paste was recorded according to (AOAC, 2005) by using a digital pH meter (Model: PH6-RSCW, USA). The pH meter was standardized with the help of a standard buffer solution before measurement.

3.6.4 Titratable acidity

The titrable acidity was analyzed according to AOAC (2000), method number 942.15 (Horwitz & Latimer, 2000).Ten grams of the sample were diluted to 250 mL using distilled water. An aliquot (50 mL) was mixed with 0.2 mL of 9-phenolphthalein indicator and titrated with 0.1 N NaOH to the first appearance of the pink endpoint. TA was expressed as mg of citric acid per 100 g of tomato paste sample.

To calculate the percent acidity of fruit juice (citric acid):

Weight of citric acid = 0.1M NaOH x vol. of NaOH (in litres) x 192.43/**3**/1 ……………………………..……………………………………………………………. (1)

% of total acidity = (wt. of acid / wt. of the sample) x 100 ……………………….... (2)

- The normal range for citric acid is 0.39–1.1%.
- 192.43 g/mole is the molecular weight of citric acid.

3.6.5 Color measurements

Colour changes of tomato fruit and tomato paste of three varieties with thermal processing were investigated using a colorimeter (CM-600d, Japan).The colour parameters L* (lightness), a* (redness/greenness), and b* (yellowness/blueness) were evaluated (Win & Setha, 2022).

3.6.6 Determination of Moisture Content

The moisture content was determined according to the (AOAC, 2005) method. Five grams of the sample were taken in a flat bottom dish (pre-weighed), kept for 5 hours in a drying oven (DHG-9140) at 105 °C, and weighed. The loss in weight was regarded as a measure of moisture content, and this was calculated by the following formula:

$$Mositure(\%) = \frac{\text{weight of fresh sample} - \text{weight of dry sample}}{\text{weight of a fresh sample}} \text{x}100 \quad \text{……………………….(3)}$$

3.6.7 Water Activity (a_W)

The water activity (a_w) of the tomato paste sample was measured at 25±1 °C by a water activity meter (aqualab Dew Point 4TE, USA). Before the sample analysis, the a_W meter was calibrated with the kit provided (Sharma et al., 2015). All measurements were made in triplicate, and the averages are reported. This was evaluated by determining the total solid content as well as the water content using the methods of AOAC (2004).

3.7 Sensory Evaluation

The tomato paste products that were produced from three different varieties and stored at different temperatures (4, 14, and 24 °C) with lemon juice were evaluated by semi-trained panelists consisting of the staff, postgraduates, and undergraduate students of the Food Technology department at Bahir Dar Institute of Technology. The panel members were selected based on their ability to discriminate and scale a broad range of different attributes of tomatoes and tomato products. An orientation programme was organized for the panel members to brief them on the objective of the study. The tomato paste samples were brought to the processing lab and served to the panelists. The samples were assessed for colour, flavour, taste, and overall quality by 30 panelists. The 5-point hedonic scale (5=like extremely, 4=like moderately, 3=neither like nor dislike, 2=dislike moderately, 1=dislike extremely) was used. The panelists tested the tomato paste product and rinsed their mouths using drinking water between samples. Samples receiving an overall quality score of 3 or above were considered acceptable (Lim, 2011).

3.8 Microbial Load Determination

The total microbial load of tomato paste that was made from three tomato varieties and stored at three temperatures was conducted in the Food Grade Research Laboratory, Department of Food Engineering, and Bahir Dar Institute of Technology. The microbial load of samples was evaluated at different times (30-day intervals), and products of selected tomato varieties with a moderate heating temperature under the limit were done after 90 days at 30-day intervals. The storage conditions of the tomato variety were recorded with data loggers (HOBO® temp/RH logger, Onset®, and ACR temperature logger, USA) used for measuring the temperature and relative humidity of the storage room.

3.8.1 Total bacterial count

The determination of the total microbial contamination of the pulp samples was performed after 30 days (tangible observation of microbial detection) until three months by the method (with some modification) outlined in a compendium of methods for the microbiological examination of foods (Akhtar et al., 2010). One ml of aliquots from a suitable dilution was transferred aseptically into sterile Petri dishes, and to each dilution, 10-15 ml of melted and cooled 42°C plate count agar was added (Feldsine *et al*., 2002).The inoculums were mixed with media and allowed to solidify; the plates were then incubated at 37 ºC for 48 hours. A colony of viable bacteria was counted manually by the colony display unit, and the results are expressed in CFU per grams of sample (Bhat, 2016).

3.8.2 Yeast and mold enumeration

After a suitable dilution of the sample (0.1g chloramphenicol per one liter of medium) to inhibit bacterial growth, samples were spread all over the plates using a sterile bent glass rod. Plates were then incubated at 25–28 ℃ for 96 hours. Colony-forming units (CFU) were counted using a visible light manual, and the results are expressed in CFU per grams of sample (Pala & Toklucu, 2013)

3.9. Statistical Analysis

Each determination was performed on sixty- three different samples tested in triplicate, and the results were then averaged. The means of three replicates and their standard deviations were determined for all samples. However, the experimental data was analyzed in triplicate by using a general linear model (PROC GLM) of the Minitab software version 20. The combinations of levels of factors involved in the instruction were investigated for significant differences using an ANNOVA. The least significant difference (LSD) test was used to separate the means when there were significant differences among treatments at a 5% level of significance. The graphs were created using Sigma Plot software version 15 (Cihon *et al*., 2021).

CHAPTER FOUR

4 Results and Discussion

4.1 Physicochemical properties raw tomato and of tomato paste

The physical properties of tomato fruit, like fruit weight, firmness, color, pH, Titrable acidity, total soluble solids, vitamin C, moisture content, and water activity percentages, were measured and compared for the three varieties. The findings are presented in Table 4.1.

4.1.1 Firmness

The firmness of raw tomato fruit ranged from 4.4 to 2.4 kg in Galilea and Anna, respectively. Due to this reason, the ripening of tomatoes involves a series of biochemical and structural changes that lead to a decrease in firmness. This softening process enhances the palatability of the fruit, making it more appealing for consumption. The degree of softness can be a useful indicator for consumers and producers to determine the optimal time for harvesting and enjoying tomatoes. This pressure helps maintain the structural integrity and firmness of the tomato. Firmness measures the ripeness of tomato fruits. However, Galilea varieties have low firmness in ripe tomatoes, which is the result of the complex biochemical and physiological changes that occur during the ripening process(Hoeberichts *et al.*, 2002).These changes are orchestrated by enzymatic activities that break down structural components, leading to a softer texture that is more palatable for consumption. The firmness contents of Anna, Gabi, and Gelila in this study were 4.4, 4.1, and 2.4 grams, respectively, which is within the range of (ABDU, 2016).raw tomato weight ranged between 4.3, 4.13, and 4.09 grams.

4.1.2 Color

(Win & Setha, 2022), were evaluated the specific L*, a* and b* values for the color of raw tomatoes can vary depending on factors such as the variety of tomatoes, ripeness, and growing conditions. However, I can provide you with some general information based on typical observations (Lightness):* The L* value for raw tomatoes is generally in the range of 35 to 70. This indicates a moderately to relatively high level of lightness, as tomatoes are often bright and vibrant. a* (Green to Red). The a* value for unripe green tomatoes may be in the range of -20 to 0, indicating green hues.

As tomatoes ripen, the a* value increases, and ripe red tomatoes typically have positive a* values in the range of 10 to 30, indicating red hues. The b* (Blue to Yellow) the value for raw tomatoes is typically positive, indicating the presence of yellow hues. The range may be around 15 to 35 for yellow and ripe tomatoes. The Galilea Varity color intensity high due to that in ripe tomatoes is primarily attributed to the accumulation of lycopene, the breakdown of chlorophyll, and the overall ripening process.(Abdelhamid *et al*., 2021). This vibrant red color is not only visually appealing but also serves as an indicator of the fruit's ripeness and readiness for consumption. The Anna variety of color is low because the color of tomatoes is often associated with their maturity level.

The color content of Galilea, Gabby and Anna in this studies were a* values 37.14, 34.9 and 34.14 respectively range by the (Shatta *et al*., 2017).

4.1.3 pH

The pH of fresh tomatoes typically ranges from about 4.0 to 4.6. The pH is a measure of the acidity or alkalinity of a solution and is determined by the concentration of hydrogen ions. The pH scale ranges from 0 to 14, with 7 being neutral. Values below 7 indicate acidity, while values above 7 indicate alkalinity. Tomatoes are typically slightly acidic, with a pH ranging from about 4.0 to 4.6. This level of acidity contributes to the characteristic taste of tomatoes. The pH of a substance is a measure of its acidity or alkalinity and is determined on a scale from 0 to 14, where a pH of 7 is considered neutral, values below 7 are acidic, and values above 7 are alkaline. The three of fresh tomato variety the highest pH value is Gelila, and the lowest value Anna and respectively in Table 4.2.The acidity1of Gelila is high in tomatoes is mainly due to the presence of organic acids, such as citric acid, malic acid, and to a lesser extent, oxalic acid by(Qiu *et al*., 2018). These acids contribute to the tart flavor of tomatoes. As tomatoes ripen, their sugar content increases, which can slightly reduce their perceived acidity, but they are still considered acidic. However, Anna variety is the lowest pH value because of This acidity is primarily due to the presence of organic acids, such as citric acid and malic acid, in the fruit by (Etienne et al., 2013)The pH content of Anna, Gabby and Galilea in this studies were 4.83, 4.41 and 4.33 respectively which is within the(ABDU, 2016),raw tomato weight ranged 4.51,4.45 and 4.33.

4.1.4 Titrable Acidity

Titrable acidity (TA) is a measure of the total amount of acids present in a solution, expressed as the equivalent amount of citric acid. It is determined through titration with a base (usually sodium hydroxide) and is often reported as a percentage or grams per litre of citric acid. The acids in tomatoes include citric acid, malic acid, and others.

The Anna variety has the highest TA, and the Galilea variety has the lowest. The titrable acidity of Anna variety is highest because tomatoes contain various organic acids, such as citric acid and malic acid. These acids contribute to the overall acidity of the fruit (Hernández Suárez *et al*., 2008). While the Gelila variety has lower TA acidity due to the tomatoes ripening, they generally undergo changes in flavour and acidity. Fully ripe tomatoes may have lower titratable acidity compared to unripe or partially ripe tomatoes. The balance between sweetness and acidity often shifts as tomatoes mature(Zakriya *et al*., 2023).

The Titrable Acidity content of Anna, Gabby, and Galilea in this study was 0.51, 0.44, and 0.42 percent citric acid, respectively, which is within the range of(Tigist *et al*., 2013),Raw tomato TA ranged from 0.52, 0.46, and 0.41 percent citric acid. The titratable acidity of fresh tomatoes is typically in the range of 0.30% to 0.50% citric acid equivalent. This range can vary among different tomato varieties.

4.1.5 Total Soluble Solids

The acceptable Total Soluble Solids (TSS) content in tomatoes can vary depending on the intended use, whether the tomatoes are destined for fresh consumption or not. TSS is commonly measured in degrees Brix (°Brix), which represents the percentage of soluble solids in a solution. The highest TSS value of raw tomato Anna is 4.87 ºBrix, and the lowest is 4.33 ºBrix at Gellila variety. However, Anna Varity is the highest TSS value because of have varying natural levels of sweetness and acidity by (Agbemavor *et al*., 2014).The Gelila Varity has lowest TSS value due to tomato have different genetic profiles, and some may naturally have lower TSS content by (Athinodorou *et al*., 2021).The TSS content of Galilea, Gabby and Anna in this studies were(4.87, 4.51 and 4.33) ºBrix, respectively, which is within the range of 4.8, 4.5, and 4.33 °Brix.

4.1.6 Vitamin C

The three tomato varieties with the highest vitamin C content are Galilea (39.9 mg/100 grams) and Anna (28.7 /100 grams). The vitamin C content in Anna is highest because varieties have different genetic compositions, and some varieties may naturally have higher levels of vitamin C (Topuz & Ozdemir, 2007).Gelila variety has a low vitamin C content due to the fact that tomato varieties have different genetic compositions and may naturally have lower levels of vitamin C. Fresh tomatoes can vary based on factors such as the specific tomato variety, growing conditions, ripeness at harvest, and storage conditions. On average, tomatoes are a good source of vitamin C, also known as ascorbic acid, which is an essential antioxidant. Here are some general guidelines for the vitamin C content in fresh tomatoes: average vitamin C content, variation among the varieties, ripeness impact, growing conditions, and storage conditions. The vitamin C content of Anna, Gabby, and Galilea in this study was (28.7- 39.9 mg/100 g, respectively, which is within the range of (29.5- 36.5) mg/100 g by (Lukum et al., 2023).

4.1.7 Moisture

The moisture content of those three varieties is highest in Anna, with the lowest value put and the lowest at Galilea from Table 4.1. The tomato with the highest moisture content is Anna, because the moisture content in tomatoes tends to decrease as they ripen. They may have a higher moisture content compared to tomatoes harvested at a fully ripe stage. Galilea varieties have lower moisture content due to the fact that the moisture content in tomatoes tends to decrease as they ripen. They have a lower moisture content compared to tomatoes in the less-ripe stage. (CAROLINE, 2011).Fresh tomatoes typically have moisture content ranging from about 90% to 95% or even higher, depending on the variety and ripeness. The moisture content of, Anna, Gabby, and Galilea, in this study was (85.0- 90.00)%, respectively The moisture content of Anna, Gabby, and Galilea in this study was (83.24-96.67)%, respectively, which is within the range of(Aboagye-Nuamah *et al*., 2018).

4.1.8 Water activity

The water activity of those three varieties is highest in Galilea, with the lowest value put and the lowest at Anna from Table 4.1. The water activity (aw) of fresh tomatoes is generally high due to their high water content. Water activity is a measure of the availability of water for microbial growth and chemical reactions within a product. It is expressed on a scale from 0 to 1, with pure water having a water activity of 1. Fresh tomatoes typically have a water activity close to 1, reflecting their high water content, which is often above 90%. The exact water activity can vary depending on factors such as the specific variety of tomatoes, growing conditions, and ripeness at harvest. Anna variety water activity is high because of the genetic factor; in other words, the water activity of Anna is low due to the presence of organic acids such as citric acid and malic acid. These acids contribute to the overall acidity of the fruit and can also influence water activity (Doores *et al*., 2005).

The water activity content of Anna, Gabby, and Galilea in this study was (0.92-0.97) percent, respectively, which is within the (Muratore *et al*., 2008) raw tomato water activity range of (0.93- 0.97) percent.

Table 4. 1 Results of Raw Tomato Varieties Physicochemical Analysis (Mean ± SD)

Tomato	firmness	Color								
variety	(Kg/mm2)	L*	a*	b*	pH	TA%	TSS	Vitamin C	moisture	aw
Galilea	2.4±0.1^{c}	23.69±0.93^{c}	37.14±2.02a	29.32±6.73a	4.33±0.01^{c}	0.51±0.03^{a}	4.87±0.1^{a}	39.9±0.2^{a}	85.00±1.00^{a}	0.92±0.01^{b}
Gabby	4.1±0.1^{b}	24.45±2.97^{b}	34.9±1.22b	28.74±3.21a	4.41±0.02^{a}	0.44±0.02^{b}	4.51±0.1^{b}	32.1±0.3^{b}	85.33±1.53^{a}	0.95±0.01^{a}
Anna	4.4±0.1^{a}	32.56±2.01^{a}	34.14±0.95^{a}	29.53±5.44^{c}	4.83±0.01^{b}	0.42±0.02^{b}	4.33±0.1^{c}	28.7±0.2^{c}	90.00±1.53^{a}	0.97±0.01^{a}
p-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CV	0.033	0.0404	0.0062	0.0731	0.0045	0.0041	0.0033	0.033	.0.195	0.0044

Table 4. 2 Interaction Effects of Variety, Lemon juice, and Storage Temperature on the Physicochemical Properties of Tomato Paste zero month storage

Variety with lemon juice	Stored temperature	pH	TA	TSS	Vitamin c	Mc	aW
V1L1	4 °C	4.30±0.01^{hi}	1.24 ±0.01^{a}	25.90±0.1^{d}	21.88±2.67^{a}	75.64±0.01^{cd}	0.93 ± 0.01^{bcde}
V1L1	14°C	4.21±0.01^{ij}	1.18±0.01^{ab}	24.87±0.2^{fgh}	19.92±1.97^{b}	75.61±0.01^{cd}	0.92±0.01^{cdef}
V1L1	24°C	4.00±0.1^{ij}	1.12±0.01^{defg}	23.90 ±0.1^{k}	18.76±1.92^{b}	75.58±0.01^{d}	0.89±0.01^{fghi}
V1L2	4 °C	4.32±0.01^{efg}	0.84 ±0.01^{def}	25.40±0.1^{e}	18.76±3.49^{b}	75.69±0.01^{c}	0.90±0.01^{efgh}
V1L2	14°C	4.00±0.01f^{g}	0.90±0.01^{defgh}	24.70±0.1^{gh}	18.34±3.43^{b}	75.67±0.01^{c}	0.89±0.01^{fghi}
V1L2	24°C	3.38±0.01^{g}	0.92±0.01^{efgh}	24.00 ±0.1^{k}	17.89±3.27^{b}	75.64±0.01^{cd}	0.88±0.01^{ghi}
V2L1	4 °C	4.28±0.01^{h}	0.91±0.01^{efgh}	26.60±0.1^{bc}	21.26±1.71^{a}	74.88±0.02^{efg}	0.91±0.01^{defg}
V2L1	14°C	4.24±0.01^{hi}	0.95±0.01^{efgh}	25.10±0.1^{efg}	18.11±1.08^{b}	74.85±0.01^{fg}	0.89±0.01^{fghi}
V2L1	24°C	4.00±0.1^{ij}	0.97 ±0.01^{def}	24.00±0.1^{jk}	18.66±3.09^{b}	74.83±0.01^{g}	0.88±0.01^{ghi}
V2L2	4 °C	4.29±0.01^{ab}	0.81±0.02^{hij}	26.40±0.1^{bc}	18.30±3.53^{b}	74.93±0.01^{ef}	0.86±0.01^{ijk}
V2L2	14°C	4.10±0.01^{abc}	0.90±0.01^{defgh}	24.90±0.1^{gh}	17.69±3.17^{b}	74.92±0.01^{ef}	0.83±0.01^{kl}
V2L2	24°C	3.36±0.1^{bcd}	0.94 ±0.01^{cd}	24.57±0.49^{ghi}	17.5±3.01^{b}	74.90±0.01^{efg}	0.78±0.02^{m}
V3L1	4 °C	4.33±0.01^{jk}	0.82 ±0.01^{hij}	27.90±0.1^{a}	15.70±0.17^{c}	72.39±0.01^{h}	0.96 ±0.01^{ab}
V3L1	14°C	4.19±0.01^{kl}	0.86±0.01^{fghi}	26.50±0.1^{bc}	15.19±0.26^{c}	72.37±0.01^{h}	0.94±0.01^{abcd}
V3L1	24°C	3.90±0.01^{l}	0.90 ±0.01^{cde}	25.30±0.1^{ef}	14.84±0.21^{c}	72.34±0.01^{h}	0.91±0.01^{defg}
V3L2	4 °C	4.20±0.01^{bcd}	0.77±0.03^{j}	27.90±0.1^{a}	15.50±0.27^{c}	72.39±0.01^{h}	0.96 ±0.01^{ab}
V3L2	14°C	4.10c±0.01^{de}	0.80 ±0.02^{ij}	26.50±0.1^{b}	14.49±0.36^{c}	72.37±0.01^{h}	0.93±0.01^{bcde}
V3L2	24°C	3.60±0.2^{def}	0.84±0.01^{ghi}	25.30±0.1^{bc}	13.84±0.22^{c}	72.32±0.01^{h}	0.92±0.02^{cdef}
C1		4.39±0.10^{ab}	0.86±0.01^{fghi}	22.30±0.1^{kl}	15.40±0.27^{c}	74.90±0.01^{efg}	0.95±0.01^{abc}
C2		4.10±0.1^{efg}	0.88±0.01^{efgh}	22.40±0.30^{k}	14.42±0.36^{c}	76.19±0.01^{a}	0.92±0.01^{cdef}
C3		4.30±0.02^{defg}	0.94±0.01^{efgh}	22.70±0.1^{k}	13.64±0.22^{c}	75.69±0.01^{c}	0.82±0.02^{kl}
	CV	0.001	0.004	0.021	0.002	0.003	0.001
	P-Value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

4.3. Interaction Effects of Variety, Lemon juice concentration, and Storage Temperature on the Physicochemical Properties of Tomato Paste after three month storage

Effect of tomato variety, lemon juice, and storage conditions (temperature) of the physicochemical analysis of the tomato paste was presented in Appendix Table 4.4. Generally, the interaction of the three factors variety, lemon juice, and storage temperature had a highly significant effect ($P<0.01$) on all physiochemical properties. A detailed discussion of each result and possible justifications for each type of physicochemical property is presented below.

4.3.1Total Soluble Solids (TSS)

Total Soluble Solids (ºBrix) are considered a measure of quality for most fruits and one of the main parameters to indicate tomato fruit quality for processing tomato paste (Ferreira *et al*., 2022). C3 was observed is low TSS value due to Storing the tomato paste at 24℃ is relatively warmer than typical refrigeration temperatures. At higher temperatures, enzymatic and microbial activity can accelerate, leading to the degradation of sugars and other compounds responsible for TSS. The total soluble solid (TSS) content of V1P1T1, V2P1T1 and C3 in this studies were (28.00, 26.60 and 22.30) % respectively which is within the (Anthon & Barrett, 2010),tomato paste TSS ranged 30,28 and 24 (ºBrix).

Lemon juice naturally contains sugars, including fructose and glucose. Even in small amounts, the sugars from lemon juice contribute to the overall total soluble solids (TSS) value of the tomato paste (STUMMER et al., 2005)and also stored at Lower temperatures inhibit the growth of microorganisms, preventing the fermentation or degradation of sugars in the tomato paste. This microbial stability helps maintain the sugar content and total soluble solids (TSS) concentration over time(Regmi, 2018). According to (N. Kumar *et al*., 2021) at lower temperatures, such as 4 degrees Celsius (the typical refrigeration temperature), enzymatic and microbial activity are slowed down, helping to maintain the product's freshness and stability. However, the storage temperature can also affect the texture and other physicochemical properties of the tomato paste.

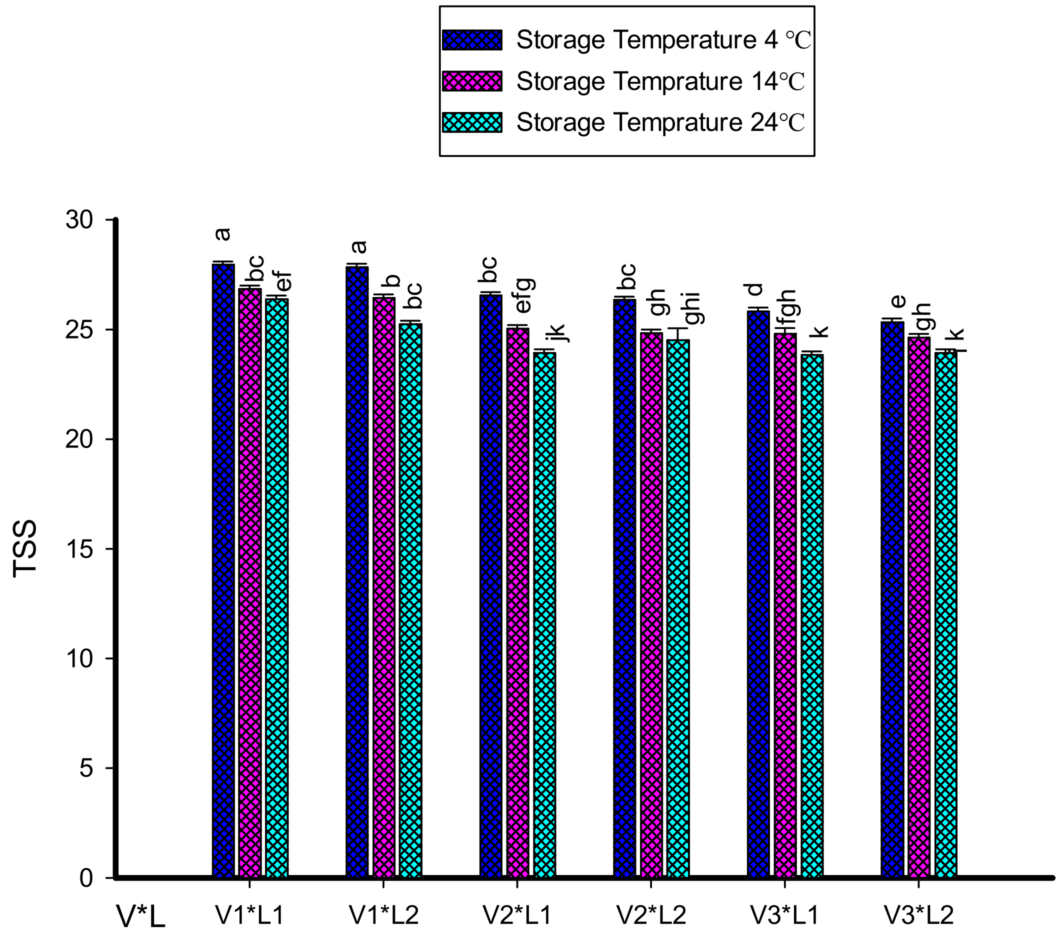

Figure 4. 1 the interaction effect of tomato variety, lemon juice concentration and storage temperature on the TSS analysis

4.3.2The Titrable acidity (TA)

The interaction of tomato variety, lemon juice, and storage temperature has a significant ($p< 0.01$) on the effect of Titrable acidity. The titrable acidity content of tomato paste ranges from 0.77 to 1.24 percent, respectively. The highest TA content value was obtained at V1P1T3 (1.24%), and the lowest titrable acidity content was observed at Anna of the control sample C3 (0.77%) of tomato paste in different ways, as shown in Table 4.2.

In the present study, the highest TA values were observed for the V1P1T3 variety due to the fact that the extended storage of the tomato paste allows for continued interaction and equilibration of flavours, including acidity from lemon juice and In some cases, citric acid or other food-grade acids may be added to tomato products, including paste, to adjust the acidity level for flavour, preservation, or other purposes. According to (Mhanga, 2015) was reported the Galilea variety itself to possess specific characteristics that contribute to higher acidity levels compared to other tomato varieties. Varietal differences in acidity can arise due to differences in genetic makeup. The storage temperature of 24°C can accelerate chemical reactions within the tomato paste. At higher temperatures, enzymatic and microbial activities increase, which can lead to the breakdown of organic compounds, including sugars and organic acids. This breakdown can release additional acidic components into the paste, contributing to higher titrable acidity values. While the lowest titrable acidity values were observed for the C3 variety because storing tomato paste at low temperatures can slow down enzymatic reactions and metabolic processes that contribute to acidity. Cold storage might inhibit the development of acidity in the paste, especially if the starting acidity is already low.

The titratable acidity TA of tomato paste can vary, however it’s generally in the range of 0.5% to 2.0%. The actual value depends on factors such as the type of tomatoes used, the ripeness of the tomatoes, and the processing methods employed during the production of the tomato paste. It's essential to strike a balance in titratable acidity because too little acidity can result in a bland taste, while too much acidity can make the product overly sour. The specific target for titratable acidity may also vary based on regional preferences and the intended use of the tomato paste.

The titrable acidity is also affected by genetic makeup, similar to the processing conditions of tomato paste. The current study's findings are similar to those reported by (Dumas *et al*., 2003), who worked on three tomato varieties and found significant differences in TA among the tomato varieties. The Galilea variety itself may possess specific characteristics that contribute to higher acidity levels compared to other tomato varieties. Varietal differences in acidity can arise due to differences in genetic makeup.

The TA content of (C3 -V1P1T3) in this study was (0.7-1.24)%, respectively, which is within the(Abdu, 2016)and Tilahun *et al*., 2017) tomato paste titrable acidity range of 0.73–1$^{\%}$).

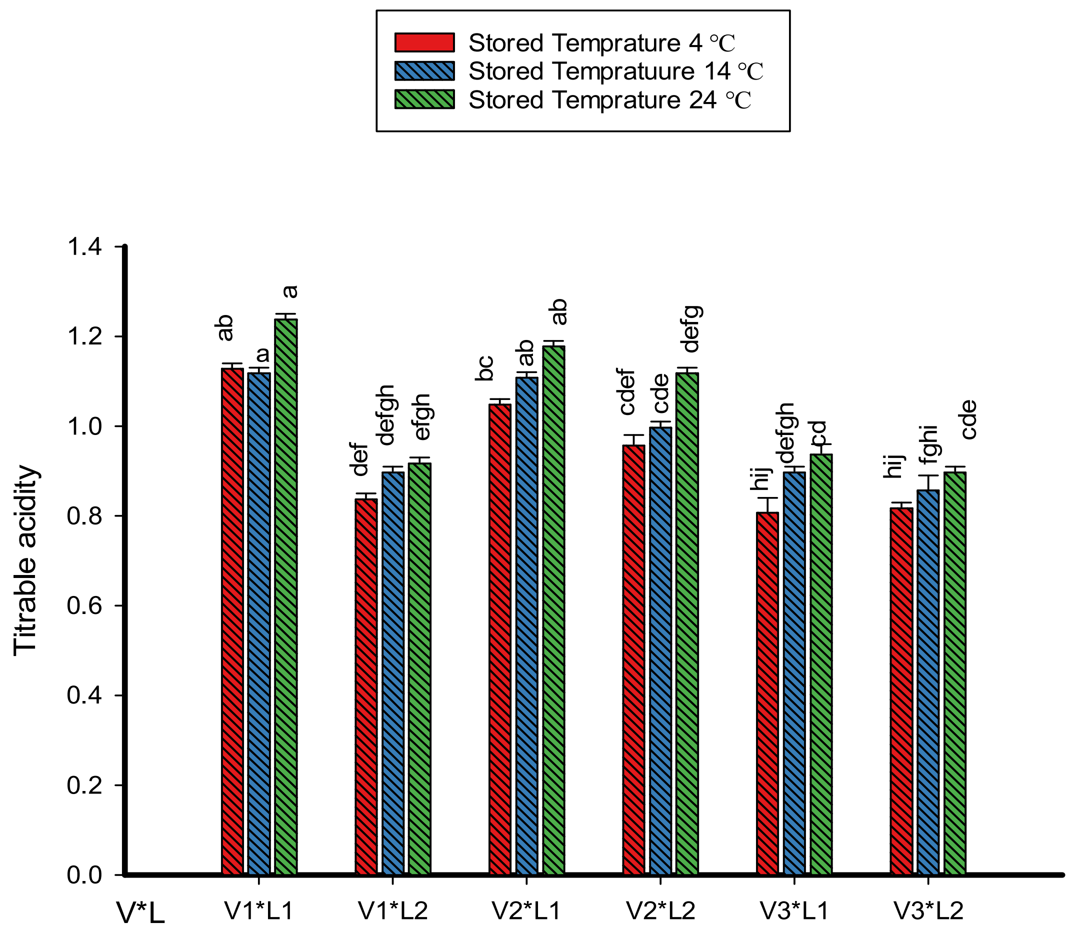

Figure 4. 2 The interaction effect of tomato Varity, lemon juice concentration and storage temperature on the physico chemical analysis of titrable acidity

4.3.3 Moisture content

The interaction effect of the three main factors, variety, lemon juice, and stored temperature, showed a significant ($P<0.01$) effect on the moisture content of the tomato paste (Table 4.2). On average, more than 70% moisture content was measured for all varieties of each treatment, and significantly different ($P<0.05$) moisture content was observed across varieties. This could be a result of the initial moisture content variation in the three tomato varieties before lemon juice and storing temperature treatment. The difference in moisture content of the tomato paste after lemon juice and stored temperature treatment is very prominent in terms of fresh tomato products, and it is understood that lemon juice treatment of the tomato paste causes some changes in the moisture content of the paste on three tomato varieties. For example, a higher moisture content value of tomato paste was found in V3P2T1 (76.19%) was obtained at Anna; and lemon juice concentration and stored temperature-treated tomato paste of variety were stored, while a lower moisture content was found in C3 (72.32%) control sample. In the V3P2T1, it was observed that moisture content had the highest value due to the fact that lemon juice added at a concentration of 10% could introduce additional moisture to the tomato paste. Lemon juice itself contains water, so adding it to the paste can increase the overall moisture content. Additionally, the acidity of the lemon juice may affect the texture and water-binding properties of the paste. However, both tomatoes and lemons contain pectin, a substance that contributes to the texture of fruits. The interaction between pectin and other soluble solids can affect the overall texture and mouthfeel of the product, giving a sensation of increased moisture (Harker & Johnston, 2008).

Lemon juice added at a concentration of 10% could introduce additional moisture to the tomato paste. Lemon juice itself contains water, so adding it to the paste can increase the overall moisture content. Additionally, the acidity of the lemon juice will affect the texture and water-binding properties of the paste.

Storing the tomato paste at 4°C helps retain moisture within the product. Lower temperatures can slow down evaporation and moisture loss, leading to higher moisture content in the paste. Additionally, the colder temperature might affect the texture of the paste, making it feel more moist or juicy.

C1 was observed to have the lowest moisture content because the C1 variety of tomatoes naturally has a lower moisture content compared to other varieties. Some tomato varieties are bred for traits such as denser flesh or lower water content, which can influence the overall moisture content of the resulting tomato paste. While higher temperatures accelerate moisture loss, it's possible that variations in storage conditions or packaging could impact the moisture content of the paste. Proper packaging and storage are essential for maintaining the quality of the product and preventing excessive moisture loss.

The moisture content of tomato paste by Galilea, Gabby, and Anna in this study was 77.13, 74.94, and 72.34%, respectively, which is within (Koh *et al*., 2012) the tomato paste titrable acidity ranged from 72.34 to 76.19.

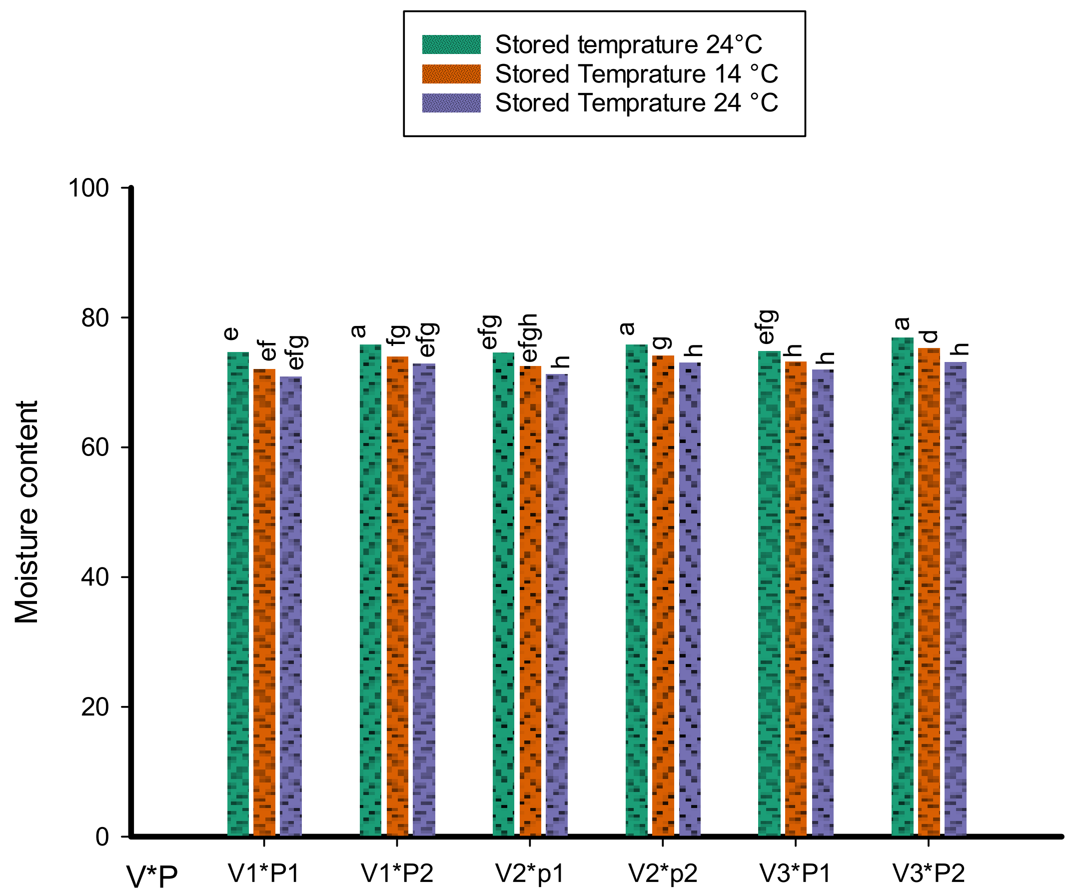

Figure 4. 3 The interaction of tomato variety, lemon juice concentration and storage temperature on the Physico chemical analysis of moisture content

4.3.4 pH

The interaction effect of the three main factors, variety, lemon juice, and stored temperature, showed a highly significant ($P<0.01$) effect on the moisture content of the tomato paste (Table 4.2). The highest pH content value was obtained from the C1 (4.46), and the lowest pH content was observed at V1P1T3 (3.36) of tomato paste. The highest pH content was observed at the C1 variety due to the fact that varieties of tomatoes can have varying levels of acidity. C1 varieties naturally have higher pH levels than others.

The lowest pH content was observed at V1P1T3 in the control sample at table 4.4 due to the fact that lemon juice contains citric acid, which is a strong acid. When added to the V1P1T3 tomatoes, which may have a relatively higher pH compared to other tomato varieties, the acidity of the mixture increases; however, higher temperatures can accelerate chemical reactions, including the breakdown of organic compounds such as citric acid. Storing the V1P1T3 tomato-lemon juice mixture at 24°C facilitated the breakdown of citric acid, leading to the release of more protons (H^+ ions) into the solution and thus lowering the pH. This increase in acidity leads to a lower pH (Olaiya & Aremu, 2013).

The pH content of the tomato paste of Gabby, Anna, and Galilea in this study was 4.46, 4.48 to3.38, respectively, which is within the (Deha, 2019) pH range of 4.45, 4.30,4.30 and 4.20 (%).

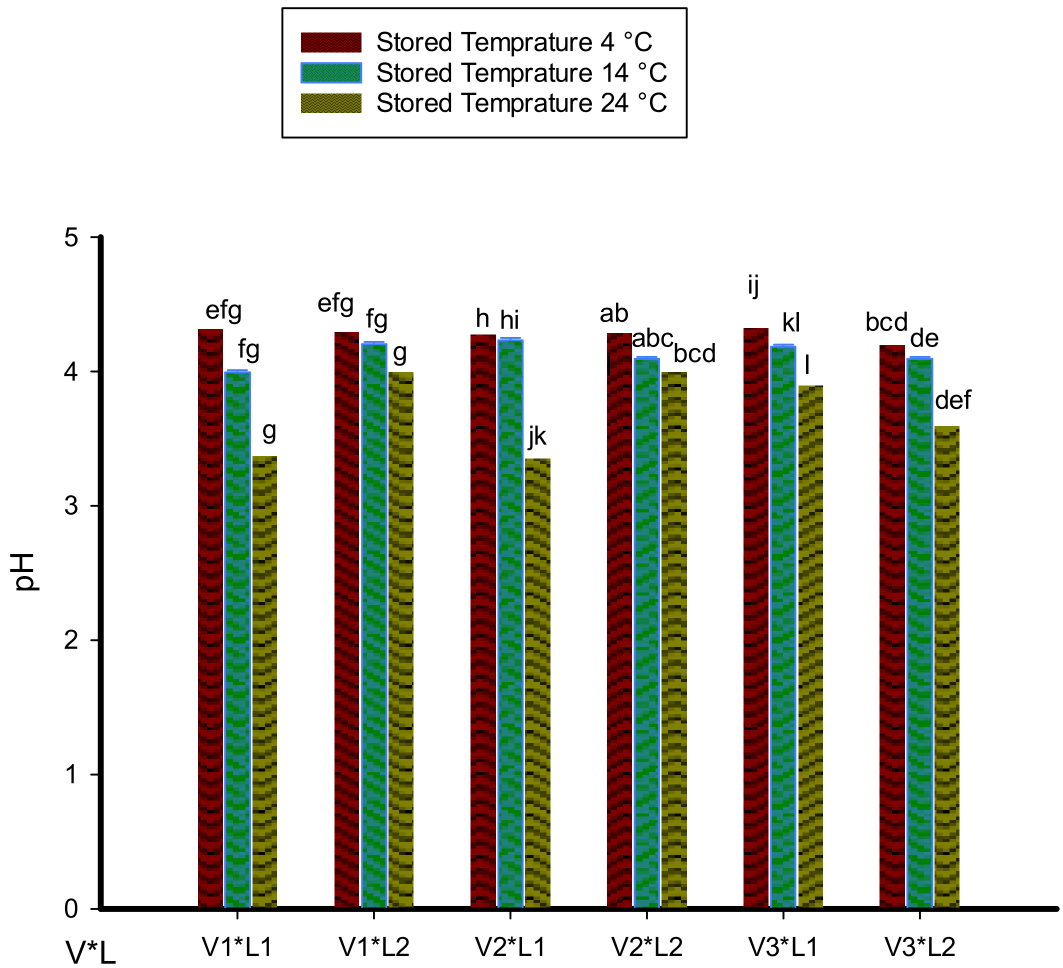

Figure 4. 4 The interaction effect of tomato variety, lemon juice concentration, and storage temperature on the physicochemical analysis of PH

4.3.5 Vitamin C (AA)

The interaction effect of the three main factors, variety, lemon juice, and stored temperature, showed a significant ($P<0.01$) effect of vitamin C content on Table 4.2. The highest vitamin C content was obtained in V1P1T1 (25.10), and the lowest vitamin C content was observed at C3 (16.26) in the control sample of tomato paste. However, the V1P1T1variety had the highest vitamin C content due to the presence of citric acid, which can help preserve the vitamin C content of the tomatoes. Acids can act as antioxidants, helping to prevent the oxidation and degradation of vitamin C. The acidic environment created by the lemon juice may contribute to maintaining higher levels of vitamin C in the tomato paste. The addition of lemon juice to tomato paste contributed to the overall vitamin C content of the product, and lemon juice is known for its high vitamin C content. When added to tomato paste, it not only contributes to the flavour profile but also enhances the overall vitamin content of the product. Storing food products, including tomato paste, at lower or cold temperatures inhibits the growth of microorganisms and slows down enzymatic reactions, which can contribute to the deterioration of nutrients. This can result in an extended shelf life for the product while retaining its nutritional content(Abbas *et al*., 2009).

The interaction between the components in the tomato paste, including citric acid from lemon juice and other compounds in the tomato paste, helped stabilize vitamin C molecules, preventing their degradation. This stabilization could be more effective at lower temperatures, such as 4°C (refrigerator).

The lowest vitamin C content was observed at the Anna C3 sample due to the fact that even though stored at normal temperatures, fluctuations in temperature and humidity levels can still occur, which contribute to the degradation of vitamin C over time. Improper storage conditions, such as exposure to light or moisture, can also exacerbate the loss of vitamin C (Sam *et al*., 2018).

The vitamin C content of tomato paste from (C3,- V1P1T1) in this study was (16.26 - 25.10) g/100g respectively, which is within the range (Joel *et al*., 2020).

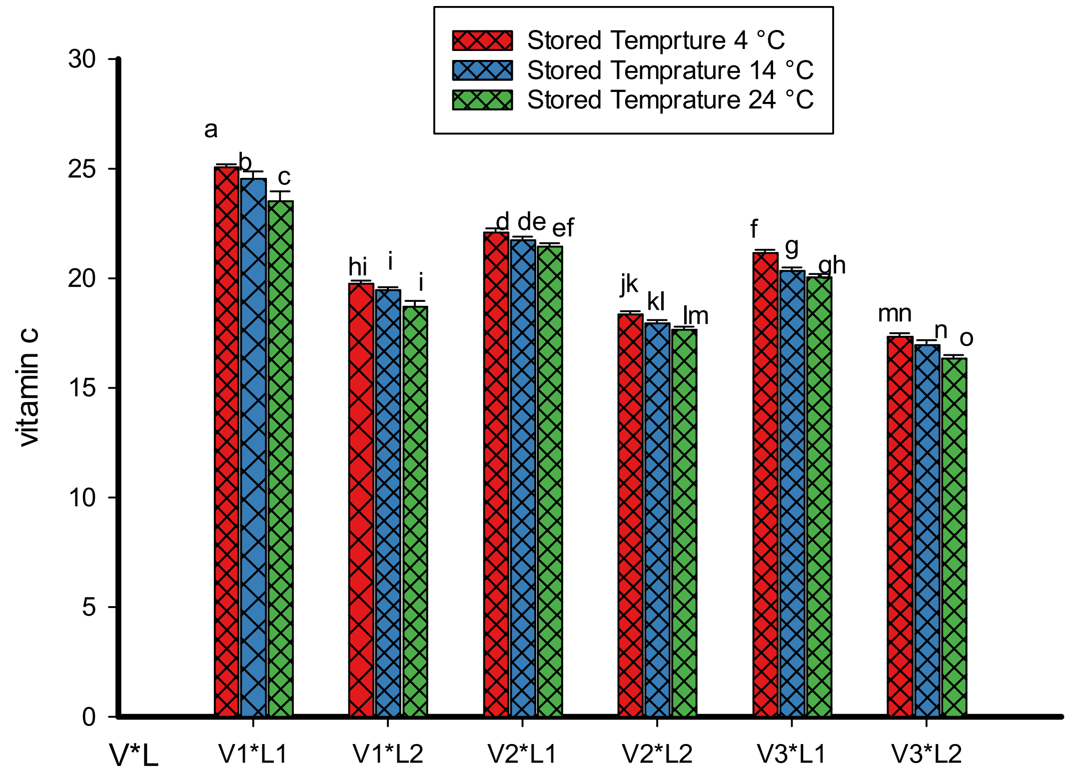

Figure 4. 5 The interaction of tomato variety, lemon juice concentration, and storage temperature on the physicochemical analysis of vitamin C

4.3.6 Water Activity (aW)

The interaction effect of the three main factors, variety, lemon juice, and stored temperature, showed highly significant (P<0.01) effect on the water activity of the tomato paste (Table 4.2). The highest water activity content value was obtained at V3P2T2 (0.93), and the lowest water activity content was observed at V2P2T3 (0.74) of tomato paste stored. The highest water activity was observed in Anna Varity due to the fact that the lemon juice used has high water content, or if additional water is added along with the lemon juice, it can contribute to the overall water activity. During the processing of tomato paste, if the evaporation process is not complete, some water might remain in the final product (Barbosa-Cánovas, 2003). In addition to that, lemon juice, with its high citric acid content, contributes to creating an acidic environment when combined with the Anna variety of tomatoes. This acidity can influence the water activity of the mixture. While acidity can inhibit microbial growth, it doesn't necessarily reduce water activity, which is a measure of the availability of water for microbial growth and chemical reactions.

The storage temperature, at 14°C, is relatively moderate. This temperature had been low enough to significantly inhibit microbial activity or reduce water activity in the tomato-lemon juice mixture. Higher temperatures generally increase water activity as they promote the mobility of water molecules, making them more available for chemical reactions and microbial growth. While the lowest water activity was observed in the Gaby variety because of the addition of lemon juice, acidity not only contributes to flavour but can also impact water activity. Acids can bind with water molecules, reducing the amount of free water available for microbial activity and contributing to lower water activity. Additionally, the lemon juice, with its high citric acid content, contributes to creating an acidic environment when combined with the Gaby variety of tomatoes. This acidity can influence water activity to some extent. Acids like citric acid can bind with water molecules, potentially reducing the amount of free water available for microbial growth and chemical reactions. In addition to this, at 24°C, the storage temperature is relatively higher than typical refrigeration temperatures. Higher temperatures generally increase the mobility of water molecules, making them more available for chemical reactions and microbial growth. However, in this case, the acidic environment created by the lemon juice, combined with the other factors was counter act the effects of temperature to some degree.

The water activity content of tomato paste in all samples in this study was 0.93, 0.83, and 0.74, respectively, which is within the range of (Olaniran *et al.*, 2015), tomato paste vitamin C ranged from 0.92, 0.88, and 0.75.

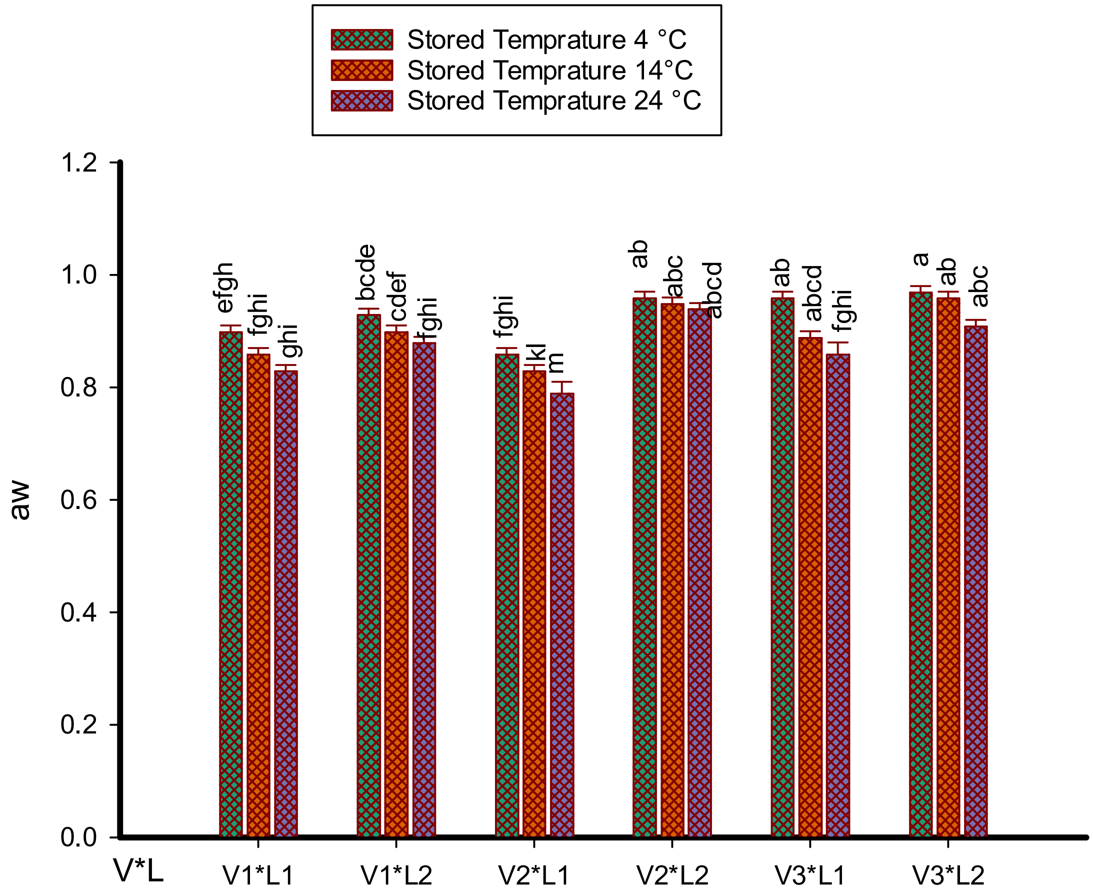

Figure 4. 6 the interaction effect of tomato variety, lemon juice concentration, and storage temperature on the water activity of tomato paste

Table 4. 2 Interaction effects of variety, lemon juice, and storage temperature on the physicochemical properties of tomato paste

Factors			Parameters					
Variety	lemon juice	stored Temperature	PH	TA	TSS	VC	MC	aw
		T1	4.32±0.01^{efg}	1.13±0.01^{ab}	28.00±0.1^{a}	25.10±0.10^{a}	74.94±0.01^{e}	0.92±0.01^{a}
V1	L1	T2	4.00±0.01^{fg}	1.20 ±0.01^{a}	26.90±0.1^{bc}	24.57±0.31^{b}	74.91±0.01^{ef}	0.89±0.01^{a}
		T3	3.36±0.01^{g}	1.24 ±0.01^{a}	26.45±0.1^{ef}	23.57±0.40^{c}	74.90±0.01^{efg}	0.86±0.01^{abc}
		T1	4.30±0.01^{hi}	0.84 ±0.01^{def}	27.90±0.1^{a}	19.80±0.10^{hi}	76.19±0.01^{a}	0.89±0.01^{ab}
V1	L2	T2	4.21±0.01^{ij}	0.90±0.01^{defgh}	26.50±0.1^{b}	19.50±0.10^{i}	75.69±0.01^{c}	0.860.01^{abc}
		T3	4.00±0.1^{ij}	0.92±0.01^{efgh}	25.30±0.1^{bc}	18.77±0.20^{j}	75.67±0.11^{c}	0.83±0.01^{abcd}
		T1	4.28±0.01^{h}	1.05±0.01^{bc}	26.60±0.1^{bc}	22.13±0.15^{d}	74.87±0.01^{gh}	0.90±0.01^{ab}
V2	L1	T2	4.24±0.01^{hi}	1.11±0.01^{ab}	25.10±0.1^{efg}	21.80±0.10^{de}	74.84±0.01^{hi}	0.87±0.01^{abc}
		T3	3.38±0.1^{g}	1.18±0.01^{ab}	24.00±0.1^{jk}	21.50±0.10^{ef}	74.81±0.01^{i}	0.84±0.01^{abcd}
		T1	4.29±0.01^{ab}	0.96±0.01^{cdef}	26.40±0.1^{bc}	18.40±0.10^{jk}	74.95±0.02^{e}	0.96±0.01^{ab}
V2	L2	T2	4.10±0.01^{abc}	1.00±0.01^{cde}	24.90±0.1^{gh}	18.00±0.10^{kl}	74.91±0.10^{f}	0.95±0.01^{abc}
		T3	4.00±0.1^{bcd}	1.12±0.01^{defg}	24.57±0.49^{ghi}	17.70±0.10^{lm}	74.88±0.01^{fg}	0.94±0.01^{abcd}
		T1	4.33±0.01^{ij}	0.81±0.02^{hij}	25.90±0.1^{d}	21.20±0.10^{f}	75.00±0.01^{bc}	0.91±0.08^{ab}
V3	L1	T2	4.19±0.01^{kl}	0.90±0.01^{defgh}	24.87±0.2^{fgh}	20.40±0.10^{g}	73.40±0.01^{c}	0.93±0.01^{a}
		T3	3.90±0.01^{l}	0.94 ±0.01^{cd}	23.90 ±0.1^{k}	20.10±0.10^{gh}	72.10±0.02^{k}	0.90±0.01^{ab}

		T1	4.20±0.01 ^{bcd}	0.82 ±0.01 ^{hij}	25.40±0.1 ^{e}	17.40±010 ^{mn}	77.00±0.01 ^{a}	0.88±0.14 ^{abc}
V3	L2	T2	4.10c±0.01 ^{de}	0.86±0.01 ^{fghi}	24.70±0.1 ^{gh}	17.03±.15 ^{n}	75.52±0.01 ^{ab}	0.93±0.01 ^{a}
		T3	3.60±0.2 ^{def}	0.90 ±0.01 ^{cde}	24.00 ±0.1 ^{k}	16.40±0.10 ^{o}	73.35±0.01 ^{jk}	0.90±0.01 ^{ab}
Control1			4.39±0.10 ^{ab}	0.86± 0.01 ^{fghi}	22.70±0.1 ^{k}	21.96±0.15 ^{a}	72.38±0.01 ^{j}	0.80±0.01 ^{bcd}
Control 2			4.39.±0.10 ^{ab}	0.91±0.01 ^{efgh}	22.70±0.1 ^{k}	19.30±0.10 ^{b}	72.35±0.01 ^{jk}	0.77±0.01 ^{cd}
Control 3			4.46±0.01 ^{abc}	0.77±0.03 ^{j}	22.30±0.1 ^{kl}	16.26±0.43 ^{c}	72.32±0>01 ^{k}	0.74±0.01 ^{d}
P-Value			<0.01	0.01	<0.01	<0.01	<0.01	<0.01
CV			0.0015	0.0043	0.021	0.022	0.0015	0.86

Note. Mean values not followed with the same letter in a column are significantly different at P< 0.05. pH, TA), TSS (total soluble solid),vitamin c, mc(moisture)and aW(water activity),lemon juice(at 5 and 10)% Temperature (°C), (T1,T2 and T3), and CV (Coefficient of variance).

4.4 interaction effect of variety lemon juice concentration and storage temperature on the color properties of tomato paste

The tomato paste colour of tomato fruits as influenced by different varieties showed high significant ($p<0.01$) differences with respect to L*, a*, and b*, as shown in Table 4.5.

The L* (lightness) values were observed to be significantly higher in V1L1T3 (21.25), and tomato paste in V3L1T`1 (10.61) had the lowest value.

L* values were observed to be significantly higher in V1L1T3, and paste V3L1T1 had the lowest value followed. The highest L* values were observed in V1L1T3 due to the fact that varieties of tomatoes have varying levels of pigments and compounds that contribute to color. V3L1T`1 Variety of tomato paste had a low L* value due to processing tomatoes into paste, such as cooking, concentration, and the addition of lemon juice, which can affect color. Longer cooking times or different processing conditions may contribute to a darker colour (Shi & Maguer, 2000). L* values of tomato paste of V1L1T3, V2L1T3, and V3L1T1 in this study were 21.25, 15.44, and 10.61, respectively, which is within the Katırcı *et al*., (2020).

The highest significant a* (redness) values of tomato paste colour were seen in V2L2T1 (35.62) and the least a* values in V1L1T3 (25.90) in the colour evaluation of tomato paste. The highest value of colour content is V2L2T1, due to the ripeness of tomatoes at the time of processing, which can impact color. Ripe tomatoes tend to have more developed pigments, contributing to a richer red colour in the resulting paste. (Kaur *et al.*, 2013).While V1L1T3 observed the lowest colour content of a* due to the presence of certain additives or ingredients that can influence color. For example, some formulations may include ingredients that affect the appearance of the final product, and proper storage conditions, such as exposure to light, air, or high temperatures, can contribute to colour degradation over time(Martínez-Hernández *et al*., 2016).

a* values of the tomato paste of V2L2T1,V3L2T and V1L1T3 in this studies were (25.90-35.62) respectively range (22.73-30.68)(Sobowale *et al*., 2012).

The highest significant b* (yellowness) values of tomato paste colour were seen in V2L1T3 (26.19) and the least b* values in V3L1T1 (17.87) were found in the colour evaluation of tomato paste. Variations in the colour of tomato paste may occur due to variety, and in this study, varieties were grown under the same conditions and assessed at the same maturity stage. Therefore, the observed variations are due to the characteristics of each variety.

Table 4. 3 interaction effect of variety lemon juice and storage temperature on the color properties of tomato paste

Factors			**Parameters**		
Variety	lemon juice	Temperature	**L***	**a***	**b***
V1	L1	T1	12.58 ± 0.28^{h}	34.30 ± 0.30^{b}	21.70 ± 0.36^{hi}
		T2	15.60 ± 0.10^{c}	26.32±0.17fg	24.53 ± 0.25^{cd}
		T3	21.25 ± 0.13^{a}	25.90 ± 0.72^{g}	19.43 ± 0.35^{j}
V1	L2	T1	11.77 ± 0.17^{h}	31.72 ± 0.17^{c}	19.96 ± 0.36^{j}
		T2	14.56 ± 0.23^{def}	34.75 ± 0.14^{ab}	25.92 ± 0.07^{ab}
		T3	17.88 ± 0.16^{b}	27.33 ± 0.21^{ef}	22.89 ± 0.19^{efg}
V2	L1	T1	11.40 ± 0.36^{i}	35.44 ± 0.15^{a}	19.60 ± 0.41^{j}
		T2	14.27 ± 0.14^{efg}	27.60 ± 0.44^{e}	24.31 ± 0.03^{cd}
		T3	15.44 ± 0.29^{c}	32.10 ± 0.36^{c}	26.19 ± 0.35^{a}
V2	L2	T1	13.83 ± 0.15^{fg}	35.62 ± 0.27^{a}	23.72 ± 0.17^{de}
		T2	15.26 ± 0.13^{cd}	32.43 ± 0.07^{c}	26.12 ± 0.16^{a}
		T3	13.61 ± 0.15^{g}	34.26 ± 0.30^{b}	17.93 ± 0.25^{k}
V3	L1	T1	10.61 ± 0.51^{j}	34.71 ± 0.77^{ab}	17.87 ± 0.15^{k}
		T2	14.63 ± 0.25^{de}	26.73 ± 0.38^{efg}	22.47 ± 0.45^{fgh}
		T3	14.71 ± 0.25^{de}	33.83 ± 0.21^{b}	25.14 ± 0.41^{bc}
V3	L2	T1	12.74 ± 0.28^{h}	34.92 ± 0.08^{ab}	23.07 ± 0.21^{ef}
		T2	14.58 ± 0.19^{de}	27.66 ± 0.39^{e}	25.69 ± 0.18^{ab}
		T3	15.27 ± 0.19^{cd}	29.55 ± 0.14^{d}	21.54 ± 0.23^{i}
	C1		12.733 ± 0.05^{cde}	25.90 ± 0.72^{g}	19.56 ± 0.22^{cd}

	C2	11.460±0.02^{e}	32.09±0.38^{abcde}	17.93±0.25^{d}
	C3	13.753±0.05^{bcde}	29.55±0.14^{defg}	14.0 ± 0.23^{abcd}
P- Value		<0.01	<0.01	<0.01
CV		0.033	0.051	0.038

Note: The values expressed in mean ± standard deviation with triplicate experiments; Means with different superscript letters (a-k) in columns were significantly different at the level of p<0.05. L*= lightness, a= green to red color, b= blue to yellow color

4.5 Interaction Effect of tomato variety lemon juice and storage temperature on sensory attributes tomato paste

The sensory analysis of different varieties of tomato paste with tomato variety, lemon juice concentration, and storage temperature was done by using a 5-point hedonic scale in terms of colour, flavour, taste, and overall acceptability. Table 4.4 represents the sensory values of tomato paste of different varieties adding lemon juice and stored temperature of tomato through a bar diagram, and the average value of scores obtained for different varieties treatment of lemon juice and stored temperature of tomato paste during evaluation for various sensory attributes is shown in Table 4.4.

4.5.1Color

The colour of the three tomato varieties differ significantly (p< 0.01), as shown in Table 4.4. The interaction effect of tomato varieties, lemon juice, and storage temperature has a significant (p<0.01) effect on the colour of tomato paste. The highest average sensory score of tomato paste was obtained for the V1L1T1 (4.60) tomato variety. The lowest average sensory score was obtained for the tomato paste of the C3 (2.82) tomato variety.

4.5.2Flavor

The flavor of the three tomato varieties differ a significantly (p< 0.01) as shown in Table 4.4 The interaction effect of tomato varieties, lemon juice and stored temperature has a significant (p<0.01) effect on flavor of tomato paste. The maximum mean score was obtained for tomato paste of V1L1T1 (4.63) with addition lemon juice. While the lowest mean score was obtained for tomato paste of Galilea tomato with 10 ml of lemon juice the color value C3 (2.82) variety.

4.5.3Taste

The tastes of the three tomato varieties differ highly significantly ($p < 0.01$), as shown in Table 4.4. The interaction effect of tomato varieties, lemon juice, and stored temperature has a significant ($p<0.01$) effect on the taste of tomato paste. Taste is the primary factor that determines the acceptability of many fruits and has the highest impact as far as the market success of the product is concerned. The maximum mean score of taste for tomato paste of V1L1T1 (4.59) tomato variety, while the lowest score for C3 (2.82) tomato variety paste. The score for the taste of the different varieties with treatment in lemon juice and stored temperature (4 to 24 °C) of tomato paste varied in the range color, flavor, taste and overall acceptability of 4.60 to 2.82, 4.63 to 2.82, and 4.59 to 2.81 for V1L1T1, C3, and V3L2T3, respectively.

4.5.4 Overall acceptability

The overall acceptability of the three tomato varieties differs highly significantly ($p < 0.01$), as shown in Table 4.4. The interaction effect of tomato varieties, lemon juice concentration, and stored temperature has a significant ($p<0.01$) effect on the overall acceptability of tomato paste. It was observed that the higher mean score for the overall acceptability of tomato paste was obtained for the V1L1T1 (4.59) variety of tomato. A lower score was obtained for the C3 (2.80) variety of tomato paste. The mean score for overall acceptability of tomato paste of different varieties, lemon juice, and stored temperature varied in the range color, flavor, taste and overall acceptability of 4.60 to 2.82, 4.63 to 2.82, and 4.59 to 2.81 for V1L1T1 to C3 respectively. Overall acceptability is an important parameter in organoleptic estimation (Basak, 2018).

Table 4. 4 Interaction effect variety, lemon juice concentration and storage temperature of sensory tomato paste

Factors			**Parameters**			
Variety	lemon juice	Temperature	**Color**	**Flavor**	**Taste**	**OA**
		T1	4.60±0.01a	4.63±0.01a	4.59±0.01^{a}	4.59±0.02^{a}
V1	L1	T2	4.59±0.01^{a}	4.59±0.02^{ab}	4.56±0.01^{ab}	4.55±0.01^{ab}
		T3	4.56±0.01^{ab}	4.56±0.01^{bc}	4.53±0.01^{abc}	4.52±0.01^{abc}
		T1	4.27±0.02^{f}	4.27±0.02^{g}	4.32±0.01^{efghij}	4.31±0.01^{efghij}
V1	L2	T2	4.23±0.01^{g}	4.23±0.01^{h}	4.29±0.01fghij	4.28±0.01^{fghij}
		T3	4.19±0.01^{g}	4.19±0.01^{h}	4.26±0.01^{ghij}	4.25±0.01^{ghij}
		T1	4.57±0.01^{ab}	4.57±0.01^{bc}	4.50±0.01^{abcd}	4.49±0.01^{abcd}
V2	L1	T2	4.53±0.01^{bc}	4.53±0.01^{cd}	4.47±0.01^{abcde}	4.46±0.01^{abcde}
		T3	4.50±0.01^{c}	4.50±0.01^{d}	4.44±0.01^{abcdef}	4.43±0.01^{abcdef}
		T1	4.14±0.02^{h}	4.14±0.02^{i}	4.23±0.01^{hij}	4.22±0.01^{hij}
V2	L2	T2	4.08±0.02^{i}	4.08±0.02^{j}	4.20±0.01^{ij}	4.19±0.01^{ij}
		T3	4.03±0.03^{j}	4.03±0.03^{h}	4.17±0.01^{jk}	4.14±0.04^{j}
		T1	4.40±0.01^{d}	4.40±0.01^{e}	4.41±0.01^{bcdefg}	4.40±0.01^{bcdefg}
V3	L1	T2	4.37±0.01^{de}	4.37±0.01^{ef}	4.38±0.01^{cdefgh}	4.37±0.01^{cdefgh}
		T3	4.34±0.01^{e}	4.34±0.01^{f}	4.35±0.01^{defghi}	4.34±0.01^{defghi}
		T1	3.88±0.02^{k}	3.88±0.02^{l}	4.01±0.14^{k}	3.93±0.14^{k}
V3	L2	T2	3.85±0.01^{kl}	3.85±0.01^{lm}	3.83±0.01^{l}	3.83±0.01^{k}
		T3	3.82±0.01^{l}	3.82±0.01^{m}	3.71±0.18^{l}	3.59±0.19^{l}
C1			3.27±0.03^{bc}	3.27±0.03^{bc}	3.24±0.04^{cd}	3.19±0.05^{cd}
C2			2.79±0.01^{c}	2.79±0.01^{c}	2.86±0.12^{d}	2.89±0.11^{cd}
C3			2.82±0.01^{c}	2.82±0.01^{c}	2.81±0.01^{d}	2.80±0.01^{d}

P- Value	<0.01	<0.01	<0.01	<0.01
CV	0.0019	0.0019	0.0077	0.0079

Note: The values expressed in mean ± standard deviation with triplicate experiments; Means with different superscript letters (a-k) in columns were significantly different at the level of $p<0.05$, OOA = all over acceptability

4.6 Microbial Load of tomato paste

4.6.1 Temperature and Relative humidity for Microbial Load Analysis

Each treated sample was stored in this laboratory for three months (April, June, and July 2023). The monthly average temperature and relative humidity of the experimental storage room were recorded hourly, and the average value is presented in Figure 4.7 below. The storage room temperature ranged from 21.6 to 26.95°C and the relative humidity from 44.47 to 62.22%. The temperature of the storage room increased in April and decreased in June, whereas the relative humidity of the storage room increased from 44.47 to 62.22%.

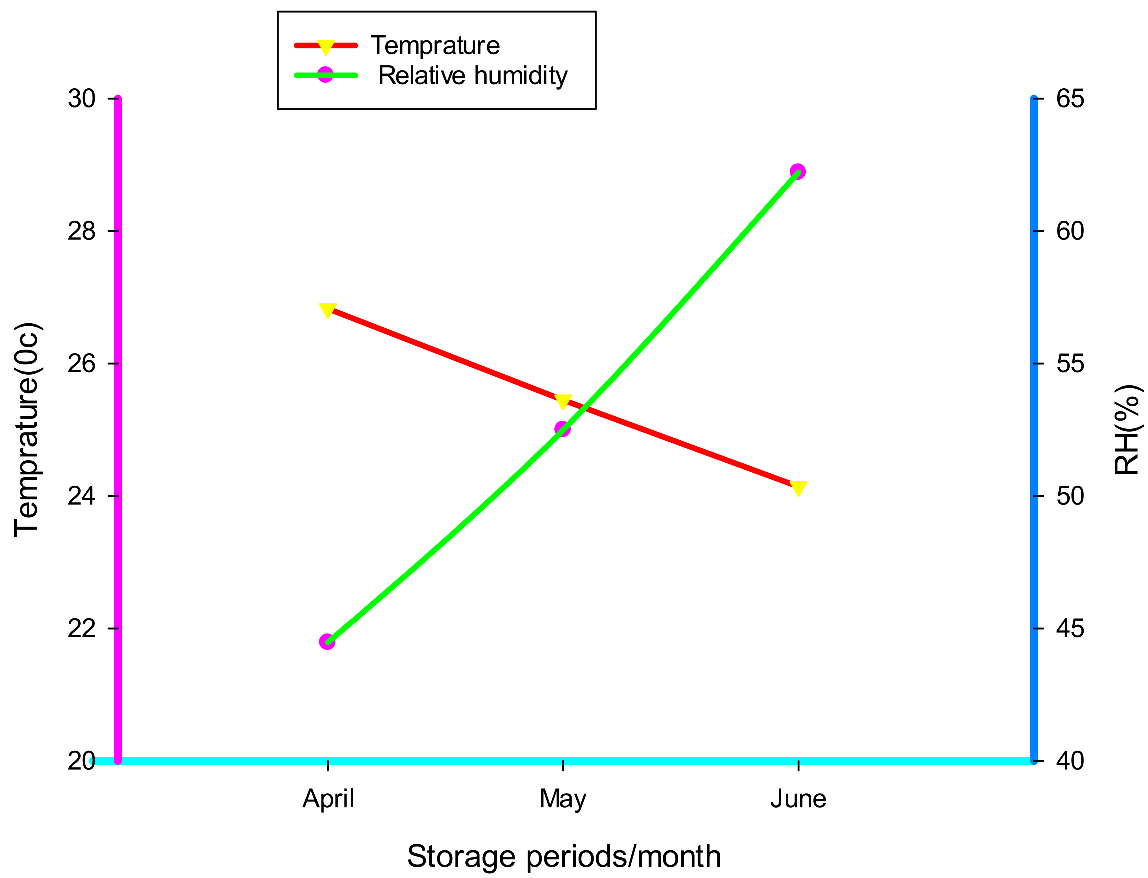

Figure 4. 7 Storage conditions of tomato paste for three tomato varieties at different lemon juice level and stored temperature

4.6.2 Microbial Analysis of tomato paste

The microbial load (total bacteria, yeast, and mould) analysis of the three tomato varieties is presented in Table 4.5. A significant ($P<0.01$) load variation was observed for each treatment after a 30-day storage period. Despite variety differences, lemon juice and stored temperature variation showed a significant microbial load variation on each product. Even though an insignificant microbial load was observed due to variety differences, the interaction of lemon juice with storage temperature had a significant effect on microbe load. Lemon juice concentration between L1 and L2 and its interaction with varieties and storing temperature were found to be significant ($p<0.05$) on the microbial activity of tomato paste. The data recorded in the present investigation indicates that the fungal and bacterial load on tomato paste increased from 0 days up to 90 days of storage, and the rate of increase in fungal and bacterial colony load is only affected by lemon juice concentration. The bacterial growth pattern at various time intervals shows the systematic increase in CFU/g of the tomato paste samples, corresponding to the lemon juice and storage period of three tomato varieties (table 4.5).

4.6.3Total bacteria counts in different storage periods of tomato paste

The growth was found to be maximum in tomato paste treated at 90 °C for 2 hours and stored at ambient temperature for 90 days, while it was not detected in all varieties with a 0 day storage period stored at ambient temperature. Appendix Table 4.7 below indicates that the bacterial growth of thermally preserved tomato paste increased with the advancement of storage duration. At 0 days of storage, no bacterial growth was observed, which means it was safe. The maximum bacterial growth was recorded in (C3) (6.23CFU/g (log10) at room temperature in 90 days, and the lowest in (V1P1T1) at 30 days.

According to (Ogodo *et al*., 2016), the approximate microbial and fungal count in most of the processed fruit juice products is in the order of 10^3 to 10^5. The lower order of microbial count is an indicator of a safe and consumable fruit puree, while the high order ($>10^5$) is not safe for consumption. In the current study, at ambient temperature, the microbial count was observed to increase for all treatments and remained within a safe range for up to 60 days of storage for all treatments.

The yeasts and moulds recorded the highest counts after 90 days of storage in three varieties of tomatoes with their treatment temperatures. Tomato paste prepared at a high temperature (90 °C) and stored at ambient temperature in metal cans had a low surviving population of microorganisms (yeasts and moulds).

4.6.4 Yeast and mold counts in different storage periods of tomato paste

The data given in Table 4.5 below revealed that fungal growth on lemon juice and thermally preserved tomato increased as the storage duration increased. It was significantly affected from 0 to 90 days of storage duration. Among the treatments, the minimum fungal growth (ND) was recorded from treatment storage temperature (4 ,14 and 24)$°c$ and the lemon juice (5-10)% at 0 days of storage at ambient temperature and high temperature (90°C) in three varieties, and maximum fungal growth was recorded after 90 days of storage in all varieties of tomato with their lemon juice concentration and storage temperature. Lower fungal growth occurred in V1P1T1variety at lemon juice concentration(5 and 10)% and storing temperature (4,14 and 24)°C with the different storage periods of 0, 30, 60, and 90 days of the value of 0, 3.96 to 1.01, 4.93 to 1.61, 5.76 to 3.81 cfu/g for TBC and 0, 4.94 to 0, 5.15 to 3.86 and 6.23 to 5.24 cfu/g for yeast and mold, respectively, at ambient temperature due to maximum physiological activities of acidity in the tomato paste (table: 4.5). The results of the present study substantiated that none of the chemical preservatives used was able to completely inhibit the bacterial growth in the specified varieties of tomato paste for a period of 90 days of storage; however, the lemon juice and storage treatment conditions had been active in the inhibition of the microbial growth in the tomato paste samples.

Table 4. 5 Results of paste Tomato varieties microbiological analysis

Sample Factors	Storage periods Total bacterial count (logCFUg^{-1})				Yeast and Mold count (logCFUg^{-1})			
	0 Day	30 Days	60 Days	90 Days	0 Day	30 Days	60 Days	90 Days
V1L1T1	ND	1.01±0.02^{j}	1.61±0.01^{q}	3.81±0.01^{bcd}	ND	ND	4.22±0.03^{n}	5.24±0.01^{cd}
V1L1T2	ND	2.00±0.02^{gh}	2.86±0.01^{m}	3.91±0.01^{h}	ND	ND	3.86±0.04^{J}	5.37±0.16^{l}
V1L1T3	ND	3.00±0.03^{bcd}	3.71±0.01^{ij}	4.67±0.02jkl	ND	ND	4.29±0.02^{n}	5.46±0.15^{l}
V2L1T1	ND	1.03±0.03^{j}	1.95±0.01^{o}	4.47±0.15^{a}	ND	4.28±0.01^{gh}	4.75±0.01^{ij}	6.01±0.01^{efghi}
V2L1T2	ND	2.01±0.03^{gh}	2.87±0.01^{l}	4.82±0.02^{j}	ND	3.87±0.05^{j}	4.51±0.01^{ij}	5.81±0.01^{ij}
V2L1T3	ND	3.81±0.01^{a}	3.75±0.01^{f}	4.70±0.02^{klm}	ND	3.92± 0.01^{ij}	4.45±0.01^{kl}	5.76±0.01^{j}
V3L1T1	ND	1.39±0.53^{i}	1.89±0.02^{p}	4.73±0.03^{jkl}	ND	4.29±0.01^{gh}	4.68±0.01^{ij}	6.06±0.01^{defg}
V3L1T2	ND	1.98±0.02^{gh}	2.77±0.01^{m}	4.77±0.02^{jk}	ND	3.91±0.01^{ij}	4.77±0.01^{ij}	5.87±0.01^{ghij}
V3L1T3	ND	2.23±0.02^{fg}	3.21±0.01^{l}	4.27±0.01^{n}	ND	3.79±0.01^{j}	4.32±0.01^{lm}	5.53±0.01^{kl}
V1L2T1	ND	2.54±0.02^{ef}	3.51±0.01^{k}	4.42±0.01^{n}	ND	4.25±0.01^{ghi}	4.65±0.02^{ijk}	6.05±0.13^{defgh}
V1L2T2	ND	2.74±0.03^{de}	3.74±0.01^{ij}	4.65±0.01^{lm}	ND	3.85±0.01^{j}	4.62±0.01^{ij}	5.92±0.01^{fghij}
V1L2T3	ND	2.81±0.02^{de}	3.89±0.02^{ij}	4.71±0.01^{klm}	ND	4.56±0.01^{efg}	5.28±0.01^{e}	6.11±0.02^{def}
V1L1T1	ND	3.14±0.02^{bc}	4.11±0.0 ^{g}	5.01±0.01^{i}	ND	4.48±0.01^{fg}	5.15±0.01^{ef}	6.16±0.03^{cde}
V2L2T2	ND	3.23±0.02^{b}	4.21±0.01^{f}	5.19±0.01^{h}	ND	4.23±0.03^{ghi}	4.84±0.01^{ghi}	5.92±0.01^{fghij}
V2L2T3	ND	3.79±0.02^{a}	4.69±0.01^{f}	5.42±0.01^{g}	ND	4.03 ±0.01^{hij}	4.73±0.01^{ij}	5.81±0.01^{ij}
V3L2T1	ND	1.76±0.02^{h}	2.71±0.01^{n}	4.66±0.01l^{m}	ND	4.30±0.33 ^{fgh}	4.45±0.32^{kl}	5.72±0.06^{jk}
V3L2T2	ND	2.27±0.02^{fg}	3.26±0.01^{l}	4.21±0.01^{n}	ND	4.64 ±0.07 ^{def}	4.83±0.12^{hi}	5.81±0.01^{ij}
V3L2T3	ND	2.82±0.03^{de}	3.79±0.01^{i}	4.62±0.01^{n}	ND	4.36 ±0.40^{fgh}	4.71±0.01^{ij}	5.85±0.01^{ghij}
C1	ND	3.91±0.01^{a}	4.77±0.02^{e}	5.61±0.01^{f}	ND	4.97±0.01^{cd}	5.05±0.01^{fg}	6.11±0.01^{def}
C2	ND	3.93 ±0.01^{a}	4.87±0.06^{d}	5.72±0.01^{e}	ND	4.90±0.02^{cde}	5.01±0.02^{fgh}	5.83±0.16^{hij}
C3	ND	3.96±0.01^{a}	4.93±0.01^{c}	5.76±0.01^{de}	ND	4.94±0.01^{cd}	5.04±0.01^{fg}	6.23±0.1^{cd}
P- Value		<0.01	<0.01	<0.01		<0.01	<0.01	<0.01
CV		0.012	0.007	0.007		0.012	0.012	0.012

Note: Galilea (V1), Gabby (V2) & Anna (V3)); T1-4oC, T2-14oC & T3-24o, Not detected (ND)

The values expressed in mean ± standard deviation with triplicate experiments; CV (%) = coefficient of variation; Means with different subscript letters (a-q) in column were significantly different at a the level of $p<0.05$

5. CONCLUSION AND RECOMMEDATIONS

5.1. Conclusion

The present study was conducted on production of tomato paste from different mainly cultivated varieties of tomato with processing conditions of lemon juice concentration as reservation. The results of this study revealed that the effect of varieties,lemon juice concentration and storgae temorature temperature had a significant effect on the physicochemical properties and microbial stability of preserved of tomato paste.

Accordingly, Galilea,Gabby and Anna variety of tomato were considered,lemon juice concentration (5 and 10) % and storing temprature (4,14 and 24)ºC were selected for lemon juice concentration and storing temprature treatment in varity property. From the evaluated varieties V1P1T1 exhibited a beneficial effect on high vitamin C, moderated TSS, TA, color, flavor, and overall acceptability of tomato paste. The study suggests, a better understanding of lemon juice preservation and storing tempratures relative to different varieties of tomato; is necessary to minimize the degradation of the volatile components, and to maximize the physicochemical, sensorial properties, and microbial safety of tomato paste. The low degradation of vitamin C and other components were obtained with natural treatments (5-10)% lemon juice concentration of tomato paste production. Since the microbial load of the tomato paste should be concerned during the storage of tomato paste, results showed an increasing trend with the storage period. A minimum fungal and bacterial colony was found in Galilea paste stored at average temperature of 22°C and average RH of 67% throughout the 90 days of storage period. On the other hand, the higher the treatment lemmon juice concentration, the lower the microbial counts. At ambient temperature the microbial count was observed to get increased for all treatments and remained within safe range up to 60 days of storage for all treatments. Thus, safe and qualified tomato paste could be produced from V1l1T1 of tomato, However cold chain storage conditions should be applied to extend the product shelf life beyond 60 days.

5.2 Recommendation

With the continuity of research activities, several research opportunities exist that can further expand and improve the methodology presented in this thesis. The following are some of the recommendations:.

- ✓ Conduct further research to identify additional tomato varieties that exhibit superior nutritional profiles and flavour characteristics for tomato paste
- ✓ Further research activities will also be required on the different tomato varieties, lemon varieties, and lemon juice concentration percentages. Optimization of lemon juice concentration with different preservation methods will also be required for the production of tomato paste.
- ✓ Further investigation will involve collaborating with industry partners, researchers, and regulatory agencies to develop best practices and quality standards for tomato paste manufacturing and storage.
- ✓ Study findings would be helpful for consumers, manufacturers, and industry policymakers. Producers and stakeholders can enhance the nutritional quality, flavour, and shelf life of tomato paste.
- ✓ The most preferred Paste by the panelists was produced from Galilea and Gaby tomato with the treatment of lemon juice 5%& at 4°C for. Generally, this study concluded that V1L1T1 and V2L1T1 separately could be recommended in the production of Tomato paste.

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APPENDICES

Please use the scales given below and taste the given samples, and then write your mark on the appropriate boxes to express your degree of liking for each of the sensory attributes provided. Please rinse your mouth between tests.

Sex: Male ☐ Female ☐ Age ------------

Panelist No: --------Date: ----------------Time-------------

Appendix table 1 Sensory Evaluation score sheet

Sample code	Sensory attributes			
	Color	Flavor	Taste	OAA
V1P1T1				
V1P1T2				
V1P1T3				
V2P1T1				
V2P1T2				
V2P1T3				
V3P1T1				
V3P1T2				
V3P1T3				
V1P2T1				
V1P2T2				
V1P2T3				
V2P2T1				
V2P2T2				
V2P2T3				
V3P2T1				
V3P2T2				
V3P2T3				
C1				
C2				
C3				

Score: 1 = dislike extremely, 2 = dislike moderately, 3 = neither like nor a dislike, 4 = like moderately, and 5 = like extremely

Additional comments --- --------