PREPARATION AND STORAGE STABILITY EVALUATION OF TAMARILLO SAUCE WITH VARYING STORAGE TEMPERATURE AND PACKAGING MATERIAL

by

Bibita Joshi

Department of Food Technology

Central Campus of Technology

Institute of Science and Technology

Tribhuvan University, Nepal

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A dissertation submitted to the Department of Food Technology, Central Campus of Technology, Tribhuvan University, in partial fulfillment for the degree of B.Tech. in Food Technology

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Tribhuvan University

Institute of Science and Technology

Department of Food Technology

Central Campus of Technology, Dharan

Approval Letter

This *dissertation* entitled *Preparation and Storage Stability Evaluation of Tamarillo Sauce with Varying Storage Temperature and Packaging Material)* by Bibita Joshi has been accepted as the partial fulfillment of the requirement for the B. Tech. degree in Food Technology

Dissertation Committee

1. **Head of the Department ________________________________**

   (Mr. Basanta Kumar Rai, Assoc. Prof.)

2. **External Examiner _____________________________________**

   (Mr. Birendra Kumar Yadav, Asst. Prof.)

3. **Supervisor ____**

   (Mrs. Geeta Bhattarai, Assoc. Prof.)

4. **Internal Examiner ______________________________________**

   (Mr. Navin Gautam, Asst. Prof.)

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Bibita Joshi

Abstract

Tamarillo (*Cyphomandra Betacea*) is a member of the family Solanaceae which is valued due to its high level of pectin content. The main aim of this dissertation is to add value to this underutilized fruit by making sauce and to study the storage stability by varying the packaging materials (glass and PET bottle) and storage temperature (room and refrigerated temperature). Correct recipe formulation of different ingredient such as sugar, vinegar and salt were selected through the statistical analysis of the sensory score given by panellist. Final product was prepared and kept in PET and glass bottles. In order to evaluate the storage stability, the bottles were kept at room temp. (21±3ºC) and refrigeration temp (4±1ºC) as well and chemical analysis (TSS, pH, vit. C and acidity) was carried out at each 15 days interval for 2 months followed by sensory analysis at the end.

Through sensory and statistical analysis, the optimum concentration of salt, sugar and vinegar was found to be 4%, 30ºBx and 1.5% respectively. From the sensory analysis, the product stored at refrigerator (4±1 ºC) and packaged in glass was found to be superior during 2 months storage period. Statistical analysis of sensory score showed that there was significant ($p<0.05$) difference among all the products. During storage the chemical analysis at different interval showed there was no significant difference in the TSS (30-32ºBx) whereas significant decrease in acidity (1.29-1%) and vit C (31.11-13.34%) was seen with the increase in pH value (3.87-4.13). Also, the packaging material used has no such significant effect on product quality which is why plastic or glass both can be used for packaging of sauce.

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List of Abbreviations

Abbreviations	Full form
ANOVA	Analysis of Variance
Bx	Brix
DFTQC	Department of food technology and quality control
LSD	Least significant difference
PET	Polyethylene terephthalate
TSS	Total soluble solids

Part- I

Introduction

1.1 General introduction

The Solanaceae family furnishes a number of lesser known fruit crops, such as the pepino, lulo and tomatillo and tree tomato. These species, though perhaps unfamiliar to those in the North Temperate Zone, are widely grown and esteemed in tropical and subtropical regions for their juicy, edible fruits (Bakshi *et al.*, 2016). *Cyphomandra betacea*, commonly known as tamarillo or tree tomato is a member of the family Solanaceae. This species was first described in 1801 by Cavanilles under the name *Solanum betaceum* and later in 1845 transferred to the genus *Cyphomandra* by Sendtner (Guimaraes *et al.*, 1996). Tamarillo fruit can be consumed in many ways such as eaten raw as a dessert fruit, in salad, as an appetizer or prepared in a number of other ways. The tamarillo is such a versatile fruit that a book which only includes recipes for the tamarillo has been published. It is valued by the food processing industry due to its high level of pectins, which makes it especially suited for jams and preserves and because it has desirable properties for canning in syrup and for producing pulp, chutney, sauce, baby food and in combination with milk products like yogurt, milk shakes and ice creams (Prohens and Nuez, 2001).

The demand for the fruit remains strong due to an increasing awareness of its unique flavour and nutritional qualities (Bakshi *et al.*, 2016). Tamarillo is a rich source of vitamins and minerals viz., vitamins A, C and pro vitamin A and an excellent source of calcium, iron, potassium, phosphorus and magnesium respectively (Nallakurumban *et al.*, 2015). Commercial production of tree tomatoes occurred in the 1930s, and its popularity grew considerably during World War II. In 1967, its commercial name of "tree tomato" was switched to "tamarillo" as a way of distinguishing it from the classic tomato (Reddy, 2013).

Sauce is defined as the condiment or relish for food. It is something that adds zest or piquancy to the food. Sauces are not normally consumed by themselves; they add flavour, moisture, and visual appeal to another dish. *Sauce* is a French word taken from the Latin *salsa,* meaning *salted*. Sauces may be used for sweet or savoury dishes. They may be prepared and served cold, like mayonnaise, prepared cold but served lukewarm like pesto, cooked and served warm like béchamel (white sauce made with milk infused with herbs and other flavourings) or cooked and served cold like apple sauce. Sauces may be freshly prepared by the cook, especially in restaurants, but today many sauces are sold premade and packaged like Worcestershire sauce, HP Sauce, soy sauce or ketchup (Anonymous., 2014).

Many fruits and vegetables contain vitamin C, but excess amount of heat can destroy the vitamin completely. At high temperature, in the presence of sunlight and oxygen in air, vitamin C reacts and it is oxidized. Cooking in high temperature also destroys vitamin C since it easily leaches into the cooking water being a water-soluble vitamins (Igwemmar *et al.*, 2013).

1.2 Statement of the problem

Tamarillo is a fruit with abundant food uses and nutritive value but study on its process optimization and value addition is very less in context of Nepal and world as a whole. Study on this fruit may help to know its optimum method of preparation and may be marketed. The production of tamarillo products in the industrial scale may find difficulty as it is the seasonal fruit and is grown only in the hilly areas. There are no any research work done in the utilization of fruit for making product except by Nallakurumban *et al.* (2015), so the recipe formulation is done on the basis of tomato sauce preparation.

Thus the present work is solely concerned with the study of preparation and quality evaluation of tamarillo sauce.

1.3 Objectives

1.3.1 General objective

The general objective of this work is the preparation and quality evaluation of Tamarillo sauce and to study its storage stability with varying storage temperature and packaging material.

1.3.2 Specific objective

The specific objective of the present work are pointed out below:

a) To optimize the recipe for tamarillo sauce preparation through sensory analysis (salt, sugar and vinegar).

b) To carry out physio-chemical analysis (TSS, acidity, pH and vit C) of tamarillo sauce.
c) To study the effect of packaging material (PET plastic bottle and glass) on the sensory quality of tamarillo sauce.
d) To study the effect of storage temperature (room and refrigerated temperature) on the sensory quality of tamarillo sauce.

1.4 Significance of the study

The findings of this work can be further extended to document this sauce. The main aim of this study is the utilization of the tree tomato in the industrial scale as it is only used in making instant pickle for the household consumption. If the study on the sensory evaluation and storage stability shows a promising result then the product can be further recommended as the substitution of tomato sauce which not only helps in the utilization of fruit but also helps economically to the farming communities of the hilly areas of Nepal. This work would further provide a basis in the industrial and commercial field.

Furthermore, the study on the retention of vitamin C, acidity, pH and TSS might be helpful to businessman or scholar for future studies.

1.5 Limitations of the study

a) Varieties were not considered during study.
b) Antioxidant properties of the tamarillo sauce was not studied.
c) Proximate analysis was not carried out.

Part II

Literature review

2.1 Tamarillo

2.1.1 Historical background

The tamarillo (*Cyphomandra betacea*) is a small tree or shrub in the flowering plant family Solanaceae (the nightshade family). It is best known as the species that bears the tamarillo, an egg-shaped edible fruit. It is also known as the tree tomato, tomate andino, tomate serrano, tomate de yuca, sachatomate, berenjena, tamamoro, and tomate de arbol in South America (Anon.,2018c).

The tree tomato is native of the Andean regions of South America, from Peru to Argentina, where it has been cultivated for a long time. From there it is spread to other subtropical and tropical parts of south and Central America, including Brazil, the West Indies and Mexico. Later, it was taken to the south of Europe, Madeira, and Azores and was introduced in England for the first time by James Edward Smith in 1803. In the late 19th century, seeds were sent to the British colonies (India, Ceylon, Hong Kong, Australia, New Zealand and South Africa) and to China. Nowadays, tamarillos are grown in many parts of the world, namely the USA, Brazil, India, Sri Lanka, Australia, Kenya and Southern Europe among other places, but New Zealand is without doubt, the main producing and exporting country and it has here become an important crop (Guimaraes *et al.*, 1996).

2.1.2 Botanical profile

The tamarillo is a fast-growing tree, reaching a height of between 1 and 5 m. It is short-lived, with a life expectancy of only 5 to 12 years. The root system is shallow and not very extensive. In general, it forms a single trunk that is woody at the base and branches out at a height of 1.5 to 2 m to form a large spreading crown. The leaves are perennial, large (20 to 40 cm long and 20 to 35 cm wide), simple and have a strong musky smell(Prohens and Nuez, 2001). The pentamerous, pendent flowers have corollas ranging in colour from white or pinkish to lavender, violet, and green or greenish-yellow. . The fruit is a berry that is glabrous or variously pubescent at maturity. The fruits of most wild species are yellow when ripe, but those of *C. betacea* are orange or red; darker longitudinal stripes are often apparent on the fruit surface. In many species, sclerotic concretions are present in the mesocarp and can occasionally reach several centimeters in length. The meaty mesocarp just inside the skin varies from creamy yellow to pale orange and has a bland or bitter flavor, whereas the mucilaginous watery pulp surrounding the seeds is subacid and sweet (Bohs, 1989).

Tamarillo plants start to produce fruit in the first or second year after transplanting. It is self-compatible and usually autogamous, but the flowers need to be shaken by the wind or visited by insects for pollination to take place. If grown in conditions where flower vibration is limited, such as in a greenhouse, fruit set can be very low (Prohens and Nuez, 2001).

There are mainly three varieties of tamarillo which are red, yellow and purple variety. The red type being more widely-grown because of its bright colour i.e. reddish orange skin when ripe. It is oval-shaped and the flesh is orange-coloured and weighs between 50 and 80g. Red type includes ‘Oratia Red’, ‘Secomes Red’, ‘Ecuadorian Orange’ ‘Red Beam’, ‘Andys Sweet Red’, ‘Solid Gold’, ‘Red Delight’ and ‘Red Beau’. The yellow type is more popular with home gardeners as it is sweeter. It has bright yellow skin, with brown to green hardly noticeable longitudinal stripes. It is oval shaped and fruit weight varies between 50 and 70 g. Flesh is yellow coloured. Purple type is also known as “dark-red or “black”. The fruits have a strikingly dark red skin. It is round to oval in shape and fruit usually weighs between 60 and 100 g. Flesh is purple coloured (Bakshi *et al.*, 2016).

2.1.3 Harvesting and yield

Tamarillos usually start to bear within 18 months of planting. They usually come into full production within 3 or 4 years, but from a commercial point of view they are usually only profitable for 7 - 8 years. Under suitable conditions, a tree may produce 20 kg or more fruit annually. On seed derived plants fruit production starts after about 18 months whereas plants obtained from cuttings reach maturity earlier. A tree in a good environment will produce about 15-20 kg of fruits per year during 6-10 years (Bakshi *et al.*, 2016).

Tamarillos are picked when fully coloured. Fruit can be picked when they are at the turning stage (when the green colour of the skin begins to change and the characteristic skin colour begins to show) and then treated with ethylene to stimulate ripening. This early picking and subsequent postharvest ripening reduces the risk of crop failure, increases earliness and concentrates harvesting as it allows harvesting to be advanced by up to one month (Prohens and Nuez, 2001).

2.1.4 Chemical composition of tamarillo

Tree tomato (*Cyphomandra betacea*) is appreciated for its excellent nutritional qualities, being considered a good source of antioxidants compounds, calcium, phosphorus, potassium and iron, sugars, organic acids, pectin and flavonoids(Torres, 2012). It also produces edible fruits with a high content of vitamins, minerals, phenolic and carotenoids compounds as well as low carbohydrates content (Bakshi *et al.*, 2016).

The chemical composition of tamarillo is shown in Table 2.1.

Table 2.1 Composition of tamarillo

Parameters	1	2
Total soluble solids	10-13.5 ºBx	4.8%
Water	(81-87)%	83.56%
Fat	0.05-1.28 mg/100g	0.81%
Total acidity	1.0-2.4 mg/100 g	0.81%
Protein	1.5-2.5 g	0.52%
Calcium	3.9-11.3 mg/100 g	9.51 mg

Source: (1) Bakshi *et al.* (2016) Source: (2) Nallakurumban *et al.* (2015)

Table 2.2 Phytochemical and antioxidant composition of tamarillo

Parameters	Fresh fruit
Ascorbic acid (mg/100g)	33.6
Total phenols (mg GAE/100g)	190.0
Total flavonoids (μg/g)	81.22
Antioxidant activity (mg AA eq/100g)	208
Beta carotene (μg/g)	1.72

Source: Nallakurumban *et al.* (2015)

Table 2.3 Vitamin content of tamarillo

Vitamins	1
Folates (µg/100 g)	4
Niacin (mg/100 g)	0.271
Pyridoxine (mg/100 g)	0.198
Thiamine (mg/100 g)	0.043
Vitamin A (µg/100 g)	630 IU (189.17 µg)
Vitamin C (mg/100 g)	29.8
Vitamin E (mg/100 g)	2.9

All the values are per 100 g edible portion

Source: (1) Anon., (2017)

2.1.5 Food uses

Tree tomatoes are eaten by scooping out the entire inner part of the fruit, discarding the exocarp and outer layer of the mesocarp. The latter has a disagreeable bitter taste and must be removed; this is facilitated by immersing the fruits in boiling water for several minutes. The seeds may be eaten or strained out. The taste is much like that of the garden tomato, but the fruits are more acid and less juicy and have a noticeable aftertaste. Because of their resemblance to tomatoes, they may be used in similar ways: eaten raw, cut up in salads, or cooked or stewed with meat. The fruits of *C. betacea* are relatively nutritious because of their high vitamin content. They are very rich in d-carotene, making them good sources of pro vitamin A, and they also contain large amounts of ascorbic acid or vitamin C. Their high pectin content makes them especially suitable for jam- and jelly-making. Levels of nitrogen and free amino acids are higher than those of most fruits except avocados and bananas; the values for potassium and phosphorus are also high among fruits, which are normally poor sources of these elements (Bohs, 1989).

Tree tomato slices, alone, or combined with sliced apple, are cooked in pies. They may be packed in preserving jars with water or sugar syrup and cooked for 55 min, or may be put into plastic containers with a 50% syrup and quick-frozen for future use in pies or puddings. The peeled fruits can be pureed in a blender or by cooking, strained to remove the seeds and then packed in plastic containers and frozen. Lemon juice may be added to the puree to enhance flavour. The peeled, stewed fruits are combined with gelatin, milk, sugar and lemon juice to make a dessert which is then garnished with fresh tree tomato slices. Peeled, sliced and seeded tree tomatoes, with lemon rind, lemon juice and sugar, are cooked to a jam; or, with onions and apples, are made into chutney. Chutney is prepared commercially in a factory in Auckland, New Zealand. Being high in pectin, the fruit is easily made into jelly but it oxidizes and discolours without special treatment during processing. Whole, peeled fruits, with sugar, are cooked to a sauce for use on ice cream. The peeled fruits may be pickled whole, or may be substituted for tomatoes in a hot chili sauce (Morton and Collectanea, 1982). Tamarillos can also be added as a secondary fermentation flavouring to Kombucha Tea for a tart and tangy taste. The fruit should be mashed and added at a ratio of 3 tamarillos to 1 litre of Kombucha, however great care should be taken to not allow too much carbon dioxide gas to build up in sealed bottles during secondary fermentation. The sugar content of fresh tamarillos added to Kombucha can generate a rapid carbon dioxide production in secondary fermentation within just 48-72 (Anon.,2018c).

In Nepal, a version of the South American fruit is decently popular. It is typically consumed as a chutney or a pickle during the autumn and winter months. It is known as Tammatarand, Ram Bheda (Anon.,2018c).

2.2 Sauce

There is no essential difference between sauce and ketchup. However, sauces are generally thinner and contain more total solids than ketchups. Tomato, apple, papaya, walnut, soybean, mushrooms etc. are used for making sauces. Sauces/ketchups are prepared from more or less the same ingredients and in the same manner as chutney, except that the fruit or vegetable pulp or juice used is sieved before cooking to remove the skin, seeds, and stalks of fruits, vegetables and spices and to give the smooth consistency to the final product. However cooking takes longer because fine pulp or juice is used (Srivastava and Kumar, 2007).

Freshly prepared products often have a raw and harsh taste and are, therefore, to be matured by storage. High quality sauces are prepared by maceration of spices, herbs, fruits and vegetables in cold vinegar or by boiling them in vinegar. The usual commercial practice is to prepare cold or hot vinegar extracts of each kind of spices and fruits separately, and then blend these extracts suitably to obtain the sauces which are then matured. Many sauces use a seasoned mix of onion, ginger and garlic paste as the base of various gravies and sauces. Various cooking oils, ghee and/or cream are also regular ingredients in Indian sauces (Anon.,2014). Thickening agents are also added to the sauce in order to prevent sedimentation of solid particles. A fruit sauce should be cooked to such a consistency that it can be freely poured without the fruit tissues separating out in the bottle. The colour of the sauce should be bright. Sauces usually thicken slightly on cooling. By using a funnel, hot ketchup is filled in bottles leaving a 2 cm head space at the top and the bottles are sealed or corked at advisable to pasteurize sauces after bottling since there is always a danger of fermentation, especially in tomato and mushroom- based sauces. Other sauce are more acidic and less likely to ferment but should be pasteurized all the same. For this the bottle are kept in boiling water for about 30 min (Srivastava and Kumar, 2007).

2.2.1 Types of sauces

Sauces are basically of two kinds and they are thin and thick sauces:

2.2.1.1 Thin sauces

Thin sauce mainly consist of vinegar extract of various flavouring materials like spices and herbs. Their quality mainly depends on the piquancy of the material used. Some sauces are matured by storing them in wooden barrels. This develops their flavour and aroma. Freshly prepared products of this kind often taste raw and harsh. For sauces of high quality, the spices, herbs, fruits and vegetables are macerated in cold vinegar. Sometimes, extracts are prepared by boiling them in vinegar. The sauce is filtered through a fine or coarse mesh sieve of non-corrodible metal according to the quality required. The skins, seeds and stalks of spices should not be allowed to pass through the sieve as they spoil the appearance of the sauce. The usual commercial practice is to prepare vinegar extracts of each kind of spice and fruit separately either by maceration or by boiling and then to blend them suitably before putting them into barrels for subsequent maturing (Lal *et al.*, 2011a).

2.2.1.2 Thick sauces

A sauce which does not flow freely and which has a high viscosity is called a thick sauce. It should contain at least 3% acetic acid so that it has good keeping quality. The acidity should not, however exceed 3.4 otherwise, the sauce would taste sharp. The sugar content may vary from 15 to 30%., according to the kind of sauce made. Usually, malt vinegar is used which in addition to producing acidity improves the flavour. The sweetness is derived partly from fruits like date, raisin, apple, and tomato and partly from the sugar. The colour of the sauce varies with the raw material used. Sometimes a little caramel is added (Lal *et al.*, 2011a).

2.2.2 Ingredients used in sauce making

2.2.2.1 Spices

The geneva based International Organization for Standardization (ISO) defines spices and condiments as “vegetable products or mixtures thereof free from extraneous matter, used for flavouring, seasoning and imparting aroma in foods”. The term “applies equally to the product in the whole form or in the ground form”(Parthasarathy and Kandiannan, 2008). Webster describes spices as: Any of various aromatic vegetable productions as pepper, cinnamon, nutmeg, mace, allspice, ginger, cloves, etc., used in cookery to season and to flavour sauces, pickles, etc.; a vegetable condiment or relish, usually in the form of a powder; also, as condiments collectively (Peter, 2001).

Spices have been so valued primarily for their ability to make food taste better and sometimes for a perceived ability to make people feel better and fight disease. Their functional properties as antioxidants, preservatives, anti-microbial, antibiotic and medicinal have been well recognised and made use of. Spices have also characteristic, often very attractive colours, which are an important part of their appeal to be used as natural colours in the foodstuffs. The concept of flavour in spices comprises a range of olfactory and tastes perceptions. The constituents responsible for these sensations are the volatile / essential oil and resinous compounds, which are a wide range of different natural organic chemicals and which generally have little or no nutritional value(Parthasarathy and Kandiannan, 2008). Spices can be added to foods in several forms: as whole spices, as ground spices, as essential oils, as oleoresins or as prepared and filtered vinegar infusions. A more recent alternative is spice extracts. These consist of the flavour components of a spice, dispersed on one of several types of base, the most suitable bases for pickle and sauce use, for example, being salt or dextrose Flowers, leaves, roots, bark, seeds and bulbs (the simplest of natural ingredients) are used in endless combinations to produce an infinite variety of flavors: sweet, sharp, hot, sour, spicy, aromatic, tart, mild, fragrant or pungent (Peter, 2001).

Different spices used in making sauce are described:

2.2.2.1.1 Cardamom

Small cardamom *(Elettaria cardamomum)* belongs to family Zingiberaecae, exhibits an array of variations and naming of types after the place of cultivation has led to confusion regarding identity of varieties. Based on the size of fruits, two types are recognized. They are *Elettaria cardamomum* var. *major* Thw. and *E. cardamomum* var. *minor* WaIf. (Parthasarathy and Kandiannan, 2008). It is popularly known as 'Queen of Spices'. Cardamom oil is used in food, perfumery and liquor and pharmaceutical industries as a flavour and a carminative. Its use in the food industry is in flavouring pickles, meat and canned soups. It is available as a powder, dried pods, or loose seeds. Cardamom has a sweet, lemony, eucalyptus flavour. It is world's second most expensive spice (Peter, 2001).

2.2.2.1.2 Cloves

The clove, *Syzygium aromaticum* (L.) Merrill et. Perry, belongs to the family Myrtaceae. The use of clove in whole or ground form is mainly for domestic culinary purposes and as a flavouring agent in the food industry. Clove can also be used as food. Cloves are often used in the form of ground, extracted essential oils or oleoresin in a small amount because of their intense flavour. Food products which use clove are mainly curry powder, sauces and baked foods. Whole cloves are frequently used to flavour meat dishes, curries and soups (Peter, 2001).

2.2.2.1.3 Cinnamon

Cinnamon (*Cinnamomum verum*) (Family: Lauraceae) is one of the earliest known spice mainly cultivated for the dried inner bark of the tree. Cinnamon bark primarily is one of the most popular spices in use in every house. It has a delicate fragrance and a warm agreeable taste. It is extensively used as a spice or condiment in the form of small pieces or powder. It is aromatic, astringent, stimulant and also possesses the property of checking nausea and vomiting. Cinnamon is used for flavouring confectionary, liquors, pharmaceuticals, soaps and dental preparations (Parthasarathy and Kandiannan, 2008).

2.2.2.1.4 Garlic

Garlic (*Allium satium* L.) is a bulbous perennial vegetable spice. The bulb is composed of pungent bolblets, commonly known as cloves. Garlic is a semi-perishable product. It is mainly used as a condiment in various food preparations such as flavouring mayonnaise and tomato ketchup-sauce, salad dressing, meat sausages, stews spaghetti, chutney, and pickles etc. (Singh *et al.*, 2014).

2.2.2.1.5 Onion

Onion (*Allium cepa* var. *cepa*) represents a source of cysteine derivatives, which makes it a good antioxidant additive for food (Kavalcova *et al.*, 2014). The distinctive flavour of alliums have established plants as an essential part of the cuisine of the world. It is used as immature, mature bulbs as vegetable and spice as well as food for poultry and non-milking cattle. Onion is processed in the form of pickled onion, as onion in brine and onion in acetic acid (Peter, 2001).

2.2.2.1.6 Chilli powder

It is very hot because it is made from the dried, ground seeds of the chilli, its hottest part. The main source of pungency in peppers is the chemical group of alkaloid compounds called capsaicinoids (CAPS), which are produced in the fruit. It is made by grinding the seeds of chilli and dried chilli. It is used as a colorant, flavourant, and/or as a source of pungency, depending on the processed product (Peter, 2001).

2.2.2.1.7 Ginger

The spice ginger is obtained from the underground stems or rhizomes of *Zingiber officinale* (Rosc.), a herbaceous tropical perennial belonging to the family Zingiberaceae. The whole plant is refreshingly aromatic, but it is the underground rhizome, raw or processed, that is valued as spice. The refreshing pleasant aroma, biting taste and carminative property of ginger make it an indispensable ingredient of food processing throughout the world. Fresh ginger, ginger powder from dry ginger, oleoresin and oil are all used for this purpose. Fresh ginger is unique for its flowery flavour and spicy taste. Ginger makes a tasty paste, especially if mixed with garlic. It can be used in sweet dishes, desserts, or in piquant dishes such as hot curries and stir fries (Vasala, 2001).

2.2.2.1.8 Black pepper

Among the spices, black pepper is the king. It is the most important, most popular and most widely used spice in the world. It has extensive culinary uses for flavouring and preserving processed foods and is important medicinally. Black pepper is obtained from mature fruits of Piper nigrum L., a perennial woody evergreen climber, native to the evergreen forests of the Western Ghats of South India. Pepper is the only spice that is used to flavour food before, during and after cooking (Ravindran and Kallupurackal, 2001).

2.2.2.2 Salt

Salt has been used both to flavour and preserve food since the earliest recorded times. The word 'salt' as commonly used an in the sense used here denotes a single substance, in chemical nomenclature "sodium chloride". It is a compound of sodium ions (positively charged sodium atoms) and chloride ions (negatively charged chlorine atoms). They are present in equal numbers but the proportion of chloride to sodium by weight is roughly 60:40. Both are essential nutrients but sodium has attracted more attention. They are necessary for the transfer of molecules (e. g. amino acids) across membranes, for the transmission of nerve impulses, for the digestion of food and for muscular action (Heimbach, 1986).The maximum recommendation of salt for adult as given by WHO (1990) is 6 g per day.

As a way of preserving food, salt works primarily by rendering any water present unavailable for the growth of micro-organisms. The effect on taste and flavour, however desirable, is incidental to this. When salt is used for flavouring, it not only adds its own taste, but modifies and intensifies the intrinsic flavour of the food (Anon.,2018b).

2.2.2.3 Vinegar

Vinegar is one of the oldest known fermentation product. It consists about 5% acetic acid in water, varying amounts of fixed fruit acids, colouring matter; salts and a few other fermentation products which impact a characteristic flavour and aroma to the product. Vinegar is a liquid deprived from various materials, containing sugar and starch, by alcoholic and subsequent acetic fermentation. It should contain at least 4 g of acetic acid per 100 ml and a corresponding quantity of the mineral salts of the material from which it is made (Lal *et al.*, 2011b).

2.2.2.4 Sugar

Sugars are widespread in nature and are the building blocks of carbohydrates. Sugar is naturally found in many foods, including milk, grains, fruit, and vegetables. The sugar found in these foods provides an important fuel source. Certain tissues in the body, such as the brain and red blood cells, exclusively use sugar for energy. Furthermore, these carbohydrate-rich foods provide a variety of other nutrients, such as fiber, vitamins, and minerals. The World Health Organization recommends consuming no more than 10% of daily calories from added sugar and 'free sugars,' such as honey, syrup, or juices (Anderson, 2016).

2.2.3 Flow sheet for sauce preparation

Raw material (Tree tomato (fully ripe, red)

↓

Washing and sorting

↓

Holding for 2 min at temp. 97±3ºC (To soften)

↓

Peeling and removing seeds

↓

Pulping

↓

Incorporation of tree tomato pulp at 50%

↓

Cooking pulp with two third quantity of sugar

↓

Putting spice bag into boiling pulp and pressing occasionally

↓

Judging the TSS

↓

Addition of remaining amount of sugar

↓

Addition of salt, vinegar and added preservative

↓

Judging of end – point (TSS - 30º brix - by hand refractometer)

↓

Filling hot into bottles at about 88ºC

↓

Capping

↓

Pasteurization and cooling

↓

Storage

Fig. 2.1 Preparation of tamarillo sauce

Source: Nallakurumban *et al.* (2015)

2.2.3.1 Selection of raw material

The raw material used for the preparation of sauce should be ripe and of good quality. The preserved pulp can also be used in the preparation of sauce or ketchup. The raw material should be cleaned and sorted before processing (DFTQC, 2003).

2.2.3.2 Blanching

Blanching is a unit operation prior to freezing, canning, or drying in which fruits or vegetables are heated for the purpose of inactivating enzymes; modifying texture; preserving colour, flavour, and nutritional value; and removing trapped air. Hot water and steam are the most commonly used heating media for blanching in industry. Water blanching is performed in hot water at temperatures ranging typically from 70ºC to 100ºC. However, low temperature long-time (LTLT) blanching and combinations of LTLT with high-temperature short-time (HTST) blanching have also been studied (Reyes *et al.*, 2004).

According to (Nieves *et al.*, 2001), blanching is an important pre-processing heat treatment of vegetables which inevitably causes separation and losses of water soluble nutrients as minerals, water soluble vitamins and sugars. Blanching also affects the texture but it should be optimum not to bring undesirable changes (Mepba, 2007).

2.2.3.3 Method of pulping

2.2.3.3.1 Cold break process

In this method, tomatoes are cut into four halves and pulping is done with the help of grinding machine without cooking of tomatoes. The taste and flavour is retained in greater proportion in this kind of pulp but the pulp are thin and the amount of pectin is also less and the colour of tomato is degraded as well (DFTQC, 2003).

2.2.3.3.2 Hot break process

In this method, tomatoes are cut into four halves and cooked for about 5-10 min at 80-90ºC and kept in grinder for pulping. The amount of pectin and natural tomato colour is more compared to cold break process and hence most of the industries apply hot break process in order to prepare sauce/ketchup. The standard tomato sauce should contain not less than TSS 5.66% and density must be 1.0220. If TSS is less when measured with refractometer, the product should be cooked for a bit more time to make it thick (DFTQC, 2003).

2.2.3.4 Addition of ingredients

The spices should be of good quality and should be added in proper proportions to give an agreeable flavour. The mixture made should be such that no one spice dominates the natural flavour of tomatoes. The spices can be used in the following way:

2.2.3.4.1 Bag method

The spices are tied loosely in a muslin bag and it is placed in the juice during boiling. It is removed before bottling the product. The spice bag can be used for the second batch of juice also. This method has the following drawbacks:

- The bag may give way and spoil the whole product. In that case, even if the pulp is again forced through a very fine sieve, particles of the spices will still pass and darken the product.
- The taste and flavour may vary every time according to the duration of boiling and variation in the composition of spices used on different occasions.
- All the flavours are not extracted in the first boiling. Moreover some of the volatile flavouring substances may be lost during boiling. To counteract these a quantity of spices larger than what is actually required will have to be used. This will add to the cost although the used spices can be utilized for the preparation of pickles. In spite of these drawbacks, the bag method gives a product of high quality (Lal *et al.*, 2011a).

In spite of having these drawbacks, the bag method gives the product of superior quality.

2.2.3.5 Use of salt and sugar

Salt bleaches the tomato colour and also dissolves to some extent copper from the kettle or the coil, when the equipment is made of copper and tinned. So the addition of salt should be done at last while making sauce/ketchup. The addition of salt at prior stage may lead to the degradation of sauce colour. In commercial ketchups/sauce, the proportion of salt ranges from 1.3-3.4% (Lal *et al.*, 2011a).

Similarly, sugar should not be used all at once. This may lead to the increase in boiling point and cooking time. So two third quantity of sugar should be mixed at first and the remaining amount should be added at last (DFTQC, 2003). This helps to intensify and fix the red tomato colour. If the whole of the sugar is added in the beginning itself, the pulp will have to be boiled for longer period of time and at a higher temperature with the result that the colour of sauce will be adversely affected (Lal *et al.*, 2011a).

2.2.3.6 Cooking and concentration

The total solid should be maintained constant at the same level in order to get the product of uniform taste and flavour an also of fine texture and thickness or body. In commercial ketchups/sauce, the percentage of total solid varies from 20-37. A higher proportion of total solids dilutes the concentration of tomato solids, because it contains more of sugar and vinegar. Hand refractometer is used in order to determine the total solid content of the product as it is convenient method (Lal *et al.*, 2011a).

2.2.3.7 Sterilization of bottle

Detergents can be used for the sterilization of bottle. Hot water boiled for about 30 min can also be used for cleaning. The bottles should be dried with the help of drier and care should be taken so that the foreign materials are not adhered in the bottle. The dried bottle can be used for filling sauce/ketchup (DFTQC, 2003).

2.2.3.8 Bottling

When the product is ready at the end of boiling, it is passed through a finishing machine fitted with a very fine sieve, to remove any tomato fibre, small pieces of paper, wood, etc., that might have got in through sugar or spices.

The product should be bottled hot at about 88ºC to prevent darkening of its colour and loss of vitamin content during subsequent storage and distribution. On cooling, the sauce shrinks in volume producing thereby a high degree of vacuum in the bottle. Sometimes, a black ring is formed on the surface of the product in the neck of bottle which is termed as black neck (Lal *et al.*, 2011a).

2.2.3.9 Pasteurization

Pasteurization is relatively mild heat treatment, in which food is heated to below 100ºC. In low acid foods (pH > 4.5, for example milk), it is used to minimize possible health hazards from pathogenic micro-organisms and to extend the shelf life of food for several days. In acidic foods (pH < 5, for example bottled fruit) it is used to extend the shelf life for several months by destruction of spoilage micro-organism (yeasts or molds) and/or enzyme inactivation. In both type of food, minimal changes are caused to the sensory characteristics of nutritive value (Fellows, 2000).

The bottle filled with sauce should be kept upright in a vessel with water and should be boiled at 85-90ºC for about 30 min. The pasteurized bottle should be immediately kept at cold air (DFTQC, 2003).

2.2.4 Packaging materials used in filling sauce

Food packaging is defined as a co-ordinated system of preparing food for transport, distribution, storage, retailing, and end-use to satisfy the ultimate consumer with optimal cost (Shin and Selke, 2014). The packaging materials used in filling sauce are described below:

2.2.4.1 Glass

Glass is defined as "an amorphous inorganic product of fusion that has been cooled to a rigid condition without crystallizing". For food packaging, bottles or jars are the types of glass packaging most often used, bottles being the primary use. Glass is inert to a wide variety of food and non-food products, very rigid and strong against pressure, transparent, and nonpermeable (excellent barrier properties). However, glass has disadvantages due to its heavy weight and fragility. For food packaging, the fragility has caused some safety concerns such as the possibility of the presence of chipped glass in food products. Glass for food packaging has declined over the last three decades, with glass losing market share to metal cans and, increasingly, to plastics. However, it still plays an important role in packaging (Shin and Selke, 2014).

2.2.4.2 Plastics

Plastics are a special group of polymers that can be formed into a wide variety of shapes using controlled heat and pressure at relatively low temperatures, compared to metals and glass. Plastics are actually a subcategory of polymers, but in packaging the terms tend to be used interchangeably. There are hundreds of identified "species" of synthetic polymers but in practice, only a few polymers are often used for food packaging. The use of plastics has increased more rapidly than any other material, and plastic is now the second most used material for packaging (Shin and Selke, 2014). Some of the plastic packaging material used in food industry are described in the following sections:

2.2.4.2.1 Polyethylene terephthalate (PET)

Polyethylene terephthalate or PET is one of the world's most commonly used plastics in the world, both in textile manufacture, where it is known as polyester, and in packaging where it is common for drinks packaging (Wight, 2015). PET Bottles are used to packing of Edible oils, jams and sauces, Butter, syrups, Drinking water etc. having the capacity from 500ml to 2 liters. PET resin are extruded and converted to pre-forms and later molding is done to make the PET Bottles by using the pre-forms. Major application areas of PET bottles are carbonated soft drinks, mineral water packing, syrups, edible oil packing, butter and mayonnaise, wine, liquor and spirit packing, sauce, jam and squashes packaging, agro chemical packaging and house hold containers (Anon.,2018a).

2.2.4.2.2 Polyethylene

It is most widely used mass produced plastic. Polyethylene are made by pressure polymerization of ethylene. High pressure makes low density (low molecular weight) polymer and low pressure produces high density polymer. They have low barrier to gases, aroma and fats. They have good chemical stability and are tough and easily heat sealed (Subba, 2073).

2.2.4.2.3 Biaxially oriented polypropylene (BOPP)

BOPP is used as a barrier film, usually with a surface coating. They have higher strength characteristics, at substantially lower materials consumption, thermal stability, up to + 130°C, and the ability to withstand loads during autoclave sterilisation without changes in shape of the packaging. It also have better barrier properties (Yudin *et al.*, 2002).

2.3 Storage stability of fruits and vegetables based products

All food products are inherently unstable and quality retention depends upon a number of factors, including storage time and temperature. This is recognised in all new product work, in changing or improving existing products, and in modifying process. Storage stability technologies have come a long way in a few short years. This can be seen visually in the evolution of systems for holding products to study storage stability, first in desiccators, to programming storage cabinets, to storage rooms which can be programmed to duplicate the climate of any place on earth (Desrosier and Desrosier, 1977). Packaging material used has no significant effect on the chemical composition of product (Li *et al.*, 2018).

1. Effect on colour: The product kept at -17°C or -28°C has a slightly lighter appearance whereas the product stored at 21°C and 37°C tend to darken. The degradation in colour may be due to maillard reaction and degradation of lycopene. Lycopene is not only an important characteristic component, but also the major coloring ingredient of tomato and tomato products. Thus lycopene has been a hot topic among the researches on the color changes of tomato products (Li *et al.*, 2018). Also, the use of salt in the product do not affect the color of it (West and Merx, 1995).
2. Effect on flavour: Flavour changes are generally tended to be associated with colour changes (Desrosier and Desrosier, 1977). The use of salt in product increases flavor release due to the salting-out phenomenon as NaCl decreases the availability of water in food, thus increasing volatility of aroma compounds. Sucrose, however, decreases aroma compounds due to sucrose-sucrose interaction and sucrose-water interaction (Patana-anake and Barringer, 2015). Sugar also affects the sweet taste attribute that has an influence on overall acceptability of the product (Auerswald *et al.*, 1999).
3. Effect on texture: Extremes of temperature had adverse effects on texture. Freezing damaged such items as tomatoes and beans enough to reduce them to substandard grades. Most of the sauces and gravies separated with freezing, and noodles, spaghetti tended to soften or slough (Desrosier and Desrosier, 1977).
4. Effect on fluidity: The consistency of tomato products depends on the amount of suspended particles (pulp) in a dispersing medium and is directly related to the tomato fruit constituents such as pectin. Other factors such as enzymatic degradation, pulp network, homogenization process and concentration also play an important role in determining the consistency of tomato products. Viscosity is usually considered an important physical property related to the quality of food products. The viscosity of fluid foods is an important parameter of their texture. It determines to a great extent the overall mouth-feel and influences the intensity of flavour (Desouky, 2016). It also helps in determining the cost of the products such as sauce or ketchup. Products with low viscosity may be sold at lower price or even graded unacceptable (Sharoba *et al.*, 2004).

2.3.1 Chemical changes during storage

TSS, pH, vit C and acidity are generally measured for the storage stability of fruit and vegetable products.

- TSS: The prolong storage shows increase in the total solid content of the product. Increase in TSS during storage may be due to acid hydrolysis of polysaccharides especially gums and pectin. However, this rise in TSS is functional to storage temperature and a direct relation has been reported between increase in TSS and storage temperature(Singh and Sharma, 2017). Packaging materials that are used for the storage of product do not affect the TSS (Kumar *et al.*, 2015).
- pH: There is increase or decrease in the pH of the product during storage. pH is most important among the parameters analysed because the acidity influences the thermal processing conditions required for producing safe products. pH value increases due to the effect of sugar concentration dilute in tomato ketchup samples and secondly effect of storage condition during room temperature and refrigerator conditions (Kumar *et al.*, 2015).
- Vitamin C: Vitamin C occurs naturally in many fruits and vegetables, particularly in tomatoes, citrus fruit, cantaloupe, broccoli, spinach, green peppers, cabbage, pineapple, melons, Mangoes and potatoes. The vitamin is easily destroyed by cooking or canning foods and by exposure to air and light. Increase in temperature normally results in high percentage loss of vitamin C. Vitamin-C is the most labile of the nutrients, so its degradation is used as an indicator of quality (Famurewa *et al.*, 2013). Ascorbic acid oxidation can also cause non enzymatic browning. During storage, the ascorbic acid oxidation degradation is often dependent on the processing method and the storage conditions (Li *et al.*, 2018).
- Acidity: The acidity of the fruit is also important as a contributor to the flavour of the tomato products. pH and titratable acidity are the two most important factors in processing (Anandsynal *et al.*, 2016). The decrease in acidity might be due to acidic hydrolysis of polysaccharides where acid is utilized for converting non-reducing sugar into reducing sugar (Kilima *et al.*, 2014).

2.4 Preservatives used in food products

Food additive that are used in order to store processed or unprocessed food for a long period of time are termed as preservatives. This helps to reduce the microbial load that may hamper the quality of food and increases the shelf life. Preservatives are classified into class I and II.

2.4.1 Class I preservatives

These preservatives are basically been used in the day to day food we intake. They are salt, sugar, honey, lactic acid, vinegar, glucose, niacin, spices etc. (DFTQC, 2003).

2.4.2 Class II preservatives

Class II preservatives are especially the chemicals that has the capability of preserving foods. They are:

- Sodium benzoate: It is used as a food preservative that inhibits the growth of mould, yeast and some bacteria. Sodium benzoate is widely used food preservative suitable for acid foods. The permitted level of sodium benzoate in tomato based sauce is 750 ppm given by DFTQC (2003).
- Suphurus acid or salt of sulphurus acid: Potassium Metabisulphite or KMS is used as a source of sulphurus acid. It produces sulphur di oxide gas that reacts chemically with the water present in food. This acid works as preservative for food product. The permitted level of KMS in fruit juices is 3000 ppm as given by DFTQC (2003).

Part III

Materials and methods

3.1. Materials

Materials collected for the preparation of tamarillo sauce are described in the following sections.

3.1.1 Tamarillo

About 5 kg of ripe tamarillo was bought from Bhanuchowk, Dharan at the rate of 200/kg and were kept in the polythene sack at normal room temperature.

3.1.2 Spices

Spices used in sauce making consisted of garlic, onion, small cardamom (*Elettaria cardamomum*), powdered chilli (*Capsicum annuum*), headless clove (*Syzygium aromsticum*), and cinnamon (*Cinnamomum verum*). All the spices were bought from the local market of Dharan.

3.1.3 Bottles

PET bottle and 250 ml glass bottles were used for filling of the sauce. They were thoroughly cleaned initially with cold water and detergent followed by hot water.

3.1.4 Equipment and chemicals

The following equipment and chemicals used were available in campus.

Table 3.1 List of chemicals used

Chemical	Supplier/manufacturer	Other specification
Sodium hydroxide (NaOH)	Thermofisher scientific India Pvt Ltd., Mumbai	Pellets, AR grade, 98%
Hydrochloric acid (HCl)	Thermo Electron LLS India Pvt. Ltd., India	36% LR grade
Oxalic acid	Ranbaxy laboratories Ltd., Punjab	99% min assay
Sodium Carbonate (Na_2CO_3)	Qualigens fine Chemicals, Mumbai	
2, 6-Dichlorophenol Indophenols dye	Nice Chemicals Pvt. Ltd. India	
Metaphosphoric acid (HPO_3)	Ranbaxy laboratories Ltd., Punjab	

Equipment used were as follows:

- Hand refractometer M 'Atago H82456', made in Japan
- Electric balance Mettler Toledo India Pvt Ltd.
- Stainless steel vessel
- pH meter made by Hanna Instruments (±0.01 unit sensitivity)
- Routine glass wares

3.2 Methods

3.2.1 Washing and sorting

Damaged and immature tree tomatoes were sorted out and washed in order to remove any kind of foreign materials like dust and dirt.

3.2.2 Optimization of yield percentage

For this the temperature of water was boiled at 97±1° C. Four samples of tamarillo having average weight of about 46.5 g each were taken for different boiling time and dipped in water in order to find the maximum yield percentage of the pulp viz. 0, 2, 4 and 6 min. The yield percentage was calculated in the following way:

$$\%\ \text{Yield} = \frac{\text{final amount of pulp}}{\text{initial weight of fruit}} \times 100\%$$

Peeling was done for the further processing of fruit and the seeds were also removed.

3.2.3 Grinding and sieving

Tamarillo was grounded into the very fine particles with the help of stainless steel mixer available in the campus and water was incorporated at the proportion of 1:1 as the pulp was very viscous which would have hindered for the preparation of product. Sieving was done in order to remove the leftover seed particles.

3.2.4 Optimization of salt

Five samples of tamarillo sauce were prepared by making variation in the concentration ranging from 1, 2, 3, 4 and 5 (%) but keeping all other ingredients constant and the samples were coded. These samples were subjected to sensory evaluation in terms of color/appearance, taste, fluidity/viscosity, mouth feel, flavour and overall acceptability and the scores so obtained were statistically analysed to get optimum concentration of salt.

Recipe used for the optimization of salt is given in the Table 3.2:

Table 3.2 Recipe used for making tamarillo sauce

	Sample A	Sample B	Sample C	Sample D	Sample E
Pulp	500 g	500 g	500 g	500 g	500 g
Salt	5 g	10 g	15 g	20 g	25 g
Sugar	78.65 g	78.65 g	78.65 g	78.65 g	78.65 g
Vinegar	2.02 g	2.02 g	2.02 g	2.02 g	2.02 g
Cinnamom	0.785 g	0.785 g	0.785 g	0.785 g	0.785 g
Cloves	6 pcs	6 pcs	6 pcs	6 pcs	6 pcs
Onion	5.5 g	5.5 g	5.5 g	5.5 g	5.5 g
Cardamom	6 pcs	6 pcs	6 pcs	6 pcs	6 pcs
Chilli powder	5 g	5 g	5 g	5 g	5 g
Garlic	2.5 g	2.5 g	2.5 g	2.5 g	2.5 g

3.2.5 Optimization of sugar

With optimized level of salt concentration 4% i.e. 20 g obtained through sensory analysis, four samples of tamarillo sauce were prepared for four different sugar concentration (15ºBx, 20ºBx, 25ºBx and 30ºBx) and the samples were coded. Those samples were subjected to the sensory evaluation in the similar way as in salt optimization in terms of colour/appearance, taste, fluidity/viscosity, mouth feel, flavour and overall acceptability and the scores so obtained were statistically analysed to get optimum concentration of sugar. The amount of sugar used for sample A, B, C and D was 37.64 g, 76.17 g, 113.31 g and 157 g respectively and all other spices were kept constant as is shown in Table 3.2.

3.2.6 Optimization of vinegar

With the optimized salt and sugar concentration 30ºBx i.e. 157g obtained through previous sensory analysis, four samples of tamarillo sauce were prepared keeping all other spices constant but varying the vinegar concentration at the range of 0.5%, 1%, 1.5% and 2% and the samples were coded. These samples were further subjected to the sensory evaluation in terms of colour/appearance, taste, fluidity/viscosity, mouth feel, flavour and overall acceptability and the scores so obtained were statistically analysed to get optimum concentration of vinegar. The amount of vinegar used for sample A, B, C and D was 2.5g, 5g, 7.5g and 10g respectively. The optimized amount of salt i.e. 20 g and sugar 157 g was used and all other spices were kept constant as given in Table 3.2.

Since the literature on formulation of tamarillo sauce was not available, general recipe given by Lal *et al.* (2011a), DFTQC (2003) and the optimized amount obtained from sensory analysis were used as the basis for the formulation of sauce in the present study. The recipe of the final product is given in Table 3.3:

Table 3.3 Recipe used for making final product

Ingredients	Amount
Pulp	500 g
Salt	20 g
Sugar	157 g
Vinegar	7.5 g
Cinnamon	0.785 g
Cloves	6 pcs
Onion	5.5 g
Cardamom	6 pcs
Chilli powder	5 g
Garlic	2.5 g

3.2.7 Variation in storage temperature and packaging material

The packaging material used for the storage of sauce were plastic and glass. They were kept at different temperature i.e. room temperature (21±3^{o}C) and refrigerated condition (4±1^{o}C) in order to find out the storage stability of product.

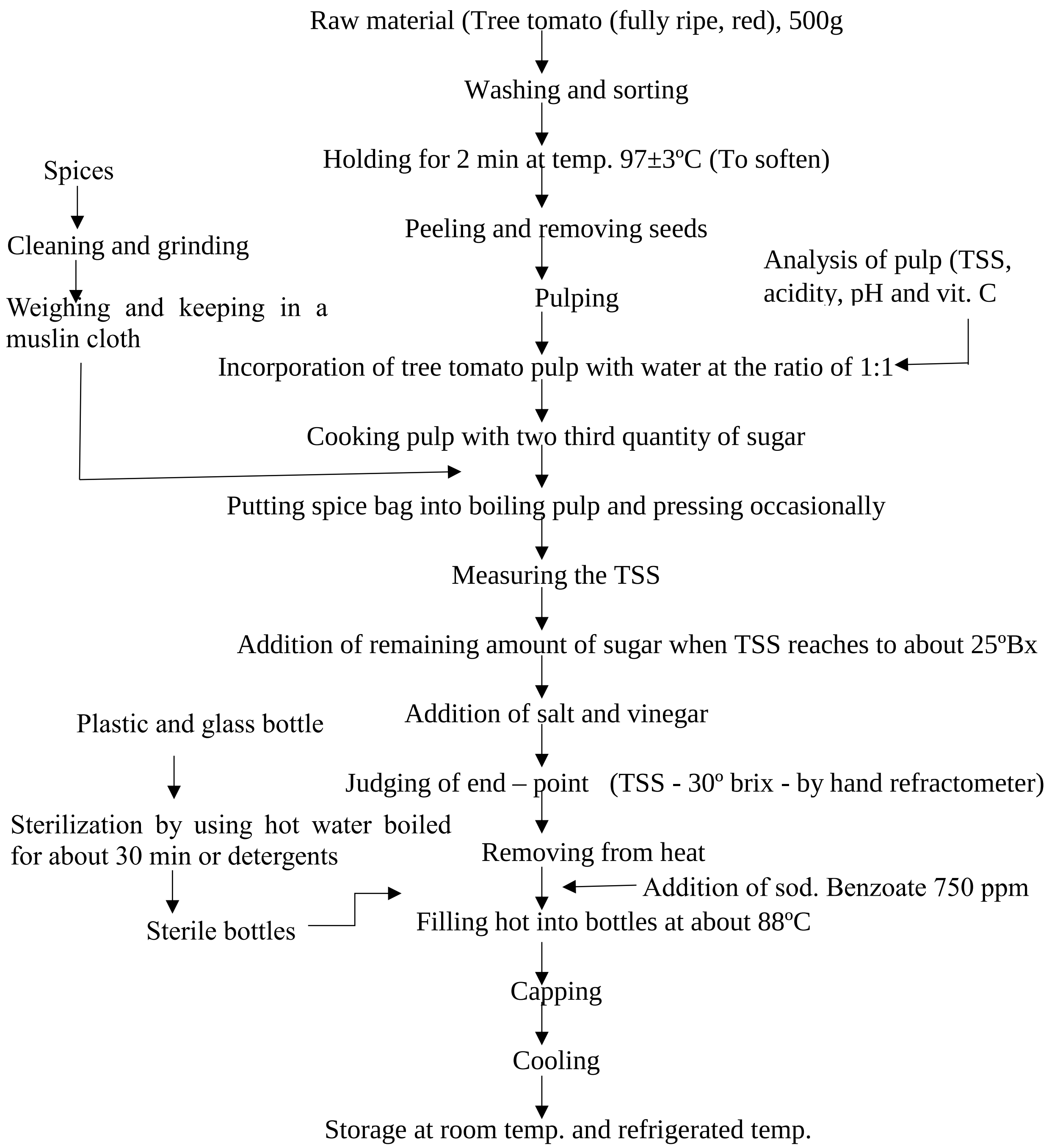

Fig. 3.1 Flow diagram of preparation of tamarillo sauce

3.3 Analytical procedure

3.3.1 Sensory evaluation of formulated products

Among the samples of sauce, the best one in terms of sensory evaluation was determined. For sensory evaluation, 9 point hedonic scale as per Ranganna (2007) was used. The panelist members consisted of research students and teachers of CCT, Hattisar who had some previous experience in the sensory evaluation.

The parameters for sensory evaluation were taken to be appearance/color, smell/flavor, taste, mouth feel, fluidity/viscosity and overall acceptability. Panelist was requested to give the points from 1 to 9, 1 for extremely disliked and 9 for extremely liked sample. Sensory evaluation was carried out in individual booth with adequate light and free from obnoxious odors. Each panelist was provided with coded samples with random numbers and evaluation card (Appendix A).

3.3.2 Analytical methods

3.3.2.1 Parameters analysed

The fruit as well as the final product were analysed for its TSS, pH, vitamin C and acidity.

- TSS: TSS of the raw material and final product was measured by using the hand refractometer and values are expressed in ºBx (Ranganna, 2007).
- pH: The pH was determined by using hand pH meter (HANNA instrument made in MAURITIUS).
- Vitamin C content: Vitamin C content of the sample was determined by using 2,6-Dichlorophenol Indophenol titration method as in (Rai and KC, 2007). To measure the vitamin C content of the final product and raw material, the sample was extracted by 3% metaphosphoric acid. The amount of vitamin C was calculated by using the formula

$$\text{mg \% ascorbic acid} = \frac{\text{Titre} \times \text{dye factor} \times \text{volume made up (ml)} \times 100}{\text{Aliquot(ml)} \times \text{weight or volume of sample taken (ml or g)}}$$

- Acidity: Acidity was determined by titrimetric method described by (Rai and KC, 2007)and calculated in % acitic acid. The volume consumed for neutralization was noted and acidity was calculated by using the formula

$$\% \text{ Total acid } = \frac{\text{Titre} \times \text{N of NaOH} \times \text{volume made up (ml)} \times 64 \times 100}{\text{Aliquot(ml)} \times \text{weight or volume of sample taken (ml or g)} \times 1000}$$

3.3.3 Statistical Analysis

All the experiment was conducted in triplicate. The data were subjected to statistical analysis and the scores given by the panellist were analysed by Two Way Analysis of Variance (ANOVA), no blocking at 5% level of significance using statistical software GenStat Release 12.1 (2009). The calculated mean values of each sensory parameter were compared with value in the LSD at 5% level of significance to determine whether the samples were significantly different from each other and also to determine which one was superior between them.

Part IV

Result and discussions

Tamarillo fruit was used in order to formulate the sauce. For this, optimization for the concentration of salt (1%, 2%, 3%, 4% and 5%), sugar (15ºBx, 20ºBx, 25ºBx and 30ºBx) and vinegar (0.5%, 1%, 1.5% and 2%) was carried out in order to formulate the recipe of tamarillo sauce. After the formulation of sauce, the final product was stored at room temperature and refrigeration temperature with varying packaging material. Chemical analysis was carried out fortnightly for 2 months.

4.1 Chemical composition of tamarillo

Chemical analysis of tamarillo was carried out to find out the acidity, pH, TSS, and vitamin C. The chemical composition of tamarillo is shown in Table 4.1

Table 4.1 Chemical composition of tamarillo

Parameters	Value
Acidity	1.37% (0.04)
pH	3.46 (0.06)
TSS	7.9ºBX (0.12)
Vitamin C	41.93% (1.72)

Values are means of three replicates. Figures in the parentheses are the standard deviation.

The chemical composition of raw tamarillo was found to be 1.37%, 3.46, 7.9ºBx and 41.93% for acidity, pH, TSS and vitamin C respectively. Similar results for TSS, acidity and pH of tamarillo was obtained by Bakshi *et al.* (2016) which were 10-13ºBX, 1-2.4 mg/100 g and 3.7-3.8 respectively. The results for vitamin C was similar to Nallakurumban *et al.* (2015) that showed 33.6 mg/100 g vit C.

4.2 Optimization of boiling time

Four samples of tamarillo each weighing about 47 g was taken and blanched at 97±1ºC for 0 min, 2 min, 4 min and 6 min. The boiling time was optimized according to yield of the pulp. The mean score for yield was found to be 51.35666667%, 59.93333333%, 54.87333333% and 55.52333333%. The graph plotted in Fig. 4.1 shows the yield percentage according to the blanching time.

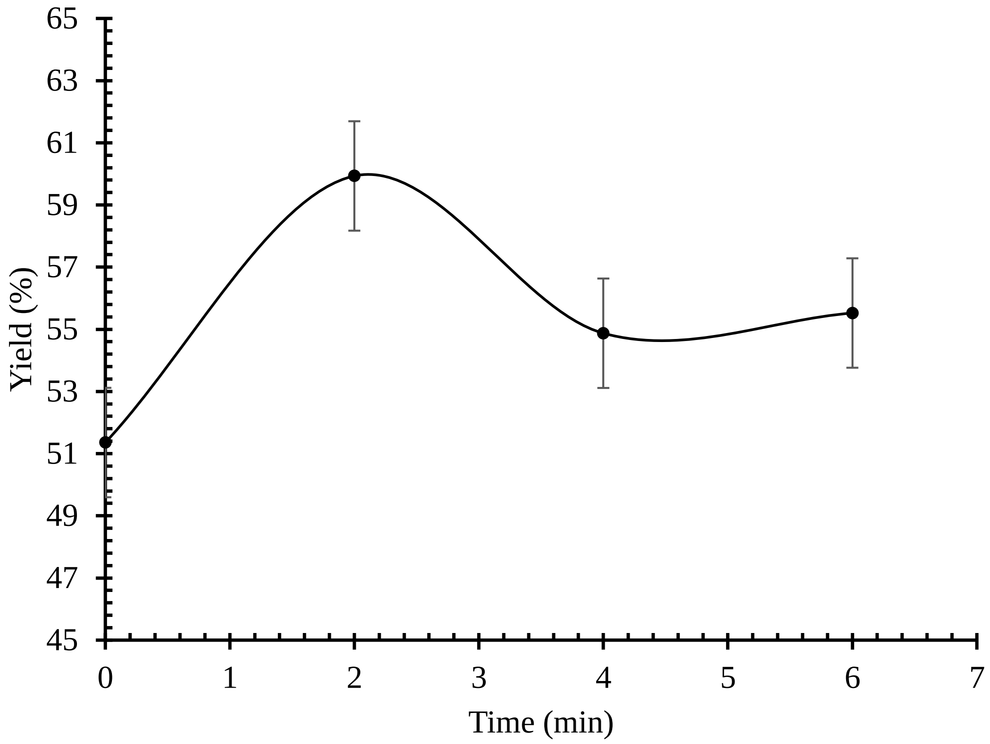

Fig. 4.1 Yield of pulp at different boiling time. Vertical error bars represent standard deviation.

The loss of pulp while peeling and removal of seeds affects the yield percentage of raw material. The boiling time effect the yield of pulp from fruits. The maximum yield of pulp was obtained at 2 min boiling time as shown in Fig. 4.1. Then as the boiling time was increased, gradual decrease in yield was observed. Boiling not only helps to make peeling easier but also inactivates the enzymes, thus preventing the possibility of discoloration. By removing undesirable acid elements and astringent taste of the peel, it also removes the flavour (Lal *et al.*, 2011a).

4.3 Optimization of salt by sensory analysis

In the preparation of tamarillo sauce ingredients viz. salt, sugar, vinegar, cinnamon, cloves, sukumel (green cardamom), onion, red chilli powder, cumin powder and garlic were added. The variation in salt was made keeping all other ingredients constant for the formulation of 500 g of sauce. 5 samples were made with varying salt concentration of 1%, 2%, 3%, 4% and 5% which were coded B, D, A, E and C respectively. The sensory analysis was carried out in terms of appearance/color, taste, mouth feel, fluidity/viscosity, smell/flavour and overall palatability and the statistical data is shown in Appendix B.

Here, Sample A=3%, Sample B=1%, Sample C=5%, Sample D=2% and Sample E=4%.

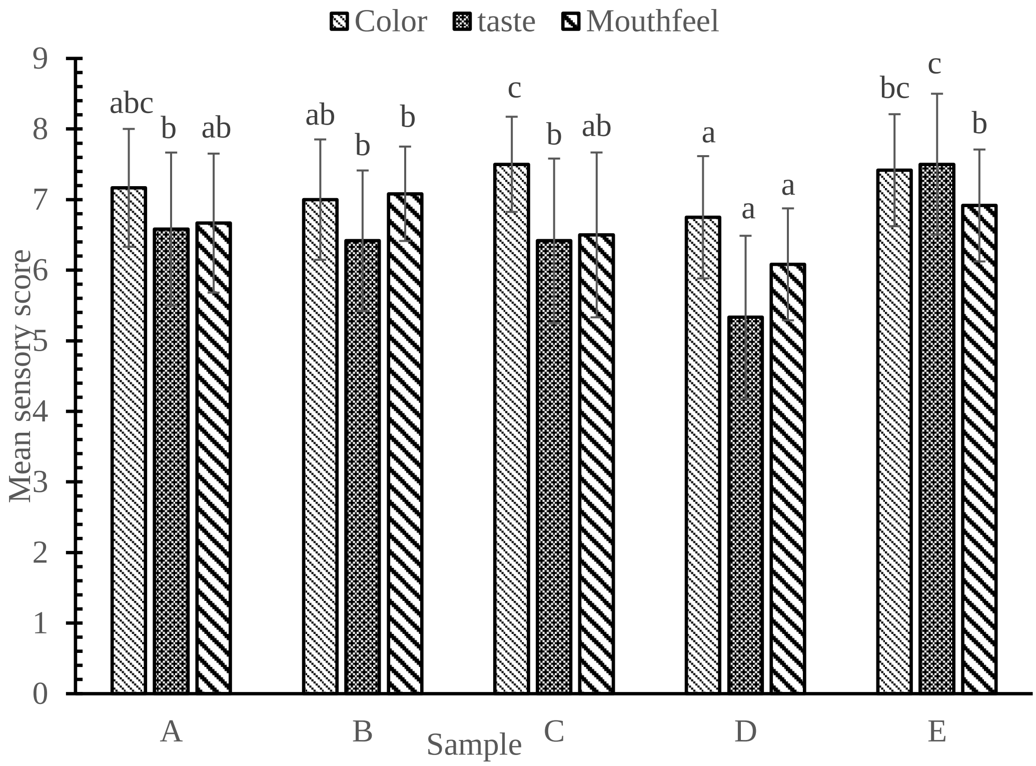

Fig. 4.2 Effect of salt concentration on colour, taste and mouth feel of tamarillo sauce. Vertical error bars represent standard deviation of scores given by panelist.

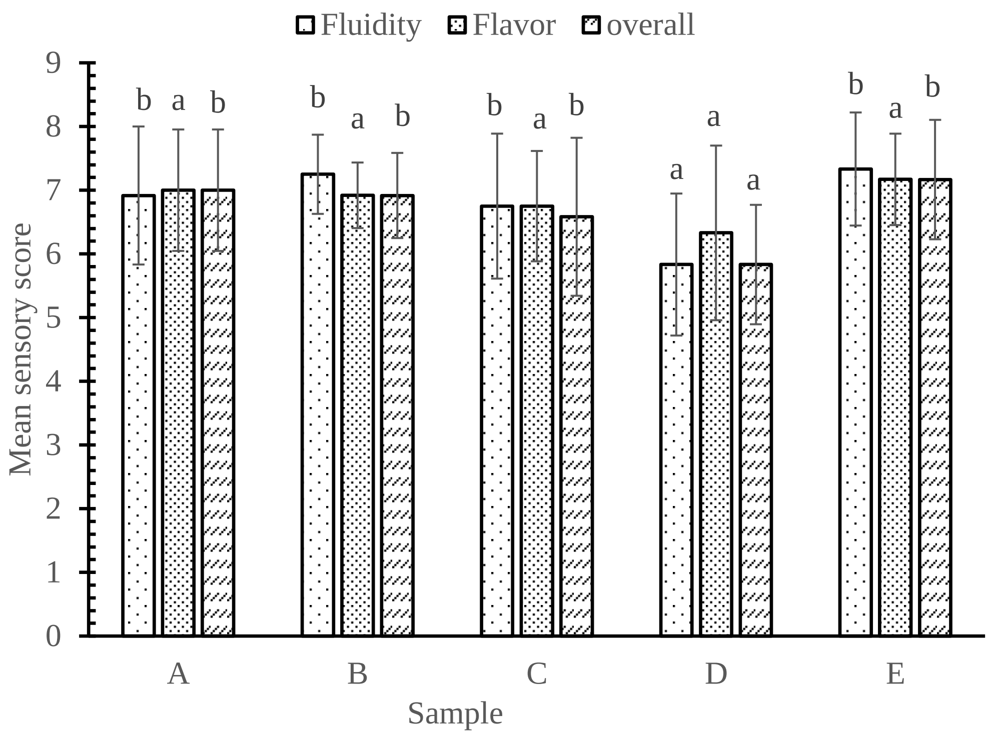

Fig. 4.3 Effect of salt concentration on fluidity, flavour and overall palatability of product. Vertical error bars represent standard deviation of scores given by panelist.

4.3.1 Appearance/Colour

The values in the Fig. 4.2 are the mean sensory scores of panelist. The similar alphabet above the bar diagram shown in Fig 4.2 indicate not significantly different ($p>0.05$).

The mean sensory score of sample A, B, C, D and E were found to be 7.167, 7, 7.5, 6.75 and 7.417 respectively. The LSD showed that there was significant difference between the samples ($p<0.05$). Sample C and D were found to be significantly different ($p<0.05$) from other samples at 5% level of significance whereas sample A, B and E had no significant difference. According to the maximum mean score obtained through statistical analysis, sample C i.e. 5% salt was found to be superior one.

The optimum salt concentration was found to be 5% in case of colour. It was found that the increase in salt concentration enhances the colour of Tamarillo which do not hold true as salt concentration do not affect the colour of the product as given by (West and Merx, 1995).

4.3.2 Taste

The values in the Fig. 4.2 are the mean sensory scores of panelists. The similar alphabet above the bar diagram shown in Fig. 4.2 indicate not significantly different ($p>0.05$).

The mean sensory score of sample A, B, C, D and E were found to be 6.583, 6.417, 6.417, 5.333 and 7.5 respectively. Statistically test showed significant difference ($p<0.05$) in terms of the variation made on salt concentration. Sample D and E were significantly different ($p<0.05$) from eachother whereas sample A, B and C were not significantly different at 5% level of significance. Statistial analysis showed that sample E was superior one as it had the high mean score.

The optimum salt concentration was found to be 4% in terms of taste through sensory evaluation. The increase in concentration of salt increases the preferance of the product. The acidic taste of tree tomato also masked by the addition of salt may be the reason for the preferance of high salt content.

4.3.3 Mouth feel

The values shown in Fig. 4.2 are the mean sensory scores of panelists. The similar alphabet above the bar diagram indicate not significantly different ($p>0.05$).

The average sensory scores for mouthfeel were 6.677, 7.083, 6.5, 6.083 and 6.917 for sample A, B, C, D and E respectively and values were singificantly different ($p<0.05$). The result of statistical analysis showed that sample D was significantly different ($p<0.05$) from sample B and E at 5% level of significance whereas sample A, B and C were not significantly different. This showed that sample B which contain 1% salt concentration was appreciated by the panelist and had the highest mean score.

4.3.4 Fluidity/Viscosity

The values in the Fig. 4.3 are the mean sensory scores of panelists. The similar alphabet above the bar diagram indicate not significantly different ($p>0.05$).

The average score for the fluidity were 6.917, 7.25, 6.75, 5.833 and 7.333 for samples A,B,C, D and E respectively. Statistical analysis showed that sample D was significantly different ($p<0.05$) from other samples at 5% level of significance whereas sample A, B, C and E were not significantly different ($p>0.05$) from each other. Thus sample E containing 4% salt concentration was found to be optimum with the highest mean score.

The viscosity of tomato ketchup is a major quality component for consumer acceptance. Several parameters contribute to the flow behavior of tomato ketchup, including the quality of the raw material and the processing conditions (Desouky, 2016).

4.3.5 Flavor/smell

The values in the Fig. 4.3 are the mean sensory scores of panelists. The similar alphabet above the bar diagram indicate not significantly different ($p>0.05$).

The average mean for the sample A, B, C, D and E were found to be 7, 6.92, 6.75, 6.33 and 7.17 respectively in terms of flavor of the product. Statistical analysis showed no significant difference ($p<0.05$) among the samples at 5% level of significance. Since sample E i.e. 4% salt concentration had high mean score, it was taken superior in terms of flavor.

It showed no significance difference between the samples($p>0.05$) which holds true as given by (West and Merx, 1995). Salt don't enhance the flavor.

4.3.6 Overall palatability

The values in the Fig. 4.3 are the mean sensory scores of panelists. The similar alphabet above the bar diagram indicate not significantly different ($p>0.05$).

The mean sensory score for overall palatability were found to be 7, 6.917, 6.583, 5.833 and 7.167 for sample A, B, C, D and E respectively. The values showed significant difference ($p<0.05$) in the samples. Statistical analysis showed that sample D was significantly different ($p<0.05$) from other samples at 5% level of significance whereas sample A, B, C and E were not significantly different ($p>0.05$) from each other. The highest mean score was obtained in sample E i.e. 4% and was termed superior.

The increase in salt concentration enhances the overall palatability of the product resulting in optimum salt concentration i.e 4%.

Based on the resut of sensory analysis, product E having 4% salt concentration was found to be superior in terms of taste, mouth feel, fluidity and overall acceptability which is shown in Fig. 4.2 and 4.3.

4.4 Optimization of sugar by sensory analysis

The optimized salt concentration 4% obtained from the sensory analysis of the Tamarillo sauce was further used for the preparation of sauce.Variation was made on the sugar according to the total solid content i.e 15ºBX, 20ºBX, 25ºBX and 30ºBX and were coded as D, B, A and C respectively and all other ingredients were kept constant. Sensory analysis was carried out among the samples and the results are plotted as bar diagram.

Here, Sample A=25 ºBX, Sample B=20 ºBX, Sample C=30 ºBX and Sample D=15 ºBX

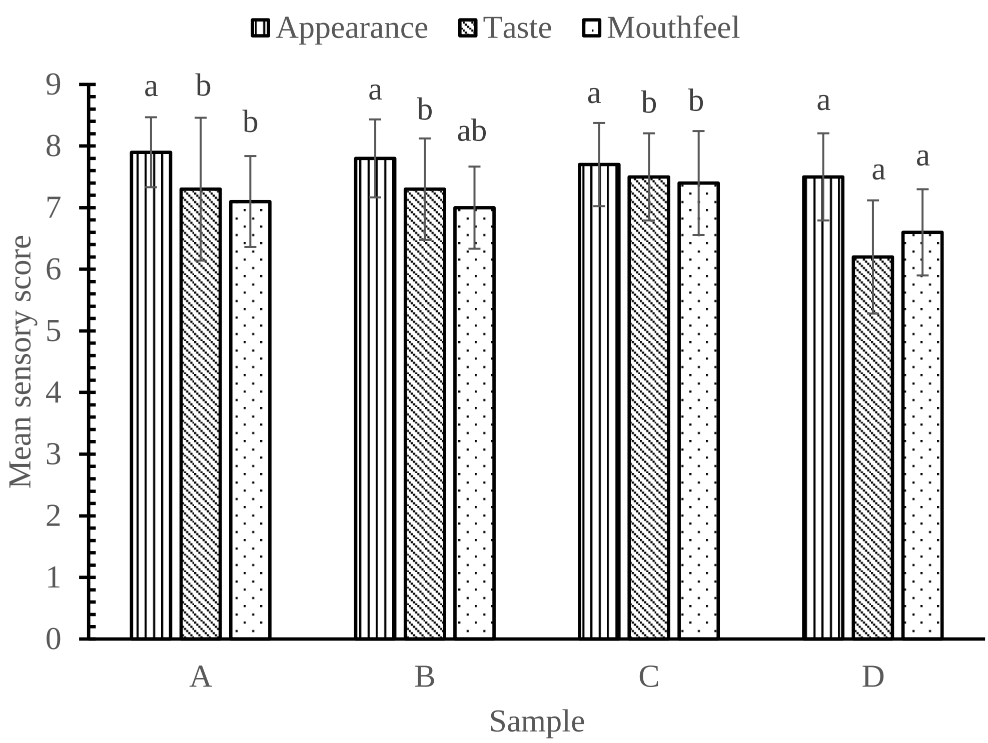

Fig. 4.4 Effect of sugar concentration on the appearance, taste and mouth feel of the product. Vertical error bars represent standard deviation of scores given by panelist.

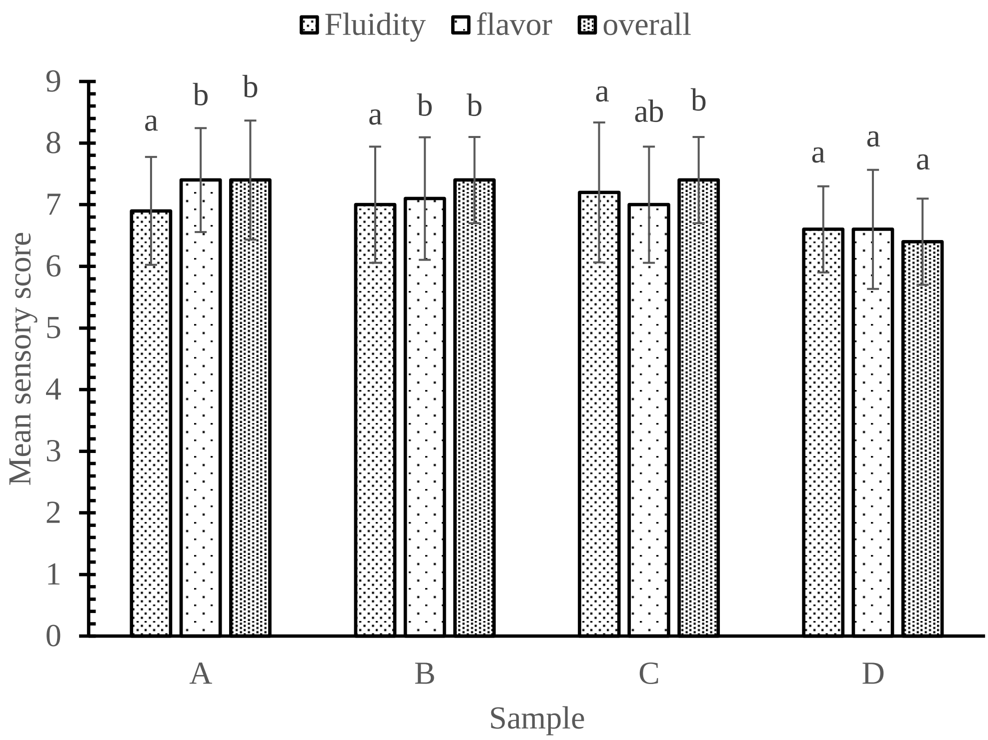

Fig. 4.5 Effect of sugar concentration on the fluidity, flavor and overall acceptance of the product. Vertical error bars represent standard deviation of scores given by panelist.

4.4.1 Appearance/color

The values in the Fig. 4.4 are the mean sensory scores of panelists. The similar alphabet above the bar diagram indicate not significantly different (p>0.05).

The average sensory score for appearance/color were 7.9, 7.8, 7.7 and 7.5 for samples A, B, C and D respectively. Statistical test showed no significant difference (p>0.05) in terms of appearance. Sample A i.e 25ºBx was found to have high mean score and was termed superior on the basis of color.

Sugar has no such significant effect on the appearance of the product. The graph showed in Fig. 4.4 also indicates that the panelist figured out no difference in the product made with different sugar concentration.

4.4.2 Taste

The values in the Fig. 4.4 are the mean sensory scores of panelists. The similar alphabet above the bar diagram indicate not significantly different ($p>0.05$).

The mean sensory score for taste were 7.3, 7.3, 7.5 and 6.2 for samples A, B, C and D respectively. Statistical test showed significant difference ($p<0.05$) in terms of taste. Sample C was found to be superior in taste in terms of sensory analysis and was significantly different ($p<0.05$) from other samples at 5% level of significance whereas l.s.d showed no significant difference between samples A, B and D. Sample C i.e. 30^{o}Bx sugar had the highest mean score and was taken as optimum concentration in terms of taste.

Sugar affects the sweet taste attribute that also influences the overall acceptability of the product (Auerswald *et al.*, 1999). The Fig. 4.4 above indicates that the product with higher sugar concentration was liked by the panelist whereas the product with least sugar concentration was not liked.

4.4.3 Mouth feel

The values in the Fig. 4.4 are the mean sensory scores of panelists. The similar alphabet above the bar diagram indicate not significantly different ($p>0.05$).

The mean score for mouth feel were 7.1, 7, 7.4 and 6.6 for sample A, B, C and D respectively. L.s.d showed that sample D was significanty different ($p<0.05$) from sample A and C whereas sample A and C were not significantly different. Increase in sugar concentration had a significant affect on the mouthfeel of the product. Sample C i.e 30^{o}BX was liked by the panelist.

The sweet aftertaste of the product with high sugar concentration was accepted by the panelist. Fluidity also influences the overall mouthfeel of the product. The added sugar may also influence the overall mouth feel of the product (Desouky, 2016).

4.4.4 Fluidity/viscosity

The values in the Fig. 4.5 are the mean sensory scores of panelists. The similar alphabet above the bar diagram indicate not significantly different ($p>0.05$).

The average score for the fluidity of the Tamarillo sauce were 6.9, 7, 7.2 and 6.6 for samples A, B, C and D respectively. Statistical test showed no significant difference ($p>0.05$) among the samples and the superior product was considered on the basis of high mean score i.e 30ºBx.

The viscosity of fluid foods is an important parameter of their texture. It determines to a great extent the overall mouth-feel and influences the intensity of flavor (Desouky, 2016).

4.4.5 Smell/flavor

The values in the Fig. 4.5 are the mean sensory scores of panelists. The similar alphabet above the bar diagram indicate not significantly different ($p>0.05$). The mean sensory score for smell/flavor were 7.4, 7.1, 7 and 6.6 for samples A, B, C and D respectively. Statistical data showed significant difference ($p<0.05$) among the samples. Sample D containing less sugar concentration was found to be significantly different ($p<0.05$) at 5% level of significance. Sample A i.e 25ºBX was choosen best in terms of smell/flavor as it had the highest mean score.

4.4.6 Overall palatability

The values in the Fig. 4.5 are the mean sensory scores of panelists. The similar alphabet above the bar diagram indicate not significantly different ($p>0.05$).

The average sensory score for overall palatability were 7.4, 7.4, 7.4 and 6.4 for samples A, B, C and D respectively. Statistical data showed no significant difference ($p<0.05$) between the samples. The result of sensory analysis showed that sample D was significantly different ($p<0.05$) from sample A, B and C at 5% level of significance. Increase in sugar concentration increased the overall palatability of the product.

Based on the sensory analysis of the product, sample C i.e 30ºBx was found superior on the basis of mouth feel, fluidity, taste and overall palatability.

4.5 Optimization of vinegar by sensory analysis

Four samples were prepared with varying vinegar concentration of 0.5%, 1%, 1.5% and 2% and were coded as sample B, C, A and D respectively. The optimized concentration of salt and sugar obtained from the previous statistical analysis and all other ingredients were kept constant. The statistical representation of the sensory analysis is given below:

Here, Sample A=1.5%, Sample B=0.5%, Sample C=1% and Sample D=2%

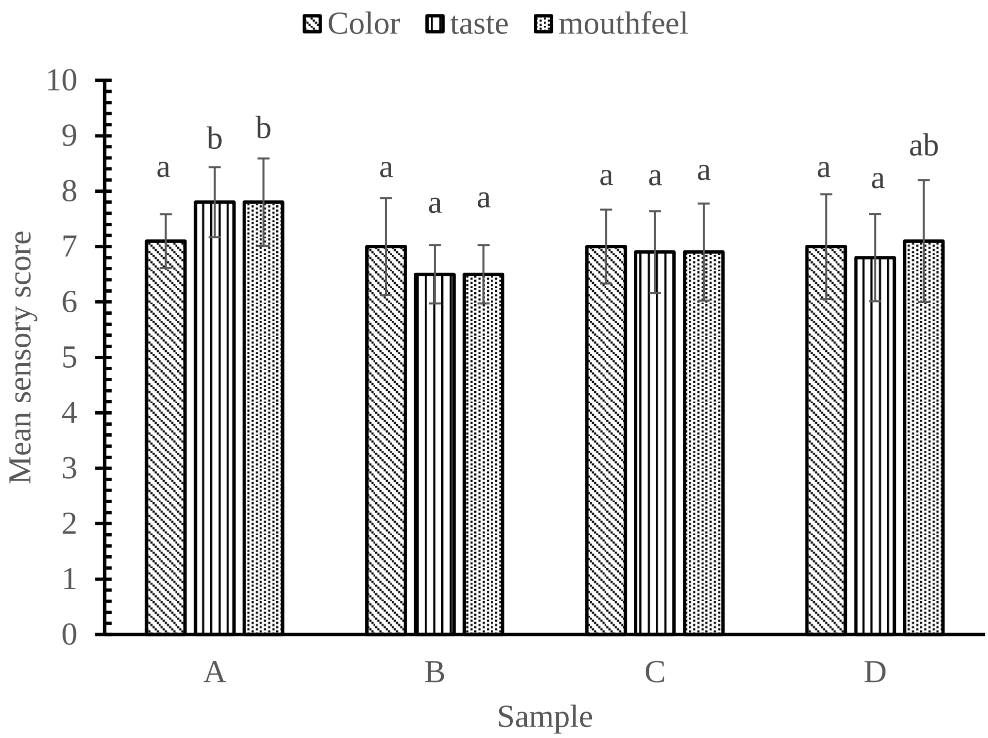

Fig. 4.6 Effect of vinegar concentration on the color, taste and mouth feel of the product. Vertical error bars represent standard deviation of scores given by panelist.

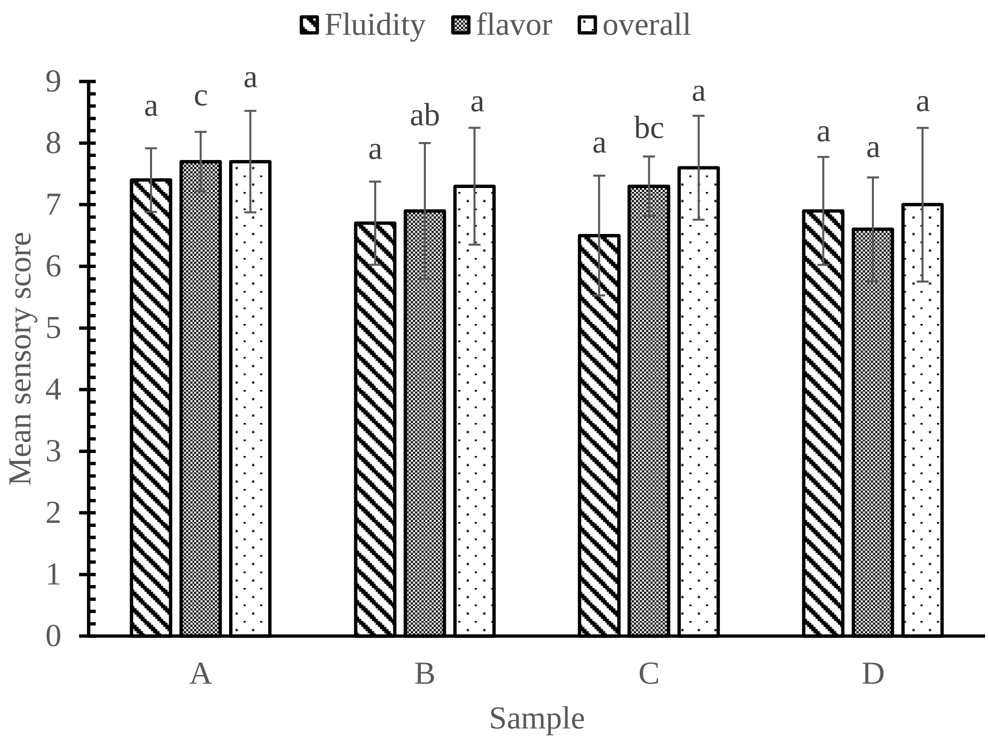

Fig. 4.7 Effect of vinegar concentration on the fluidity, flavor and overall acceptance of the product. Vertical error bars represent standard deviation of scores given by panelist.

4.5.1 Appearance/color

The values in the Fig. 4.6 are the mean sensory scores of panelists. The similar alphabet above the bar diagram indicate not significantly different ($p>0.05$).

The mean score for the color of the samples A, B, C and D were found to be 7.1, 7, 7 and 7 respectively. Statistical analysis showed that there is no significant effect ($p<0.05$) within samples at 5% level of significance. Sample A was found to be significantly different while the rest of the samples were not significantly different from one another. From the sensory evaluation and statistical analysis sample A i.e. 1.5% vinegar concentration was found to have higher mean sensory score.

4.5.2 Taste

The values in the Fig. 4.6 are the mean sensory scores of panelists. The similar alphabet above the bar diagram indicate not significantly different ($p>0.05$).

The mean sensory score for the taste of the samples A, B, C and D were found to be 7.8, 6.5, 6.9 and 6.8 respectively. Statistical analysis showed that there is significant effect ($p<0.05$) within the samples at 5% level of significance. Statistical analysis showed that sample A was significantly different from other samples whereas samples B, C and D were not significantly different from one another. From the sensory evaluation and statistical analysis, it showed that the sample A i.e. 1.5% vinegar concentration had high sensory score.

The result for the acceptance of product made with the concentration of 1.5% vinegar may be due to the preferance of acidic taste by the panelist. Acidic taste influences the overall acceptance of the product (Auerswald *et al.*, 1999).

4.5.3 Mouth feel

The values in the Fig. 4.6 are the mean sensory scores of panelists. The similar alphabet above the bar diagram indicate not significantly different ($p>0.05$).

The mean score for the mouthfeel of the samples were found to be 7.8, 6.5, 6.9 and 7.1 respectively and the graphical representation is shown in Fig. 4.6. Statistical analysis showed significant difference ($p<0.05$) within the samples at 5% level of significance. Sample A and D, sample A and B, sample A and C were found to be significantly different from one another. Sample B and C were not significantly different. From the statistical analysis of the sensory data, sample A i.e. 1.5% vinegar concentration had high mean score.

4.5.4 Fluidity/viscocity

The values in the Fig. 4.7 are the mean sensory scores of panelists. The similar alphabet above the bar diagram indicate not significantly different ($p>0.05$).

The mean sensory score for the fluidity/viscosity of the product were found to be 7.4, 6.7, 6.5and 6.9 for samples A, B, C and D respectively. The statistical data showed no significant difference ($p<0.5$) within the samples at 5% level of significance. From the statistical analysis, sample A i.e. 1.5% vinegar concentration was found to have high mean score.

Organoleptic qualties of some of the products such as sauce or ketchup depend upon their viscosity, and poducts with low viscosity may be sold at lower price or even graded unacceptable (Sharoba *et al.*, 2014).

4.5.5 Smell/flavor

The values in the Fig. 4.7 are the mean sensory scores of panelists. The similar alphabet above the bar diagram indicate not significantly different ($p>0.05$).

The mean sensory score for sample A, B, C and D were found to be 7.7, 6.9, 7.3 and 6.6 respectively. The statistical analysis showed significant effect ($p<0.05$) within the product at 5% level of significance. Sample A and B, sample A and D were significantly different from each other whereas sample A and C, Sample B and C were not significantly different. The statistical analysis of the sensory data showed that sample A i.e. 1.5% vinegar concentration had high mean score.

The flavor characteristics of processed tomato products are influenced by the balance of sugar and acid contents (Hongsoongnern, 2007). More the acidity, more the acceptance of product was found through sensory evaluation.

4.5.6 Overall palatability

The values in the Fig. 4.7 are the mean sensory scores of panelists. The similar alphabet above the bar diagram indicate not significantly different ($p>0.05$).

The mean sensory score for the overall palatability of product for samples A, B, C and D were found to be 7.7, 7.3, 7.6 and 7 respectively. The statistical data showed no significant difference ($p<0.05$) among the samples at 5% level of significance. From the sensory evaluation and statistical analysis, it showed that sample A i.e. 1.5% had high mean sensory score and was considered superior product.

4.6 Storage stability of the final product

The final product was made after the optimization of salt, sugar and vinegar. About 1 kg of the product was made with the recipe as given in Table 3.3 and filled hot in different bottles i.e PET bottle and glass bottle. The product were kept at different storage temperature i.e refrigerated temperature 4ºC and room temperature 21ºC for 2 months. TSS, pH, vitamin C and acidity were measured in every 15 days interval.

The effect of storage period on TSS in both packaging material is represented below:

4.6.1 Effect on TSS

The TSS of tamarillo sauce at room temperature and refrigerated for glass packaging was found to be increased from 30-31ºBx and 30-32 ºBx repectively. But in plastic packaged product TSS was found to be increased from 30-31ºBx at room temperature and refrigerated condition as well. The change in TSS is indicated by the fig 4.8.

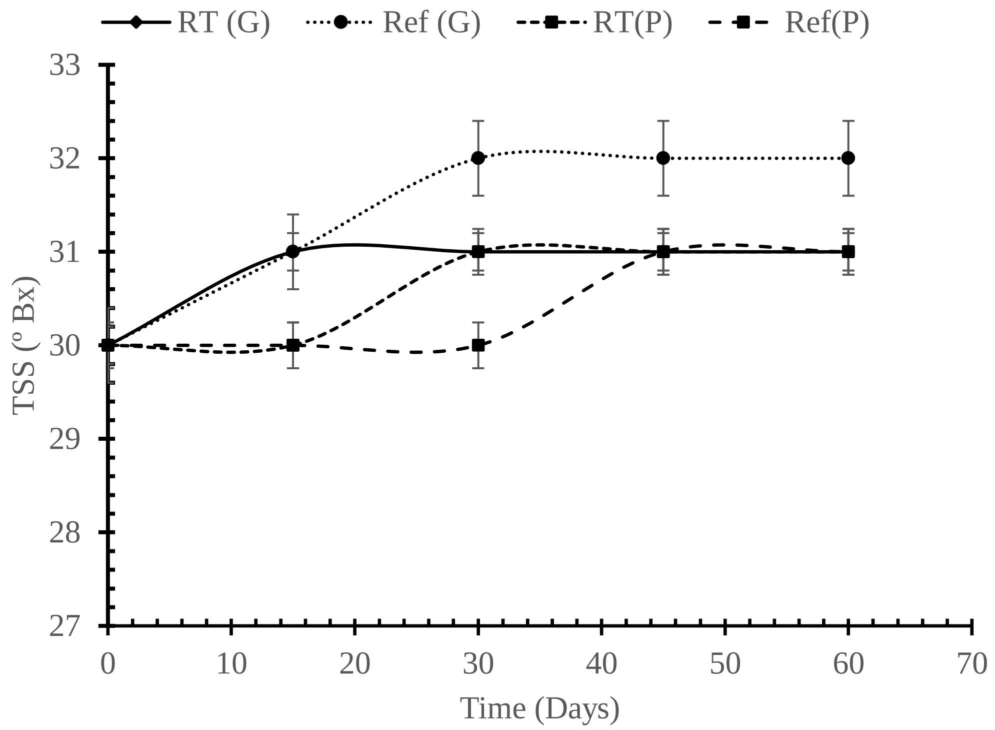

Fig. 4.8 Effect of storage period on TSS. Vertical error bars represent standard deviation..

TSS increases with the increase in storage time. This increase in T.S.S. during storage may be due to acid hydrolysis of polysaccharides especially gums and pectin (Kumar *et al.*, 2015). This showed that the soluble sugar present in sample was not affected much by the variation in packaging material. According to Desouky (2016), higher the total solid content better will be the quality of end product. The results obtained for TSS were also similar to Desouky (2016). The graph shown in Fig. 4.8 indicates that there was not much difference in the total solid content among the samples.

4.6.2 Effect on pH

The pH of samples was found to be decresed which were kept at room temperature and refrigerated temperature packaged in plastic and glass bottles. The pH was decreased from

3.8667-4.04 in RT (glass), 3.8667-3.98 in Ref (glass), 3.8667-4.13 in RT (plastic) and 3.8667-4.03 in Ref (plastic) at the 60th day of analysis. The decrease in rate of pH is plotted in the Fig. 4.9.

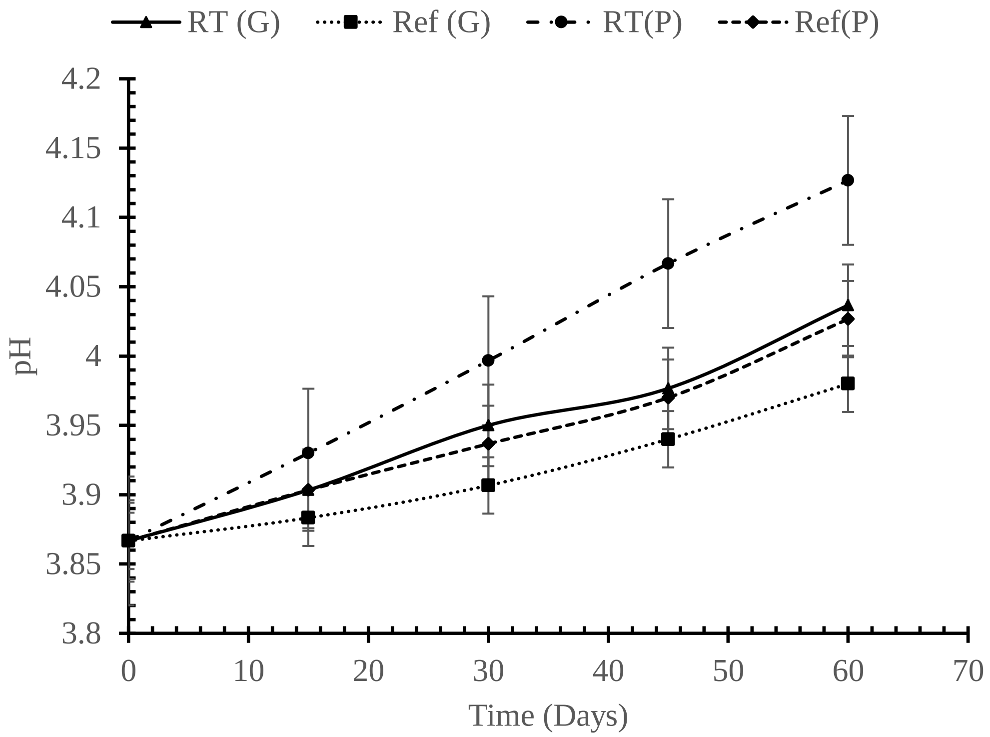

Fig. 4.9 Effect of storage period on pH. Vertical error bars represent standard deviation.

Among the parameters analyzed for the assessment of tomato quality, pH is very important because acidity influences the thermal processing conditions required for producing safe products. The pH value increase with the effect of sugar concentration dilute in tamarillo sauce samples and secondly effect of storage condition during room temperature and refrigerator conditions. Change in pH is directly related to change in acidity of samples. Similar results were obtained by Kumar *et al.* (2015) in their study on physiochemical quality of sauce. The changes in pH may be due to the biochemical reactions taking place during storage periods together with microbial actions of the product. pH was around 4 in all samples as shown in Fig. 4.9 which indicates that neither undesirable fermentations nor microbiological growth occurred in the product.

4.6.3 Effect on acidity

The effect of storage on acidity is shown in Fig. 4.10. It shows that the acidity decreased from 1.2967-1.1% in RT (glass), 1.2967-1.103% in Ref (glass), 1.2967-1% in RT (plastic) and 1.2967-1.14% in Ref (plastic). The results obtained are presented in Fig. 4.10.

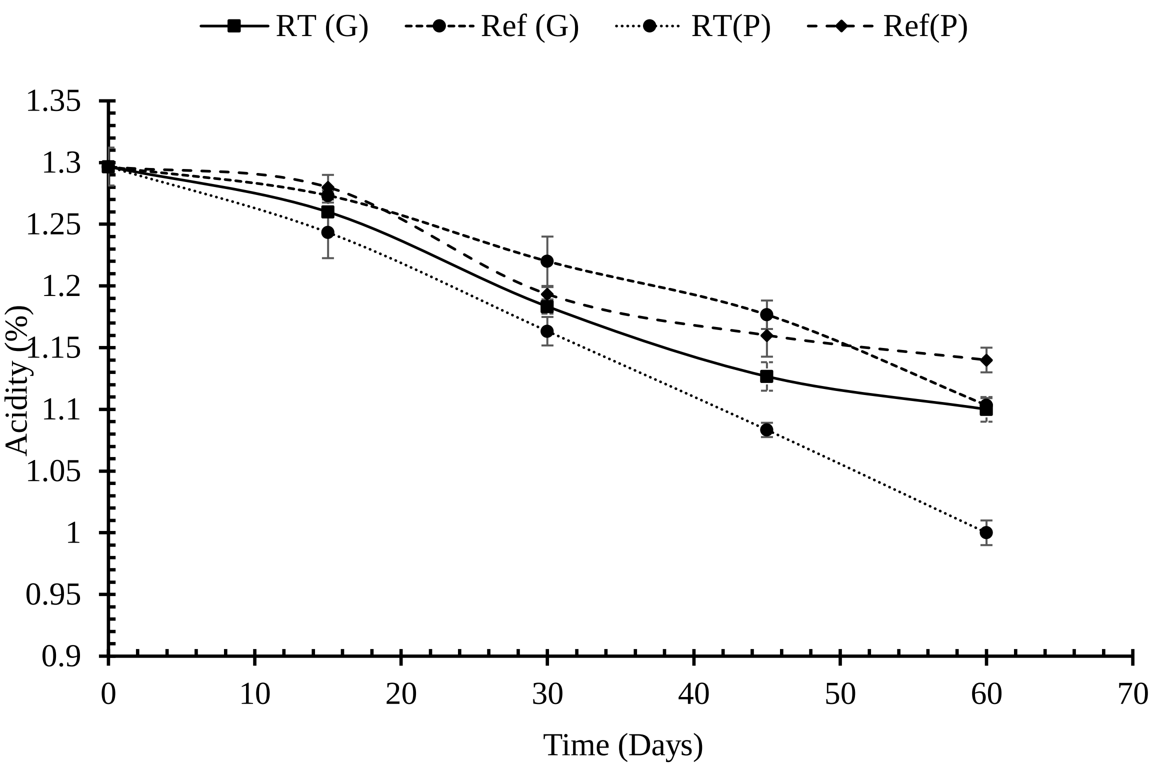

Fig. 4.10 Effect of storage period on acidity. Vertical error bars represent standard deviation.

During refrigeration and room temperature storage conditions, it was observed that acidity of all the samples was decreased with increasing storage periods. The decrease in acidity was found more in sample kept in plastic and stored at room temperature. The results obtained are plotted in the Fig. 4.10. Change in pH is directly related to change in acidity of samples. The results are in aggrement with that observed by Famurewa *et al.* (2013). The acidity of the fruit is also important as a contributor to the flavor of the products. Acidity is an important factor that may also affect the sensory characteristics of food products. The highest amount of acidity is observed in plastic packaged product kept at refrigeration temperature. Decrease in acidity might be due to acidic hydrolysis of polysaccharides where acid is utilized for converting non-reducing sugar into reducing sugar (Kilima *et al.*, 2014).

4.6.4 Effect on Vit C

During refrigeration and room temperature, vit C decreases. It is seen that vit C decreases from 31.11-15.03% in RT (glass), 31.11-20.63% in Ref (glass), 31.11-13.34% in RT (plastic) and 31.11-18.87% in ref (plastic) and the decrease of vit C is plotted in Fig. 4.11.

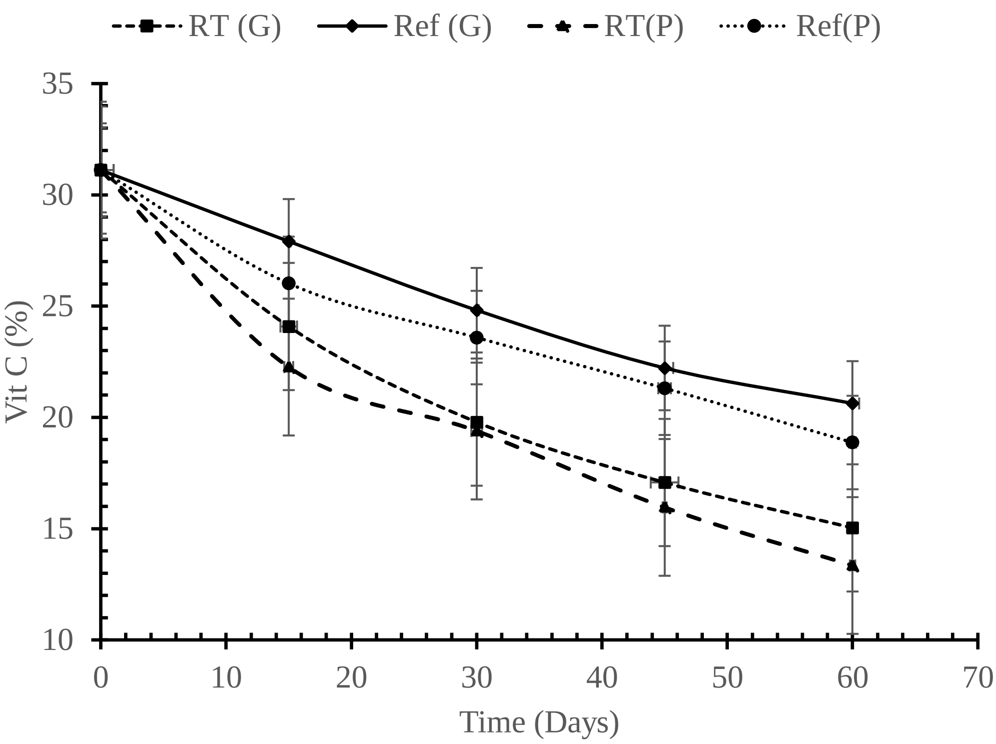

Fig. 4.11 Effect of storage period on Vit C. Vertical error bars represent standard deviation.

The graph above shows the gradual degradation of vit C in the first 15 days and then slow degradation upto 60 days. The study showed the high degradation of vit C in the sample stored at RT (P), followed by RT (G). This reveals that the storage temperature influences decrease in Vit C. Similar findings were reported by Kumar *et al.* (2015) which states that ascorbic acid may be destroyed by oxidation, especially at higher temperature. Vitamin-C is the most liable of the nutrients, so its degradation is used as an indicator of quality. Low temperature can slow down the rate of degradation of vitamin C generally while the great [high] losses seen in samples stored at room temperature may be as result of oxidation reaction by residual oxygen, followed by decomposition which may have been accelerated due to storage temperature and similar findings were observed by Ibrahim (2016) in his research on the effect of different storage condition on pH and vitamin C content of some fruits. Tamarillos are considered as the excellent source of vit C and the Fig. 4.11 shows that the produt kept at refrigeration and packaged in glass had the highest vit c retention.

4.7 Organoleptic quality of the products

The stored samples were subjected to the sensory evaluation. Among five samples, sample A and E were kept in glass bottles, sample C and D were kept in plastic jars and sample B was control sample which was freshly prepared and stored at freezing temperature. Sample A and D were kept in refrigerature whereas sample C and E were kept at room temperature. The samples were provided to the semi trained panelist in order to evaluate the product on the basis of various sensory parameter namely appearance/color, flavor/smell, taste, mouthfeel, fluidity and overall appearance. The scores were provided in the score sheets as per their perception and was analyzed using Gen Stat 12.1 using two way ANOVA.

The Statistical analysis of the final product on the basis of effect of variation of storage condition and packaging material are shown in the bardiagram:

Here, Sample A=Ref (Glass), Sample B=(control), Sample C=R.T (Plastic), Sample D=Ref(Plastic) and Sample E=R.T(Glass).

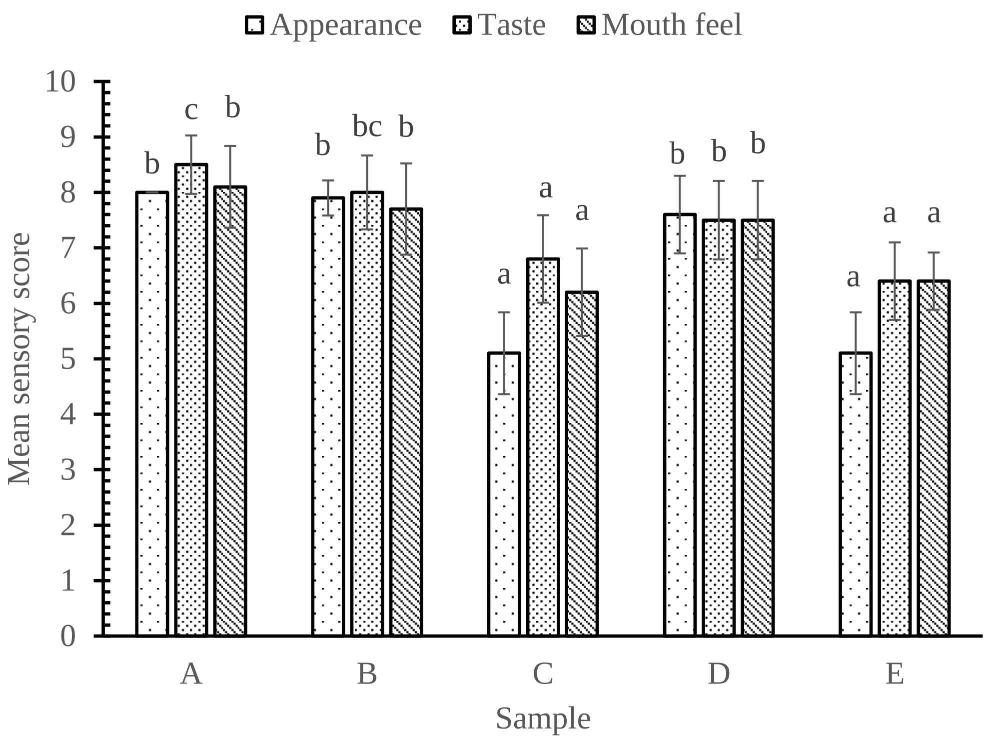

Fig 4.12 Effect of storage and packaging on the color, taste and mouth feel of the product. Vertical error bars represent standard deviation of scores given by panelist.

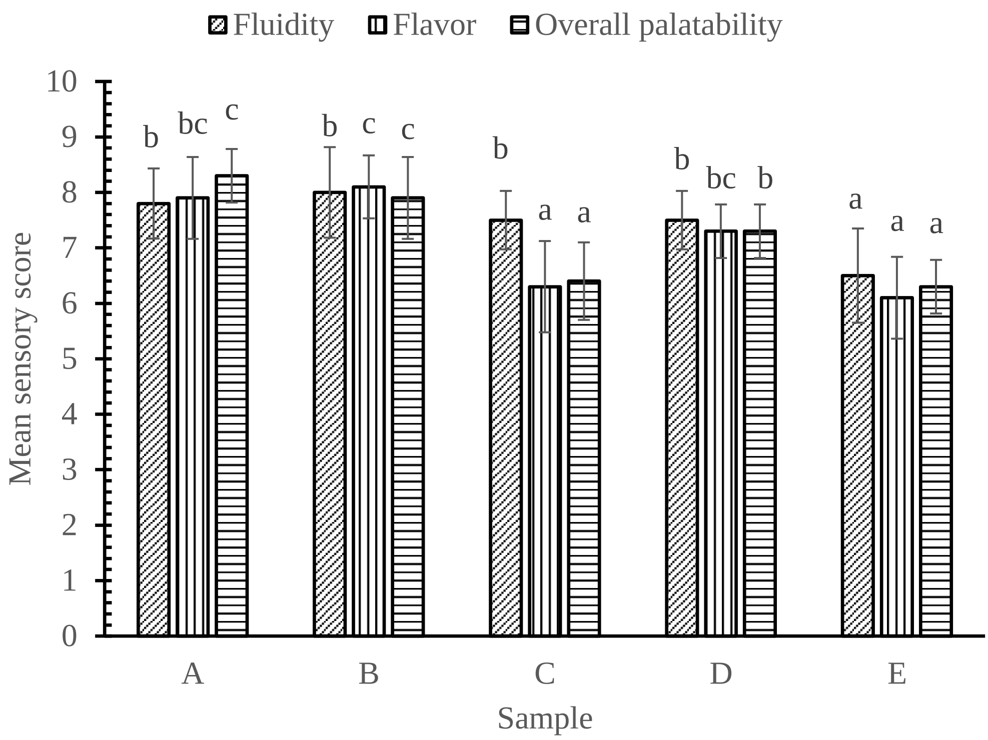

Fig 4.13 Effect of storage and packaging o the fluidity, flavor and overall acceptance of the product. Vertical error bars represent standard deviation of scores given by panelist.

4.7.1 Appearance/Color

The similar alphabets in the bar diagram i.e. Fig. 4.12 indicates that the samples are not significantly different (p>0.05).

The mean sensory score for the color of the samples A, B, C, D and E were found to be 8, 7.9, 5.1, 7.6 and 5.1 respectively. Statistical analysis showed that there is significant effect (p<0.05) within samples at 5% level of significance. Sample A, B and D were significantly different from sample C and E while sample A, B, and D were not significantly different from one another. Through the statistical analysis, sample A was found to have the highest mean score and hence it was termed superior.

The type of packaging material used did not have significant difference on the visual apperance of the product but the storage temperature greatly influenced the color of the product. The product kept at room temperature showed the degradation in colour which may be due to maillard reaction and degradation of lycopene. This implies that lower storage temperature and stronger oxygen barrier property of package could maintain color stability and extend shelf life (Li *et al.*, 2018).

4.7.2 Taste

The similar alphabets in the bar diagram i.e. Fig. 4.12 indicates that the samples are not significantly different ($p>0.05$).

The mean score for taste of the samples A, B, C, D and E are 8.5, 8, 6.8, 7.5 and 6.4 respectively. Statistical analysis showed that there is significant difference ($p<0.05$) within the samples at 5% level of significance. Samples A and B, B and D and A and D were different from one another whereas sample C and E were not different from each other. From the sensory score and statistical analysis, it showed that sample A had high mean score.

The taste may be differed due to the increase of soluble solids like sugar, salt etc. during storage. The taste may also be affected by the components which are extracted from packaging material during the storage period.

4.7.3 Mouth feel

The similar alphabets in the bar diagram i.e. Fig. 4.12 indicates that the samples are not significantly different ($p>0.05$).

The mean sensory score for the mouth feel of the final product were found to be 8.1, 7.7, 6.2, 7.5 and 6.4 for samples A, B, C, D and E respectively. The statistical analysis showed significant difference ($p<0.05$) among the samples at 5% level of significance. Sample A and C and sample A and E were significantly different whereas sample A, B and D were not different from one another. Sample A was found to be best in terms of mouth feel by the sensory and statistical analysis as it had the highest mean score.

The overall mouth feel is determined to a great extent by the viscosity of the product (Sharoba *et al.*, 2004). The changes in taste may also be the factor that affects the mouthfeel of the product.

4.7.4 Fluidity

The similar alphabets in the bar diagram i.e. Fig. 4.13 indicates that the samples are not significantly different ($p>0.05$).

The mean sensory score was found to be 7.8, 8, 7.5, 7.5 and 6.5 for samples A, B, C, D and E respectively through statistical analysis. It showed significant difference among the sampes ($p<0.05$) at 5% level of signficance. Samples A, B, C and D were not different from one another but were significantly different from sample E. On the basis of higher mean score, sample B was best among all.

The consistency of tomato products depends on the amount of suspended particles (pulp) in a dispersing medium and is directly related to the tomato fruit constituents such as pectin. Other factors such as enzymatic degradations, pulp network, homogenization process and concentration also play an important role in determining the consistency of tomato products (Desouky, 2016).

4.7.5 Smell/Flavor

The similar alphabets in the bar diagram i.e. Fig. 4.13 indicates that the samples are not significantly different ($p>0.05$).

The mean sensory score for samples A, B, C, D and E were found to be 7.9, 8.1, 6.3, 7.3 and 6.1 respectively. The statistical analysis showed signficant effect on the product ($p<0.05$) at 5% level of significance. Sample B was sinificantly different from sample C and E whereas it was somewhat similar with sample A and D. The control sample B was found to have better flavor then other samples.

Flavor changes is generally associated with the changes in color. The product which faded may have lost their flavor (Desrosier and Desrosier, 1977). It belongs to the organoleptic property which is considered a crucial point in the assessment of potential consumer acceptability of various types of foodstuffs.

4.7.6 Overall palatability

The similar alphabets in the bar diagram i.e. Fig. 4.13 indicates that the samples are not significantly different ($p>0.05$).

The mean sensory score for the overall palatability of the samples A, B, C, D and E were found to be 8.3, 7.9, 6.4, 7.3 and 6.3 respectively. Statistical analysis showed that there is significant effect ($p<0.05$) within the samples at 5% level of significance. Samples A, B and D were found to be significantly different from one another while the rest of the samples i.e.

C and A were not different from each other. From the sensory evaluation and statistical analysis, it showed that sample A had high mean sensory score.

Hence, from the above analysis samples C and E were not so different because the samples were kept in same storage conditions even though the packaging material was different. The samples were not good in terms of color, smell and other parameters as well. Color is one of the important parameter for the acceptability of any product and hence the degrade of color also influenced for less acceptance of product. Sample A and D both stored at refrigerated condition though different in packaging were given the highest score as they were good in terms of all the parameters. And also there was no such significant difference among the stored samples and control sample.

Part V

Conclusions and recommendations

5.1 Conclusions

Tree tomato is one of the most underutilized fruits in Nepal and other parts of world as well. It has got high medicinal value as well as food uses. The addition of spices to the fruit contributes to the value addition in the product. Despite of having benefits in terms of health and economy, the fruit hasnot found proper utilization. The effective and proper utilization of this fruit as a value added product can be a source of food material for the increasing population and it will also generate good source of income to the farming community. And this research work helps to add value to the tamarillo. Following things can be concluded from this dessertation work:

- Tamarillo sauce can be prepared by the use of locally available ingredients and readily available packaging materials.
- Sensory evaluation revealed that the poduct had the best acceptability at proportion keeping 4% salt, 30ºBx sugar and 1.5 % vinegar.
- Result of sensory and chemical analysis showed that the glass packaged product kept at refrigerated temperature was considered to be superior. It can also be concluded that packaging materials varied has no such effect on quality attributes of sauce and hence any packaging material either PET plastic or glass bottle can be used for storing sauce.
- The chemical composition of superior product was found to be 32ºBx TSS, 1.1033% acidity, 3.98 pH and 20.63% vit C.
- As per the chemical analysis, the shelf life of the product can be enhanced by using glass as a packaging material and storing at refrigerated condition for more than 2 months.

5.2 Recommendations

Following suggestions are recommended for the future work:

- The tamarillo sauce can be prepared by using 4% salt, 30ºBx sugar and 1.5% vinegar at large scale.
- Color properties of tamarillo can also be studied.
- Different varieties of tamarillo can be used in preparation of sauce.
- Antioxidant properties of tamarillo sauce can be measured.

Summary

Tamarillo (*Cyphomandra betacea*) is a lesser known fruit crop found in the hilly areas of Nepal and is much popular for making instant chutney in Nepalese community. Though it has several uses, it is not being utilized in the commercial way. In terms of nutrition value, tamarillo fruits have a relatively high content of potassium, iron, ascorbic acid, pro vitamin A, carotenoids and vitamin B6, as well as a high antioxidant activity, while it has low fat content and calories value. Thus the preparation of sauce leads to higher use and commercial production of tamarillo. In fact, it can be used wherever ordinary tomatoes are used. The present study deals with the formulation that can add value to tamarillo.

For the preparation of tamarillo sauce, clean and sorted tamarillo was blanched for about 2 min at temp. 97±3ºC. It was then peeled and seeds were removed. The flesh was then crushed using stainless steel mixture. The raw materials and ingredients used for the preparation of sauce were brought from the local market of Dharan. First of all, optimization of salt, sugar and vinegar was done in order to formulate the recipe of sauce and all other spices viz, cardamom, cloves, cinnamon, garlic, chilli powder and onion were kept constant. The optimized concentration was obtained from sensory analysis and statistical data showed 4% salt, 30ºBx sugar and 1.5% vinegar as optimum concentration. The final product was kept at different storage temp. and packaged with different packaging material. Control sample was brought from the local store. Sample A and E were kept in glass bottle of 250 ml and sample B and D were kept in PET bottles. Sample A and D were stored at refrigerator while sample B and E were stored at normal room temp. whereas sample B was the control.

For the storage stability, the samples were chemically analysed for 2 months at the interval of 15 days. Zero day analysis was carried out in order to find the changes in chemical composition of the product. The chemical analysis of the fresh product showed 30ºBx TSS, pH 3.86, acidity 1.30% and vit. C content was found to be 31.11%. From the statistical analysis of the sensory score, sample A was found to be somewhat related to the control sample as the mean score for both samples were slightly similar. In terms of high mean score, sample A i.e. kept at glass bottle in refrigerator was found to be superior according to two-way ANOVA analysis at 5% level of significance. The superior product had 32ºBx TSS, 1.1033% acidity, 3.98 pH and 20.62% vit C at the end of 60 days.

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Appendix

Appendix A

1. Sensory evaluation card

Sensory evaluation sheet of Tamarillo sauce

Prepared by: Bibita Joshi

Purpose: Dissertation for the *partial fulfillment of the requirements for the degree* of Bachelor's Degree in Food Technology (B.Tech Food)

Name of panelist……………………….. Date……………………

Name of the product: *Tamarillo sauce*

Dear panelist, you are given 13 sample of *Tamarillo sauce* on each proportion with variation on *storage temperature and packaging material.* Please taste the sample and score how much you prefer the each one. Please give points for your degree of preference for each parameter as shown below using the scale given.

Parameter	1	2	3	4	5
Appearance/colour					
Flavor/smell					
Taste					
Mouth feel					
Fluidity					
Overall palatability					

Give points as follows:

Like extremely **9**	Like slightly **6**	Dislike moderately **3**
Like very much **8**	Neither like nor dislike **5**	Dislike very much **2**
Like moderately **7**	Dislike slightly **4**	Dislike extremely **1**

Comments (if any)…………………………………………………………………………….

Signature………………………….

Appendix B

Table B.1 ANOVA (no blocking) for colour of salt optimization

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	4	4.5	1.125	3.67	0.012	0.4557
Panelist	11	22.3333	2.0303	6.62	<.001	0.7060
Residual	44	13.5	0.3068			
Total	59	40.3333				

Table B.2 ANOVA (no blocking) for flavour of salt optimization

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	4	4.8333	1.2083	1.85	0.137	0.665
Panelist	11	18.7333	1.703	2.6	0.012	1.031
Residual	44	28.7667	0.6538			
Total	59	52.3333				

Table B.3 ANOVA (no blocking) for fluidity/viscosity of salt optimization

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	4	17.2333	4.3083	5.72	<.001	0.714
Panelist	11	20.5833	1.8712	2.48	0.016	1.107
Residual	44	33.1667	0.7538			
Total	59	70.9833				

Table B.4 ANOVA (no blocking) for mouth feel of salt optimization

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	4	7.2333	1.8083	2.89	0.033	0.651
Panelist	11	16.85	1.5318	2.44	0.018	1.009
Residual	44	27.5667	0.6265			
Total	59	51.65				

Table B.5 ANOVA (no blocking) for taste of salt optimization

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	4	28.433	7.108	6.69	<.001	0.848
Panelist	11	17.65	1.605	1.51	0.162	1.314
Residual	44	46.767	1.063			
Total	59	92.85				

Table B.6 ANOVA (no blocking) for overall palatability of salt optimization

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	4	13.4333	3.3583	4.48	0.004	0.712
Panelist	11	18.2	1.6545	2.21	0.031	1.103
Residual	44	32.9667	0.7492			
Total	59	64.6				

Appendix C

Table C.1 Two way ANOVA (no blocking) for colour in sugar optimization

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	3	0.875	0.2917	1.8	0.171	0.3694
Panelist	9	10.725	1.1917	7.35	<.001	0.584
Residual	27	4.375	0.162			
Total	39	15.975				

Table C.2 Two way ANOVA (no blocking) for flavour in sugar optimization

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	3	3.275	1.0917	4.55	0.01	0.4494
Panelist	9	25.225	2.8028	11.69	<.001	0.7105
Residual	27	6.475	0.2398			
Total	39	34.975				

Table C.3 Two way ANOVA (no blocking) for taste in sugar optimization

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	3	10.475	3.4917	5.46	0.005	0.734
Panelist	9	13.025	1.4472	2.26	0.049	1.161
Residual	27	17.275	0.6398			
Total	39	40.775				

Table C.4 Two way ANOVA (no blocking) for mouth feel in sugar optimization

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	3	3.275	1.0917	4.55	0.01	0.4494
Panelist	9	13.225	1.4694	6.13	<.001	0.7105
Residual	27	6.475	0.2398			
Total	39	22.975				

Table C.5 Two way ANOVA (no blocking) for fluidity in sugar optimization

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	3	1.875	0.625	1.1	0.367	0.692
Panelist	9	15.525	1.725	3.03	0.012	1.095
Residual	27	15.375	0.5694			
Total	39	32.775				

Table C.6 Two way ANOVA (no blocking) for overall palatability in sugar optimization

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	3	7.5	2.5	5.87	0.003	0.599
Panelist	9	10.1	1.1222	2.63	0.025	0.947
Residual	27	11.5	0.4259			
Total	39	29.1				

Appendix D

Table D.1 Two way ANOVA (no blocking) for colour in vinegar optimization

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	3	0.075	0.025	0.04	0.988	0.71
Name	9	14.725	1.6361	2.73	0.021	1.123
Residual	27	16.175	0.5991			
Total	39	30.975				

Table D.2 Two way ANOVA (no blocking) for flavour in vinegar optimization

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	3	2.5	0.8333	1.61	0.211	0.661
Name	9	19.4	2.1556	4.16	0.002	1.045
Residual	27	14	0.5185			
Total	39	35.9				

Table D.3 Two way ANOVA (no blocking) for taste in vinegar optimization

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	3	2.075	0.6917	1.6	0.213	0.603
Name	9	13.625	1.5139	3.5	0.005	0.954
Residual	27	11.675	0.4324			
Total	39	27.375				

Table D.4 Two way ANOVA (no blocking) for mouth feel in vinegar optimization

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	3	8.875	2.9583	4.02	0.017	0.787
Name	9	6.025	0.6694	0.91	0.531	1.245
Residual	27	19.875	0.7361			
Total	39	34.775				

Table D.5 Two way ANOVA (no blocking) for fluidity in vinegar optimization

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	3	4.475	1.4917	2.27	0.104	0.745
Name	9	4.125	0.4583	0.7	0.706	1.177
Residual	27	17.775	0.6583			
Total	39	26.375				

Table D.6 Two way ANOVA (no blocking) for overall in vinegar optimization

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	3	3	1	0.98	0.416	0.926
Name	9	7.1	0.789	0.77	0.641	1.464
Residual	27	27.5	1.019			
Total	39	37.6				

Appendix E

Table E.1 Two way ANOVA (no blocking) for colour in the final product

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	4	90.52	22.63	66.34	<.001	0.5297
Panelist	9	2.82	0.3133	0.92	0.52	0.7491
Residual	36	12.28	0.3411			
Total	49	105.62				

Table E.2 Two way ANOVA (no blocking) for flavour in the final product

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	4	33.12	8.28	18.54	<.001	0.6062
Panelist	9	4.82	0.5356	1.2	0.326	0.8573
Residual	36	16.08	0.4467			
Total	49	54.02				

Table E.3 Two way ANOVA (no blocking) for taste in the final product

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	4	29.32	7.33	17.5	<.001	0.587
Panelist	9	5.92	0.6578	1.57	0.162	0.8302
Residual	36	15.08	0.4189			
Total	49	50.32				

Table E.4 Two way ANOVA (no blocking) for mouth feel in the final product

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	4	27.88	6.97	11.55	<.001	0.705
Panelist	9	1.78	0.1978	0.33	0.96	0.996
Residual	36	21.72	0.6033			
Total	49	51.38				

Table E.5 Two way ANOVA (no blocking) for fluidity in the final product

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	4	13.32	3.33	6.56	<.001	0.646
Panelist	9	2.82	0.3133	0.62	0.774	0.914
Residual	36	18.28	0.5078			
Total	49	34.42				

Table E.6 Two way ANOVA (no blocking) for overall palatability in the final product

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	l.s.d
Sample	4	31.52	7.88	22.73	<.001	0.534
Panelist	9	3.12	0.3467	1	0.458	0.7552
Residual	36	12.48	0.3467			
Total	49	47.12				

Color plates

P1: Screening of pulp

P2: Samples

P3: Panelist performing sensory

P4: Panelist performing sensory