

**DETERMINATION OF PHYTOCHEMICAL PROPERTIES AND ANTICANCER
ACTIVITY OF SOLANUM BETACEUM EXTRACT AND FOOD FORMULATION
OF ITS EDIBLE PART**

PROJECT REPORT

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Science in
CLINICAL NUTRITION AND DIETETICS

By

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**SATHYABAMA
INSTITUTE OF SCIENCE AND
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UNIVERSITY)**

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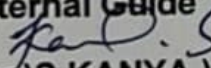
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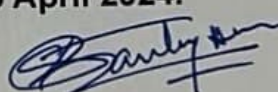
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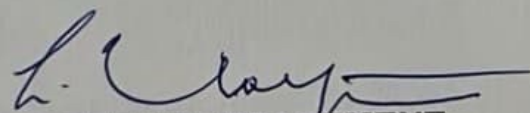
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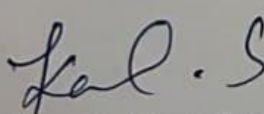
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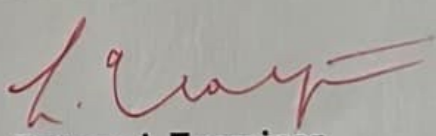

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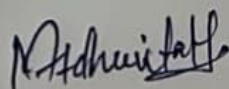

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DECLARATION

We H.MADHUMITA (41736008) And I.MEGHANA(41736009) hereby declare that the Project Report entitled " DETERMINATION OF PHYTOCHEMICAL PROPERTIES AND ANTI CANCER ACTIVITY OF SOLANUM BETACEUM AND FOOD FORMULATION OF ITS EDIBLE PART " Done by us under the internal guide of S.KANYA Assistant Professor, Department of Clinical Nutrition and Dietetics and external guide Dr. L. Stanley Abraham, Scientist E, Professor (Research), Centre for Ocean Research, Sathyabama Research Park is submitted in partial fulfilment of the requirements for the award of Bachelor of Science degree in Clinical Nutrition and Dietetics. Sathyabama Institute of Science and Technology, Chennai is submitted in partial fulfilment of the requirements for the award of Bachelor of Science degree in Clinical Nutrition & Dietetics

DATE: 27/4/24

PLACE: CHENNAI



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ABSTRACT

Tamarillo has a unique flavor and rich history. South American fruit is popular in New Zealand. Tamarillo is commercially grown in New Zealand and South America. It grows best under sub-tropical areas. It matures in 18 months. It's 2 m tall and has a lifespan of about 7 years. For propagation, seeds or cuttings are employed, and plant trimming for effective output varies according to the propagation method. Tamarillo plants are wind-sensitive and need cover or windbreaks. It's a beautiful fruit with smooth, shining skin. Yellow, red, and purple fruits are available. This fruit contains vitamins, minerals, fiber, and antioxidants. It has a very low calorie count. Breeding focuses on fruit quality through selection, hybridization, and biotechnological treatments for plantation and post-harvest management. Diseases, pests, viruses, and physiological abnormalities can be treated with plant protection techniques. Like other fruits, it's edible after harvesting. Made into juices, concentrates, jams, gelatins, and sweets. If processing facilities and transport are available, it can be exported as pulp or concentrate. The tamarillo can diversify sub-tropical fruit production as a high-value cash crop, with excellent fruits commanding premium prices in Europe, North America, and Japan.

Keywords: Botany, breeding, biotechnology, cultivation, composition, diseases, origin, production, processing, pests, trade, value addition.

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LIST OF ABBREVIATIONS

USA	United States Of America
Cm	Centimeter
Mm	Millimeter
Kg	Kilogram
Ha	Hectare
E.G.	Exempli Gratia (For Example)
Cv.	Cultivar
Spp.	Species (Plural)
Fig.	Figure
Ø	Diameter
G	Gram
Cm ³	Cubic Centimeter
¹⁴ C	Radiocarbon
Et Al.	Et Alii (And Others)
Cv.	Cultivar
F1	First Filial Generation (Hybrid Offspring)
DNA	Deoxyribonucleic Acid
RNA	Ribonucleic Acid
In Vitro	In Glass
Aux	Auxin (Plant Hormone)
GUS	B-Glucuronidase (A Reporter Gene)
NEP25	A Gene Name
Rpm	Revolutions Per Minute
µm	Micrometer
Tamv	Tamarillo Mosaic Virus
GE	Genetic Engineering
Rnai	RNA Interference
ACC	1-Aminocyclopropane-1-Carboxylic Acid (Ethylene Precursor)
Ha-1	Per Hectare
DW	Dry Weight

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CHAPTER 1

INTRODUCTION

The tree tomato (*Solanum betaceum* Cav., syn. *Cyphomandra betaceum* (Cav. Sendt.)) is a lesser-known tiny shrub or semi-woody tree that grows at elevations of 500–2500 m. The tamarillo, sometimes known as a ‘tree tomato’ because its flesh resembled that of a tomato, is a member of the Solanaceae (nightshade) family (Correia *et al.*, 2009). The tree tomato is related to a group of taxa that used to be classified under the *Cyphomandra* genus.

1.1. SPECIES OF TAMARILLO

The species of the genus *Cyphomandra* were reassigned to the genus *Solanum*, subgenus *Bassovia*, based on morphological and genetic data (Bohs *et al.*, 1994) (Bohs *et al.*, 1995). The scientific community now uses the *Solanum* designations to refer to tree tomatoes and wild cousins. In New Zealand, the term “Tamarillo” has become the usual commercial identification for the fruit (Morton *et al.*, 1987). It can be found in subtropical and mild temperate climates all over the world. Commercially, it is grown in New Zealand and a few parts of South America. Although some high-performing uniform lines have been produced, commercial plantings are of seed-propagated populations. Although it is a largely unexploited species, it presents a wonderful chance to diversify fruit production as a high-value income crop in many subtropical and mild temperate production locations. It comes in two colors red and yellow, with red being the more prevalent. It's a vivid red egg-shaped fruit with yellow-orange flesh and black seeds encased in purple gelatin. The red color comes from anthocyanin pigments, while the yellow-orange color comes from carotenoids. Tree tomatoes at the fruit-bearing stage require support to keep their branches from breaking off as they get packed with fruit. Because of its shallow root system, they are readily blown over by the wind. The plant is not affected by the duration of the day. *Cyphomandra* species such as *C. hartwegimi*, *C. sibundoyensis*, and *C. amanuensis* produce edible fruits in the wild. Other *Cyphomandra* species are employed as colors and in medical formulations. This category of plants is becoming more economically important, and it may have a lot of future promise.

1.2. AREA AND PRODUCTION

Tamarillo popularly known as arboreal tomato is a fruit tree of Andean origin and is currently grown in California, Argentina, Colombia, Ecuador, Venezuela, and New Zealand (Ordóñez *et al.*, 2010) for use in the fresh fruit market and for food processing industry. Tamarillo is also produced less widely in Zambia, Zimbabwe, Uganda, Sri Lanka, and India (Stangeland *et al.*, 2009). The fruit's distinctive flavor and nutritional benefits are causing an uptick in interest today, which is keeping prices high. New Zealand and the United States have developed extensive plant breeding programs to develop new cultivars that are more appealing to customers (Correia *et al.*, 2011). In Colombia, tamarillo orchards cover a total cultivated area of 7646 ha distributed in 18 provinces. However, Antioquia and Cundinamarca alone account for two-thirds of the total production (50 and 14%, respectively). In New Zealand, about 2000 tons are produced on 200 ha of land and exported to the United States, Japan, and Europe. New Zealand's horticultural practices, handling, storage, and transportation methods have all been enhanced via research there. Some better cultivars and shipping containers and circumstances for overseas exports have resulted from these investigations. This crop is limited by factors such as a lack of clear differentiation among varieties, low fruit quality (heterogeneity and phytosanitary issues), the use of ineffective local and foreign variety substitutions, and the fact that the tree tomato is frequently a subsistence crop and not included in genetic conservation programs.

1.3. MARKETING AND TRADE

New Zealand is one of only three countries to grow tamarillos commercially, the others being Colombia and Australia. New Zealand leads in the production and export followed by Colombia (Acosta-Quezada *et al.*, 2011). Tamarillos from New Zealand are exported to the United States, Japan, and Europe. For the export, the existing marketing channels developed for the kiwifruit are used (Prohens J *et al.*, 2000) which has greatly benefited the farmers. Due to a lack of international market and knowledge of the fruit, the export potential of this fruit crop has not been yet achieved to its level. There are relatively few barriers to trade and very few countries specifically refer to tamarillos in their tariff schedules. The United States of America continues to be the main export market for tamarillos. In Colombia, the majority of the produce is consumed locally, but some parts are also exported to the Netherlands, France,

Canada, Germany, and Spain. It is important to mention here that standards have been established among commercial growing countries that market tamarillo fruits (New Zealand, Ecuador, and Colombia), and in other countries, there is no such regulation and therefore no commercialization capacity (Vasco *et al.*, 2009) (Schotsmans *et al.*, 2011). Fresh tree tomatoes are in high demand in foreign markets, particularly in the United Kingdom, the Netherlands, and Spain, where they are especially popular if they are grown without the use of pesticides. Fair Trade accreditation also helps to open up new markets for the product. Imported fruit is processed into juices, syrups, and other beverages as well as gelatins and other treats. It might also be exported in the form of fruit pulp or concentrate if processing facilities and suitable transportation were available.

1.4. COMPOSITION AND USES

This fruit is found to be a good source of vitamins A, C, B6, and E, and antioxidants (MertzCet *et al.*, 2009). Tamarillo has a relatively high content of vitamins A and C. Levels of vitamin A are intermediate between those of tomato and carrot (Rodriguez-Amaya *et al.*, 1983), while the ascorbic acid content is similar to that of citrus fruits. Tamarillo is rich in anthocyanins and carotenoids which are responsible for their color (Kou *et al.*, 2009). The presence of anthocyanins and carotenoids shows their biological, therapeutic, and preventative properties (Kong *et al.*, 2013). [using spectroscopic analyses revealed that tamarillo fruits are a rich source of natural pigments with potential antioxidant activity, giving them a remarkable added-value. Phenolics are the main antioxidants found in the tamarillo fruit pulp (Vasco *et al.*, 2008). The seed of the fruit is consumed together with flesh (Morton JF, 2013). Tamarillo seeds made up 1.0–1.5% wet basis of the fruit (50–80 g). The seeds of tamarillo were examined for their proximate components (Ramakrishnan *et al.*, 2013). Protein content was discovered to be 22.63%, fat content to be 21.13%, and ash to be 3.15%, with a total carbohydrate content of 43.87%, in the seeds. Tamarillo seed oil's fatty acid profile revealed that linoleic acid (70.47%), oleic acid (14.93%), palmitic acid (9.41%), stearic acid (2.23%), and linolenic acid were the most prevalent fatty acids (1.73%). Apart from these, the oil included arachidic acid (0.23%), phenolic acid (0.22%), and lignoceric acid (0.23%). The fruits are very low in calories (only about 40 calories per fruit). These fruits are available in both red and yellow varieties. However, the red varieties are more popular and more common (Lister, 2005). (Acosta-Quezada *et al.*, 2011) assessed fruits of

purple and yellow/orange cultivars and did not find any relevant differences among them.

1.4.1 Nutritional composition of tamarillo fruits

Tamarillo is grown mainly for its edible fruits and to a lesser extent as an outdoor ornamental. The tamarillo fruit has been described as “brazenly beautiful” and the aroma “unusual and attractive”. They have several culinary uses and can be eaten raw in salads or as desserts but preferably cooked. The flesh can be eaten fresh or made into a range of sweet and savory dishes and condiments. Tamarillos are tangy and usually sweet with a bold and complex flavor that differs by variety. The fruit can be stewed to use on cereal or as a pie or crumble filling, added to stews, or made into a delicious chutney, which is especially good with chilies. In Jamaica and the West Indies, the fruits are considered to have beneficial effects in relieving disorders of the liver. Tamarillo is an important component in Rwanda’s exotic fruit industry and consumption of the fruit is traditionally recommended for people suffering from stomach ailments. It is processed into jams, juices, and jellies canned in syrup or prepared in combination with milk products like yogurts, milkshakes, and ice creams. The fruit has a high level of pectins, which makes it especially suited for jams and preserves. It is also used for canning in syrup and for producing pulp, chutney, sauce, baby food, and in combination with milk products like yogurt, milkshakes, and ice. The fruit can be used much as a regular tomato, but it has less moisture, so more water, stock, or gravy is needed for most cooked dishes.

1.5. ORIGIN AND DISTRIBUTION

The tamarillo *C. betaceum* (Cav.) is native to the Andean region of South America where most *Cyphomandra* species are found in cultivated states. It is also grown in New Zealand, Brazil, Argentina and Colombia. The area where *C. betaceum* originated is not known, but some wild or naturalized populations have been reported in southern Bolivia and northeastern Argentina and may give an indication of its area of origin. It is found that *S. betaceum* is closely related to *S. unilobum*, *S. roseum*, and in particular to *S. maternum*, all of which are found in Bolivia in wild status (Lester, 2001). Little information is available on the domestication of the tree tomato, and at present it is unknown when and where this process took place. In New Zealand, it is cultivated as a minor fruit crop. It was introduced to New Zealand as early as the

late 1800s and there have been several further introductions (Fletcher , 1975). It is cultivated and naturalized in Venezuela and grown in the highlands of Costa Rica, Guatemala, Jamaica, Puerto Rico, and Haiti. Tamarillo was adopted on January 31, 1963, by the growers of New Zealand as the official common trade name for *Cyphomandra betacea*. The tree tomato was named as tamarillo in New Zealand in 1967 (Hewett *et al.*, 1993). Tamarillo is a Maori word that indicates leadership, and “hello” comes from the Spanish word for yellow, “Amarillo” which was the original type of tamarillo to be grown, and only in the 1920s was a new red variety developed (Tamarillo Growers Association., 2018) . It is possible to grow it successfully in areas with Mediterranean climates, where it has good prospects as a developing new fruit crop (Grau *et al.*, 1994). In India it is found growing in Sikkim, Darjeeling hills of West Bengal, Tamil Nadu, Meghalaya, and in other northeastern states. In Nepal during the survey, it was found that it is grown in home gardens for vegetable purposes. It has been grown in Queensland and Australia in home gardens for many years and is a practical crop in the highlands of the Australian part of New Guinea. In the USA it is grown in California and occasionally in Florida in pots and indoors. The plants fruit satisfactorily in greenhouses. In Malaysia, *C. betaceum* is cultivated in Cameron Highland (Peninsular Malaysia), and Kundasang (Sabah) and is locally known as “Pokok Tomato” or “Tamarillo” in Peninsular Malaysia, and as “Buah Cinta,” “Moginiwang,” or “Tamarillo” in Sabah.

1.6. BOTANY AND TAXONOMY

The plant is a small shrub or half-woody, evergreen or partially deciduous, attractive growing, brittle tree, shallow-rooted reaching 3 m to 5.5 m in height rarely as much as 7.5 m. The dichasial branching is responsible for the shrubby habit of the tree, although seedling-grown plants do go through a juvenile phase and the initial branching pattern may not occur until after 30 nodes growth (Richardson *et al.*, 1993). The plant is not tolerant to drought stress and can be damaged by strong winds because of the shallow root system. The leaves are perennial, simple, 10–35 cm long and 4–12 cm broad, evergreen, alternate, more or less heart-shaped at the base, ovate and pointed at the apex, thin, softly hairy, with prominent veins, and have a musky smell and slightly tinged purple when the leaves are young. Flowers with fragrance are borne in small, loose clusters near the branch tips, 1.25–2 cm wide, and have 5 pale-pink or lavender, pointed lobes with 5 prominent yellow stamens and

green-purple calyx. The long-stalked, smooth, egg-shaped are borne singly or in clusters of 3–12, pointed at both ends, and capped with the persistent conical calyx. In length, it can be anywhere from 5 to 10 cm long, and in breadth, it can be anywhere from 4 to 5 cm wide. Red, orange, yellow, or red-and-yellow skin colors are all possible, as well as a variety of shades in between. Species-dependent variations in flesh color include shades of orange-red, yellow, and cream-yellow. In the two longitudinal compartments of dark-purple and red fruits, as well as yellow and orange fruits, a soft, juicy, subacid to sweet pulp surrounds the seeds. The exterior layer of flesh is luscious and bland, whereas the skin is rough and unpleasant to eat. Despite their diminutive size, the seeds are tough and bitter. A weak or under-ripe tomato with a subtle resinous aftertaste has a resinous scent and flavor. The plant bears in the first or second year after planting, but peak production is reached after 4 years and has a life expectancy of only 5–12 years. In general, it forms a large spreading crown at a height of 1.5–2 m from the base of a single upright woody trunk.

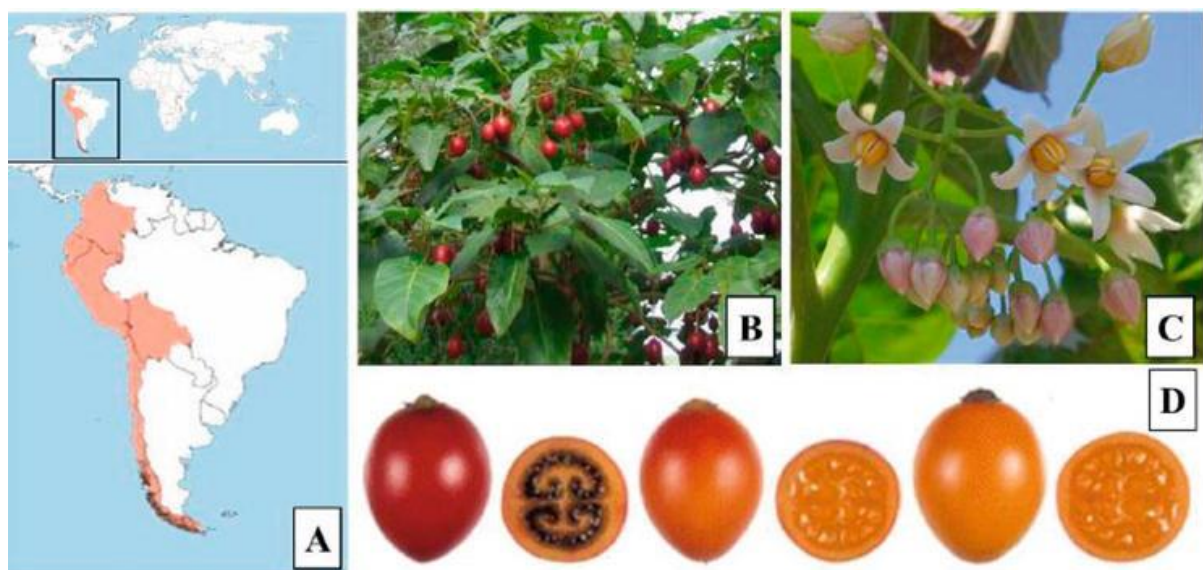


Figure 1.

Tamarillo origin and general aspects (A) Andean region from where tamarillo is native; (B) tamarillo tree with red fruits; (C) Tamarillo's flowers; (D) Tamarillo's fruits range of colors.

1.7. VARIETIES AND CULTIVARS

There are no named cultivars, but there are local preferences according to fruit color. Tamarillo have been described as three strains yellow, red (red skin, yellow-orange flesh), and purple (red-purple skin, light orange flesh), with the red being more popular and more common but no named varieties have been analyzed. In Europe and the USA, the red and purple cultivars are preferred by consumers due to their attractive color, flavor, and nutritional properties. In Malaysia, the red variety of tamarillo can be easily grown at Cameron Highlands, Pahang. It is an egg-shaped bright red fruit with yellow-orange flesh and black seeds that are surrounded by a purple seed coat. In Kenya, the main varieties grown are the Gold-mine, Inca red, Rothamer, Solid gold, and Ruby red. Red fruits are chosen for the fresh fruit markets because of their appealing color. Different selections have been developed in New Zealand from time to time. Commercial plantings of New Zealand's current dominant "black" type were selected in the early 1920s as a variation of the yellow and purple variants that had been used in the past. A reselection process resulted in the creation of this massive, higher-quality red variety. New Black was chosen by William Bridge in 1927 for its huge fruit. Ruby Red has been a staple of the New Zealand economy for decades. Heart-shaped fruit with a deep crimson color and a savory flavor were selected in 1970. Inca Gold is a canning favorite because of its amber hue and oval shape. If you are looking for something a little more vibrant, Ecuadorian Orange is a great choice. In 1979, Kaitaia Yellow was chosen for its flavor and sweetness. New Zealand is testing a new cultivar named Goldmine. Rothemer is an 85-gram fruit from San Rafael, California, with a bright red exterior and a golden yellow pulp. Solid Gold is an orange, luscious fruit with a sweet flavor. Red Delight, Yellow, and Oratia Round are also made in New Zealand.

1.8. BREEDING AND CROP IMPROVEMENT

Tamarillo's chromosomes are diploid ($2n = 2x = 24$). However, spontaneous tetraploids, aneuploids, and triploids have all been documented. The flowers are autogamous and self-compatible but flowers need to be shaken for pollination. Traditional plant breeding has largely ignored the tamarillo, and few crop improvement techniques have been applied. Most attempts to transfer this crop into new areas have failed since they have relied on a single cultivar. As a result, the ability to use variety

for local adaptation has been limited. On the other hand, the loss of genetic diversity in this crop and allied wild species is a major worry . Plantation management, fruit quality, and postharvest management are all improved through research and breeding. Breaking seed dormancy, improving fruit taste, and increasing yields are all key breeding goals. Little “stones” of sodium and calcium that occasionally form in the fruit skin offer difficulty for industrial applications and must be eradicated through breeding. The following are the most important breeding procedures in this crop.

1.8.1 Selection

Although the tamarillo is essentially autogamous, there is some variation among plants of the same accession, particularly in traditional growing methods. This variance is caused by spontaneous mutations or by the inadvertent introduction of genetic material from different populations through genotype crossover . This variation could be used to find a favorable variant that could be used in a future breeding effort for crop improvement. As a result, screening valuable genetic varieties in traditional growing areas for conservation, selection, and crop improvement for this underutilized fruit crop is critical.

1.8.2 Hybridization

Pollen tubes pierce the ovary and set fruits in most interspecific matings with *Cyphomandra*, according to , but seeds do not mature. Pringle and Murray experimented with interspecific hybridization of *Cyphomandra* with nine different *Cyphomandra* species and discovered that the majority of the crosses failed after fertilization. However, a species hybrid between the two Brazilian species *C. corymbiflora* and *C. diploconos* was obtained very easily. Most species’ combinations had reciprocal variances in compatibility. The results of these crosses indicate that the *S* locus is not involved in the regulation of interspecific incompatibility.

1.8.2.1 Intraspecific hybridization

There are no technical issues in crossing between different varieties of *C. betacea*. Tamarillo individuals have a high degree of homozygosity due to their autogamy, and crossing genetically dissimilar individuals produces homogeneous offspring. Commercial production of the hybrid tamarillo is simple because each fruit contains more than 300 seeds . The agronomic behavior of F1 hybrids, on the other hand, is

completely unknown. Most solanaceous horticulture crops have heterotic yield features , and the tamarillo is no exception. Obtaining segregant generations allows for recombination and segregation, allowing for the emergence of new superior genetic combinations. There is, however, a scarcity of investigations on the degree of diversity in segregant generations. Even though it takes several years to evaluate, tamarillo cannot be regarded as a standard fruit crop, as individual genotype evaluation can take up to 20 years. Nonetheless, evaluating each individual takes 3–5 years, making yearly species breeding schemes impracticable, as it could take up to 10 generations before an improved cultivar is released. It will be impossible to determine the best effective breeding strategy for this crop until studies are conducted to determine the corresponding value of the additive and dominant components of genetic variation for each of the primary interest traits. Breeders are interested in developing pure lines or F1 hybrids that maximize heterozygoses. Vegetative propagation, on the other hand, allows for the propagation of the most valuable genotypes that may arise in segregant generations, such as an F2 produced by complementary or transgressive crossings. Cloning permits the entire genotype to be preserved, which might be useful in the production of novel cultivars. Micropropagation for tamarillo provides for vegetative propagation without the risk of viral transmission.

1.8.2.2 Interspecific hybridization

Interspecific hybridization could be effective for transferring desirable traits from wild species to cultivated forms, such as disease and worm resistance. Crossings between *C. acuminata* Rusby and *C. uniloba* Rusby have proven successful. These species are morphologically quite similar to *C. betacea*. Fertility is low in Tamarillo hybrids with *C. acuminata*. Those obtained using *C. Manitoba*, on the other hand, are vigorous and prolific . Other *Cyphomandra* species, such as *C. hartwegii* (Miers) Sendt. Ex Walp. and *C. sibundoyensis* Bohs, are edible as well and may have some future potential as stand-alone plants or sources of genetic variety for tamarillo breeding. There is no publicly available enhanced breeding material for tree tomatoes. Nonetheless, numerous hybrids between *S. betaceum* and *S. unilobum* are being tested in Colombian fields as a result of breeding operations .

1.8.3 Polyploidy breeding

Triploid and tetraploid seedlings are found at low frequency among commercial plantings of the diploid tamarillo and may arise from the union of unreduced gametes. Further, reported successful induction of tetraploids in the tamarillo (*Cyphomandra, betacea* (Cav.) Sendt.) by the application of colchicine to the germinating seed. Triploids and aneuploids are produced from interploidy crosses. Most aneuploids produce primary trisomics ($2n = 2x + 1 = 25$), but some possess 26 chromosomes and few may be hyperpolyploids. Aneuploidy with 25 chromosomes, instead of 24 as the diploid types, shows good fertility and gives a similar or even higher yield and fruit size than their diploid counterparts. The pollen fertility of these plants can vary from 10 to 90%. The morphological traits of aneuploids and diploids were the same. For commercial use, aneuploids have fruit and seed sizes comparable to those of diploids. Tamarillo polyploids have been proven to have low fertility and poor agronomic properties, whether they are spontaneous or manufactured .

1.8.4 Biotechnological methods

Traditional techniques have revealed themselves inadequate for improving cultivars because of the low success of cross-pollination, the high incidence of incompatibility, and phytosanitary issues. A valid alternative for this plant's breeding is biotechnological methods such as in vitro cloning and genetic transformation .

1.8.4.1 In vitro regeneration systems

Tamarillo micropropagation methods have been described in various assays. In vitro cloning can be achieved through (1) axillary shoot proliferation, which was the first method to be applied (2) organogenesis, obtained on leaf explants and (3) somatic embryogenesis, first obtained from mature zygotic embryos and hypocotyls cultures, and later from other explants.

1.8.4.1.1 Somatic embryogenesis

Plant multiplication has the potential to be revolutionized by somatic embryogenesis, a powerful biotechnology tool. Auxin-rich media is used to induce somatic embryogenesis in tamarillo, where embryogenic callus is first generated (induction phase) and subsequently developed into embryos after being switched to a medium free of auxin (development phase). Several explants of tamarillo have the potential to

initiate embryogenic cultures including, mature zygotic embryos, young leaves, cotyledons, and hypocotyls. Tamarillo mature zygotic embryos were one of the first explants tested for somatic embryogenesis. The formation of embryogenic tissue offers great potential for the large-scale production of plantlets and is also useful in plant genetic transformation. Somatic embryos pass through different morphological phases similar to those occurring during zygotic embryogenesis. The subculturing of somatic embryos, on an auxin-free medium for a further 4–5-week period gives rise to green normal plantlets.

1.8.4.2 Genetic transformation

Several viral infections impact the health and vigor of tamarillo trees, as well as the appearance of the fruit. The tamarillo mosaic virus, the most important pathogenic virus, has no known resistance in *Cyphomandra* species (TaMV). There has been little success in using traditional breeding programs to increase tamarillo's virus resistance. Plants can now be genetically modified to be resistant to a variety of viruses, thanks to recent advances in molecular biology, including the tobacco mosaic virus. *Agrobacterium*-mediated transformation of tamarillo has been successfully achieved and protocols for transformation are now available. The use of genetic transformation offers a great opportunity for the improvement of many characters for which there is not enough genetic variation in the local germplasm. Genetic transformation is also being used as a functional genomics tool, helping to better understand the process of somatic embryogenesis. The most successful strategy so far has involved constitutive expression in the host plant of the coat protein gene of the target virus. Recently, the coat protein gene for TaMV has been cloned and sequenced which may allow TaMV resistance to be engineered into tamarillo. The application of the *Agrobacterium*-mediated transformation method to obtain genetically modified tamarillo plants regenerated via organogenesis was used to introduce the pKIWI110 binary vector into leaf disks by using a virulent LBA4404 and some of them also expressed the *b*-D-glucuronidase (*gusA*) reporter gene and chlorsulfuron resistance. *Agrobacterium*-mediated transformation was also used to obtain tamarillo plants resistant to tamarillo mosaic virus (TaMV) that were regenerated by shoot proliferation. The NEP25 gene has been silenced in tamarillo using *Agrobacterium*-mediated genetic transformation procedures. After undergoing somatic embryogenesis, these plants have been regenerated and are currently being

evaluated to see if they have the same capacity for somatic embryogenesis as untransformed plants.

1.8.5 Breeding for yield

At present, the tamarillo is being introduced as a promising crop in a variety of environments, e.g., regions with a Mediterranean climate. However, most attempts to introduce tamarillo culture have been based on a single cultivar and this has restricted the opportunity to exploit variation for local adaptation. For this purpose, germplasm screening is essential to select the most adapted types in local environments. Several evaluations of tamarillo germplasm have shown a high degree of genetic variation for yield and fruit weight. Differences among different plant genetic materials can be as high as two-fold for fruit weight. The fruit yield is highly affected by environmental components and exploitation of the most adapted material could maximize the selection for yield.

1.8.6 Breeding for quality

Among fruit quality parameters fruit shape is of interest because it is directly related to consumer acceptance because it affects fruit attractiveness and is important in terms of packaging and presentation. The fruit shape varies from round to elongated, with a ratio length/width higher than two among accessions. Round to oval shapes appear to be preferred. Fruit color varies from yellow types to purple and it may have stripes or not. Differences among cultivars have been found in organoleptic characters like soluble solids, titratable acidity, ascorbic acid, and other characters. Cultivars with a higher sugar/acid ratio are probably more suited for the processing industry. Sugar/acid ratio and sweetness were found to be higher in one of the seven accessions studied by that had reduced acidity (between 15% and 23% and similar levels of soluble solids). Recently developed 'Oratia Red' and 'Andys Sweet Red' have a high sugar/acid ratio (Boyce and Strubi, 1997). Breeding for nutritive value is also possible as a lot of variation for ascorbic acid content and vitamin A have been found among genotypes. Aromatic compounds of tamarillo have been and the selection of high aromatic cultivars is of interest. However, aroma is a complex character, in which many interactions among different compounds are involved and in which environmental influence is considerable.

1.8.7 Breeding for disease resistance

Few studies have been devoted to tamarillo breeding for disease resistance. Most work has dealt with TaMV resistance. Resistance to TaMV has not been achieved yet, even in wild species belonging to the genus *Cyphomandra*. Genetic transformation is being used to develop tamarillo cultivars resistant to TaMV. Strategies used up to now have mostly involved the use of genetic constructs which include sequences of the coat protein of this virus. The use of mutagenic agents, such as nitrous acid for the production of defective TaMV strains, which could be used for cross-protection has not been successful. Resistance to anthracnose is also being attempted by in vitro selection of cells capable of growing in the presence of crude filtrate of the fungus. However, there are no reports of the efficacy of this strategy in developing mature plants resistant to this disease.

1.8.8 Breeding for early harvesting

Early harvesting is of significance since different cultivars differ in how quickly their fruit ripens. This could be exploited to select the earliest cultivars. There is also quantitative variation in the response to postharvest applications of ethylene in some cultivars so it is possible to achieve successful postharvest ripening. Despite being considered a non-climacteric fruit ethylene applications stimulate ripening. Fruit can be harvested during the turning stage and allowed to ripen after harvest in materials where ethylene induces ripening. Fruits that are turning may be stored in this way and matured as needed.

1.8.9 Breeding for parthenocarpy

Occasionally, parthenocarpic (seedless) fruit-producing trees can be discovered in orchards. These trees require vegetative propagation because they are the result of spontaneous mutations. Fruits from parthenocarpy are ovoid-shaped, red to orange in color, and have stripes that range from green to coffee in hue. Orange is the color of the flesh. Fruit weighs normally only 20 g and is smaller than other fruit. Due to their lack of seeds, parthenocarpic tamarillos would be very intriguing; nevertheless, before this form of fruit can become well-known, low-weight and poor yield issues must be resolved.

1.9. SOIL AND CLIMATE

Tamarillo plants grow best in light, deep, fertile, and rich in organic matter soils. However, soils must be well-drained, since the plants are not tolerant to water logging. They grow naturally on soils with a pH of 5–8.5. The tamarillo requires full sun and freedom from competition with roots or shade from other plants. The tamarillo prefers a subtropical climate, they grow in many parts of the world with rainfall between 600 and 4000 millimeters and annual temperatures between 15°C and 20°C. Although species can also thrive in colder climates, in areas with temperatures not lower than 10°C and where extreme freezing does not occur, but it is intolerant to frost (below –2°C) and drought stress. Even though extreme cold could severely damage tamarillo plants, often the plant can recover. During the first year of planting the cuttings and seedlings should be protected from frost as plants are highly susceptible to frost and can readily be killed. Frost kills the small branches and foliage of mature trees but not the largest branches and main stem. It is assumed that the fruit set is affected by night temperatures. Areas where citrus is cultivated provide good conditions for tamarillos. Tree tomatoes cannot survive in areas with prolonged drought. They must have ample water during the dry season. The best way to retain moisture in a tree tomato plantation is to apply mulch, which also reduces weed growth. Branches of tamarillos are fragile, and brittle, and break easily when laden with fruit so windbreaks should be established before the actual planting of the fruit plants in an area where wind may be a problem. Further, these plants have a shallow root system and can be blown over by strong winds if not protected sufficiently. Hailstones can also damage the leaves and break the brittle branches. However, damage to fruit is not as severe as in other fruit crops due to their thick skin and strong attachment to the plant.

1.10. PROPAGATION AND ROOTSTOCK

The plant is mostly multiplied through seeds, cuttings, or grafting as well as more contemporary methods of in vitro clonal propagation, which include axillary branch proliferation, organogenesis, and somatic embryogenesis and are commonly referred to as micropropagation. Seed propagation is simple and best done in protected areas. Seeds produce a high-branched, erect tree, ideal for sheltered locations. Seeds for planting are first washed, dried in the shade, and then placed in a freezer for 24 hours to accelerate germination. They are then planted in boxes of rich soil by keeping a

30 cm distance between seeds and 60 cm between rows and virtually 100% will germinate in 4–6 days. Seedlings should be kept in the nursery until they reach a height of 1–1.5 m for efficient growth. Cuttings should be taken from healthy plants that are free from pathogenic viruses from the basal or aerial suckers and should be of 1- to 2-year-old wood with thickness ranging from 10 to 25 mm and length of 45–75 cm. They are planted directly in the field until they reach a height of 1–1.5 m. Cuttings develop into a shorter, bushy plant with low-lying branches, suitable for exposed, windy sites. Tamarillo can be grafted on several closely related rootstock species. In Java, *Cyphomandra costaricensis* is sometimes used as a rootstock to attain a longer-lived plant. The cuttings can also be grafted on wild tobacco trees (*Solanum mauritianum*). The Solanaceae family, which includes many tamarillo cousins, has strong and frequently undesirable alkaloids that can transmit to scions and into fruits grafted on such roots. This is important to remember. It is not advisable to integrate tamarillo on an unknown or untested rootstock.

Propagation through seeds is not recommended as this method is known to produce a high degree of genetic variability that negatively affects fruit color resulting in the rejection of fruits in the international market. Thus, methods of vegetative propagation are usually used to obtain uniform plants. Vegetative propagation by cuttings has been found to transmit deadly viral diseases. Tissue culture offers a feasible solution to produce large numbers of disease-free planting materials. It is also known that in vitro propagated Tamarillo plants produce higher yields and shorter gestation periods compared with traditional methods. Another advantage offered by tissue culture methods is the large-scale availability of planting materials at any time of the year irrespective of the season.

Nodal explants are surface sterilized, added to Murashige and Skoog media containing Benzyl amino purine (BAP), and then incubated in a growth environment with a temperature of 25°C and a 16-h photoperiod. Rooting occurs without the use of an exogenous source of auxin 2 weeks after micro shoot development, and they grow to a height of 40 mm in 4 weeks. After that, the rooted plantlets are brought to the greenhouse to begin weaning. In vitro, propagation of Tamarillo using axillary buds has been reported. Somatic embryogenesis and direct organogenesis have also been reported by. Direct organogenesis has the potential to keep regenerated plants' genomes stable, whereas regeneration through an intermediary callus phase raises

the probability of somaclonal changes. A very effective and repeatable in vitro regeneration technique is moreover an absolute requirement for creating transgenic plants.

1.11. LAYOUT AND PLANTING

The seedlings are transplanted in the field when they reach 5–7 cm in height, spaced 80 cm apart in rows and 2 m apart between rows. In New Zealand, the trees are kept 2.5–3 m apart in paired rows 2.5 m apart with 4.25 m between each pair. In mechanized production, single-row planting distances of 1–1.5 m between plants and 4.5–5 m between rows are recommended. In unprotected areas where winds are strong closer planting is recommended by keeping 1.5–1.8 m between the plants and 2.5–3 m between the rows and the trees may be staked to prevent swaying and disturbing of roots. In India, the trees are planted in pits 1.2–1.5 m apart. On poorly drained soils, plants should be planted on ridges. In poor soils or soils where nematode infestations or virus infections are possibly prevalent, replanting with clean stock will be necessary and is recommended after a period of 3 or 4 years.

1.12. IRRIGATION

To maximize and stabilize production, water and nutrient inputs should be provided when needed. The plants need a continuous supply of water due to their shallow root system. Drought stress results in a decrease in plant growth, fruit size, and productivity. The tree tomato cannot tolerate prolonged drought and must have an ample water supply during extremely dry periods. A mulch may be very beneficial in conserving moisture at such times.

1.13. NUTRIENT MANAGEMENT

The suggested fertilizer rates per hectare for intensive orchard production techniques are 170 kg of nitrogen, 45 kg of phosphorus, and 130–190 kg of potassium. While potassium and phosphorus are sprayed at the beginning of the growth season, nitrogen is applied all year round. It is recommended to apply 0.25–1.0 kg of NPK fertilizer per tree evenly between early spring and summertime. The producer should give the plants in their fifth or sixth year a special feeding of 2 parts superphosphate, 1 1/2 parts nitrate of soda, and 1 part sulfite of potash in late winter or early spring at a rate of 1–1.5 kg per plant or 100 kg per hectare.

1.14. TRAINING AND PRUNING

The plant should be trained by pruning back long shoots and pinching shoot tips to induce compact growth and the production of the fruit clusters near the center of the tree. Seedling trees are pruned back the first year after planting to a height of 0.9–1.2 m to encourage branching. Annual pruning thereafter is advisable to eliminate branches that have already fruited and induce ample new shoots close to the main branches since branches that have already carried fruits will produce smaller fruits with lower quality the next time. Annual pruning is also a must otherwise, the tree will develop a broad top with fruits only on the outer fringe, and wide-spreading branches are also subjected to wind damage. Pruning also facilitates harvesting and if done timely and appropriately can extend the total fruiting period. Light pruning facilitates the production of medium-sized fruits and heavy pruning to large-sized fruits. Under protected cultivation pruning can be helpful to prevent excessive vegetative growth. Early spring pruning of some trees brings about early maturity and fall pruning of other trees delays fruit maturity to the following fall. It is best to cut the roots on one side of the tree and lean it to the other when it is between one and one and a half meters tall (in the direction of the midday sun at about 30–45 degrees). As a result, fruiting branches can develop along the entire trunk as opposed to simply at the top.

1.15. INTERCROPPING AND INTERCULTURE

In plantations, tamarillo is frequently intercropped with citrus so that, for the first 4–6 years of its rapid growth to a productive size, it can be produced economically. Thereafter, the tamarillo plants are removed. Mulching can aid in preserving soil moisture because plants are susceptible to drought stress. As traditional soil management techniques like plowing are impractical due to the thin and delicate root system, it can also be used as a tactic to control weeds. Because of the shallow root system, deep cultivation is not possible, but light cultivation is desirable to eliminate weeds until there is sufficient vegetative growth to shade them out. The plants have to be protected from wind. Their shallow root system does not provide enough stability and the lateral branches are fragile and break easily when carrying fruits. The tree has to be protected from the wind because its roots are weak and it can easily be blown over. It is also fragile, and strong winds can easily break its branches, especially when they are heavy with fruit. Before laying out the plantation, it is advised that windbreaks

be built to protect the young plants for each 1/2 acre (1/5 hectare). In the New Zealand region of North Auckland, *Albizia lophantha* Benth. and *Hakea saligna* hedges are maintained clipped, narrow, and well-liked.

1.16. FLOWERING AND FRUIT SET

Tamarillo shows sympodial growth habit and each sympodial unit consists of 3–4 leaves and a terminal inflorescence. New season's growth begins in October with shoots that originate in the axils of the previous season's leaf scars. Before inflorescence commencement and branching, shoot extension advances up to 15 nodes at the start of the growth season. At the tip of the stalk, inflorescences develop, and later, continuation shoots develop, typically in the axils of the two most recent leaves. Monochasial and trichasial branches are also seen, despite dichasial branching being prominent. Although they begin at the shoot apex, inflorescences can eventually be found 30–40 mm above the branch fork. At maturity, the flowers and inflorescences hang pendulously, with the anthers and stigma facing downward. Typically, the inflorescence is a mono- or dichasial with flowers arranged alternately along the rachises. Up to 15 flowers per rachis and 50 in total could be seen in each inflorescence. At 2–3-day intervals, flowers open in an acropetal succession. As a result, the same inflorescence may contain fruits, flowers, and flower buds. Particularly if a fruit had already set inside the inflorescence, apical flower buds on each rachis frequently abscise before flower opening. Inflorescences formed late in the season also lose their immature flower buds, and occasionally just one or two blooms fully open.

In climates with little annual variation, tamarillo trees can flower and set fruit throughout the year. In climates with pronounced seasons (such as New Zealand), fruits ripen in autumn. The flower is pentamerous, radially symmetrical, stellate and hermaphrodite, and 24 mm in diameter when the petals are fully reflexed. The petals have a variety of colors, ranging from white to pale pink to white with purple flecks, and are relatively lengthy and meaty. Each stamen is united to a petal and forms a cone around the style. The stamens have two anther sacs on either side of a wide, yellow connective tissue, as well as a short filament and an anther. The style extends 2–4 mm beyond the anther cone and is long and thin. Small, flat, and papillate describe the stigma. Pollen is formed in large quantities in anthers (800,000 pollen). Pollen grains in their

desiccated state are oval and trilobed with a pitted exine bearing numerous fine spines. Individual flowers generally open before midday and the petals close around the anthers and style again in the evening. The following morning, each flower bloomed once more, and this pattern persisted for another 2–3 days before the petals fully closed. The number of days a flower is open has an impact on pollination. Nearly a day earlier than unpollinated blooms, pollinated flowers closed for the last time on average after 2.25 days (3.05 days). Either at the flower opening or right before it, an anther opens. Pollen is not released spontaneously but anthers release a cloud of pollen via the apical pore if touched or squeezed. If the anthers are not disturbed the pollens remain in the anthers beyond final flower closure. All flowers bear stigmatic exudate on the day of flower opening and remain present on the stigma until Day 5, even though the petals have closed. On the stigma, pollen grains and tubes can be seen from days three to four, but their abundance is greatest on days zero and two. On Day 0, pollen grain germination is at its highest, and it gradually decreases over the following days. On any given day, there are observed to be comparable numbers of pollen tubes in the style and pollen grains on the stigma. After 24 h, pollen tubes are about two-thirds of the way down the style, and after 48 h, they are present surrounding the ovules, according to observations of the pollen tube growth rate.

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. Flowers pollinated on Days –3–1 had the highest probability of fruit set. Fruit set then declined sharply until no fruit set on flowers pollinated on Day 4. Fruit set is strongly influenced by treatments designed to modify the pollen source and the vector. On average, two fruit sets in open-pollinated inflorescences and 0.6 in inflorescences bagged to exclude external sources of pollen have been found. The flower pollination is carried out by honey bees (*Apis mellifera*) and bumblebees (*Bombus terrestris* or *B. hortorum*). Although fruit set is lower in both cases than in open-pollinated flowers, the quantity of fruits set per inflorescence is unaffected by the pollen source, whether “self” or “cross” (by hand pollination). Self-pollinated or cross-pollinated flowers produce between 0.7 and 0.9 fruit sets per inflorescence on average, as opposed to 2.0 from open-pollinated blooms.

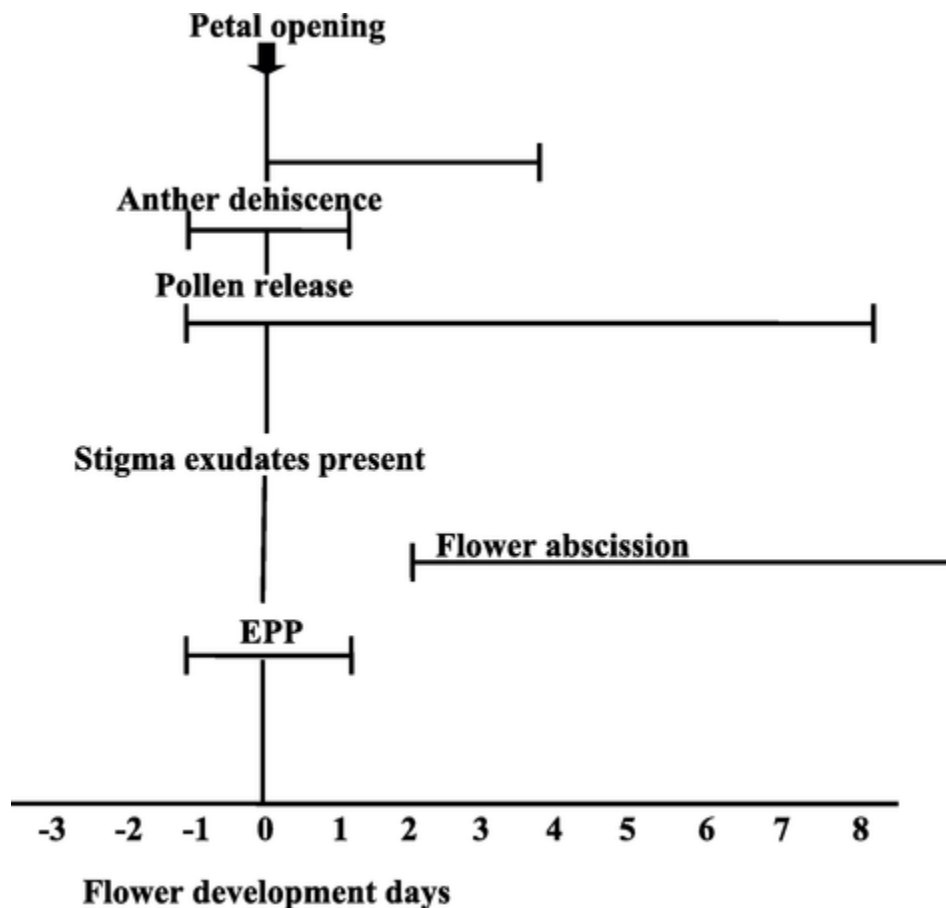


Figure 2.

Floral phenology of the tamarillo flower based on observations from 20 flowers grown under glasshouse conditions (EPP—effective pollination period) [73].

1.17. FRUIT GROWTH DEVELOPMENT AND RIPENING

Fruit growth and development involves changes in its morphology, anatomy, and physiology whilst fruit ripening is associated with dramatic changes in rind texture, color, juice composition, increase in softness due to changes in the cell walls, the metabolism of organic acids, and the development of compounds involved in flavor and taste. During development, it follows a simple sigmoid growth curve and during ripening it behaves as a non-climacteric fruit. Fruit growth shows an increase of fresh weight (and volume) fast and linear between the sixth and sixteenth week after this period the growth ceases. However, the weight dryness of the fruit continues to increase until reaching a maximum in the twentieth week after anthesis. Tamarillos are commercially mature at 21–24 weeks after anthesis. Maturity is indicated by color, firmness, juice content, and soluble solids content. Heatherbell *et al.* reported that

tamarillo fruits grew rapidly and reached full size within 16 weeks after anthesis and maturity is attained 11 weeks later i.e., at about 27 weeks. Marked changes in the skin and pulp color occur during development. After 15 weeks the first purple coloration of the skin appears and thereafter increases in intensity. The green chlorophyll underlay disappears from the fruits between 18 and 22 weeks. Tamarillo is a non-climacteric fruit; therefore, it does not exhibit an adequate self-stimulated increase in ethylene production and a consequent respiratory increase as part of its ripening behavior . Pratt and harvested red and yellow tamarillos from 5 to 23 weeks of age and they monitored their respiration rate, demonstrating that the respiratory rate decreases as the age of the fruit increases. The ripe fruits presented a relatively high respiratory rate immediately after harvest ($35 \text{ mg CO}_2 \text{ kg}^{-1} \text{ h}^{-1}$ at 20°C), which then decreased gently until the beginning of the senescence. In this study, the ethylene production of the fruits harvested was measured and it was shown to be negligible length of fruit development (less than $0.10 \text{ } \mu\text{l kg}^{-1} \text{ h}^{-1}$ at 20°C) until the beginning of the senescence, when it increases abruptly together with the respiratory rate.

Tamarillos of red cultivars remain green until the fruit grows around the sixteenth week after anthesis. From that moment, it begins to appear a violet color at the apical end subsequently, it will spread over the whole fruit. Around the nineteenth week after anthesis, the green base color begins to turn yellow and the apparent color purple is revealed to be red. Violaceous coloring of the tissue surrounding the seeds is evident around the 12th week after anthesis and intensifies until the Twenty-first week when it begins to decrease in intensity again. The fruits of yellow cultivars present a pattern of similar color change, except that the red coloration is very slight, resulting finally in a light orange color, and without that red pigmentation appears around the seeds. Changes in skin color are due to the degradation of chlorophyll and an increase in the concentration of anthocyanins and carotenes. However, the increase in the concentration of anthocyanins in the skin is very small in the 4–6 weeks before commercial maturity. The concentration of anthocyanins, carotenes, and chlorophylls from the tissue that surrounds the seeds is maximum when the fruit is in the violet state and then decreases.

The immature fruits have a high Starch content (14% of fresh weight) that, before the end of the stage of active growth, begins to decrease until reaches less than 1% in ripe fruits. The decrease in starch content is accompanied by an increase in the

concentration of soluble solids and sugars. Sucrose is the predominant sugar in tamarillos. The citric and the malic are the organic acids predominant in tamarillo throughout the fruit development. The concentration of citric acid increases rapidly during the period of active fruit growth, reaching more than 2% of the fresh weight; the decreases up to 1.4% in mature fruits. Malic acid concentration is relatively low during the entire period of fruit development (0.2% of fresh weight in mature fruits). The pectin content decreases throughout the fruit development. The lysis of unions between pectin and hemicelluloses increases the solubilization of pectins during ripening. Tamarillo's soluble solid content appears to rise to 10–12°B during ripening (normally, the values range between 10.0 and 13.5°B), while the titratable acidity gradually declines (typically, the values range between 1.0 and 2.4%), increasing the SSC/TA ratio and, as a result, the sensory flavor rating. The stems also change when the fruit ripens, turning yellow instead of green as a result of increased water loss and chlorophyll degradation. Further, according to an SSC value over 12% can qualify tamarillo either for raw consumption or industrial processing.

1.18. FRUIT RETENTION AND FRUIT DROP

Self-pollination occurs naturally in tree tomato blossoms. Unless there are bees to transmit the pollen, pollination may suffer if the wind is fully stopped so as not to move the branches. Flowers that have not been pollinated will wilt quickly.

1.19. HARVESTING AND YIELD

The tree typically starts bearing when it is 1 1/2 to 2 years old and keeps producing for another 5 or 6 years. It may continue to bear fruit for 11–12 years if given appropriate nutrition. The crop does not ripen simultaneously and several pickings are necessary. Tamarillos are picked when fully colored. The optimum time to harvest the tamarillos of red cultivars is when they are violet in color. Other recommended indices to determine the maturity of the fruit with greater accuracy are the firmness, the content of juice, and the content of soluble solids. The color of the pedicel in combination with the skin color was also suggested as the Maturity index. Fruit can also be picked when they are at the turning stage (when the green color of the skin begins to change and the characteristic skin color begins to show) and then treated with ethylene to stimulate ripening. This early picking and subsequent postharvest ripening reduce the risk of crop failure, increases earliness and concentrates harvesting as it allows harvesting

to be advanced by up to 1 month The fruits are clipped, leaving about 12.5 cm of stem attached. They are collected in bags worn by the harvesters. A single tree can produce more than 30 kg of fruits per year. A regular orchard yields 15–17 tons per hectare.

1.20. PROTECTED/HIGH TECH CULTIVATION

Tamarillos are suitable for growing as indoor container plants, though their swift growth, their light, water, and humidity requirements, and their large leaves can pose a challenge within a limited space. Plants grown in the greenhouse are heavily pruned to prevent excessive vegetative growth. Greenhouse tamarillo production can be somewhat inconvenient due to its long life and extended growing cycle .If grown in conditions where flower vibration is limited, such as in a greenhouse, fruit set can be very low .

1.21. DISEASE, PEST, AND PHYSIOLOGICAL DISORDERS

1.21.1 Diseases

1.21.1.1 Powdery mildew and leaf spot

If left unchecked, this fungus can produce a significant amount of defoliation. It is possible to remove powdery mildew by using commercial pesticide washes and neem oil sprays (*Oidium* sp.).

1.21.1.2 Bacterial blast

It is caused by *Pseudomonas syringae* and *P. solanacearum*. It affects the shoot and leaves. Anthracnose (*Colletotrichum gloeosporioides*).

1.21.1.3 Anthracnose (Colletotrichum gloeosporioides)

The damage it inflicts is immense. Good orchard management can help lower the risk of pest and disease control in markets that demand immaculate fruit. As long as the nursery is kept clean, predator insects can reduce the need for chemical pesticides.

1.21.2 Viral diseases

1.21.2.1 Tamarillo mosaic virus (TaMV)

TaMV symptoms include a mosaic mottling on the leaf and ugly irregular spots on the fruit skin that are a darker red than the cultivar's typical skin color. Inside the fruit, there are no visible symptoms, and the eating quality is unaffected. Due to the milder

background color typical of this variety of fruit, the darker red splotch on golden tamarillos is particularly ugly. The plants grow stunted as a result. TaMV can only be controlled after symptoms occur by removing trees that are seriously infested .

1.21.2.2 Cucumber mosaic virus and potato virus Y

These not only diminish the plant's strength and health but also distort the leaves, produce skin blemishes, and lower the plant's marketability. They result in fruit mottling and yield loss. The severity of the symptoms will be greater if multiple viruses have simultaneously attacked the plant and will be worse on young or sickly plants. In the valleys of Ecuador's Pichincha region, PLRV, ToRSV, PVY, and AMV were the most often discovered viruses linked to symptoms of viral diseases . Alfalfa mosaic virus (AIMV), tomato spotted wilt virus (TSWV), Arabis mosaic virus (ArMV), tobacco streak virus (TSV), and tomato aspermy virus (TAV) are other viruses that have affected the tamarillo, albeit the losses they cause are not as severe as those produced by TaMV . The Colombian tamarillo crop's declining yield is caused by a virus complex. The phytosanitary problem, among which anthracnose (*Colletotrichum acutatum*) and viruses (PLCR, CMV, Potyvirus, and ToMV) and others, apparently less influential (AMV, ToRSV, and TSWV) has a major effect on expansion plans of the tamarillo cultivation in Colombia . Good orchard hygiene, pruning and burying infected plants, and a good pest management program will help to reduce pests and diseases in the crop. A suitable spraying schedule can also be helpful. However, there is no cure for a virus once it has infected a plant; the only option is prevention. Since aphids are the primary transmitters of viruses, it is crucial to have effective control over them. Since there is no proof that viruses affecting the tamarillo may be propagated by seed, seed-based reproduction is a strategy for restricting their spread.

1.21.3 Nematodes

The plant is also harmed by *Pseudomonas solanacearum* wilt, root-knot (*Meloidogyne* sp.), root rot, crown rot, and other diseases. Good cultural norms ought to help prevent these issues.

1.21.4 Physiological disorders

1.21.4.1 Abnormality

To make jam, small, hard, irregular, semi-transparent stones that are present in the flesh of tree tomatoes must be strained out. If these resemble the two grit-filled bumps in the fruit's wall, that is unknown. Probably in the form of silicates, borates, aluminum-magnesium-oxygen complexes, aluminates, or magnesium oxides, these stones are highly concentrated sources of sodium and calcium.

1.21.4.2 Fruit scarring

Tamarillo fruit scarring is a cosmetic condition that costs New Zealand's tamarillo growers significantly lost revenue. According to estimates, the condition affects 10–20% of the fruit, which will result in considerable economic losses. When the scars are about 3 cm long, they first appear as little, dark lines on the skin of young fruit. As the fruit grows, the scars turn into corky lesions. Phillips *et al.* reported that a physical injury caused the scarring. A dark, uneven, and crazy corky scar was routinely produced when the epidermal layer was scratched with a toothbrush. Physical injury such as wind rub has been reported to cause corky scarring in other fruits also, such as avocado . Wounding fruitless by scratching or removing a patch of epidermis resulted in the characteristic scarring, which suggests that any type of physical epidermal damage incurred early in fruit development may result in scarring.

1.22. PACKAGE AND TRANSPORT

Fruits are sorted by size as small, medium, and large and packed in paper-lined wooden boxes for marketing. Polythene films can also be used to reduce water loss and maintain fruit quality. Packaging usually consists of wooden or cardboard boxes containing one tray of tamarillos or preformed plastic trays with 3–8 fruits. Because of its firm flesh and tough skin, the fruit can be transported over long distances without bruising. However, it deteriorates rather rapidly under ordinary storage conditions.

1.23. POSTHARVEST HANDLING AND STORAGE

Different studies carried out to improve post-harvesting ripeness showed that the application of ethylene or ethephon helps decrease the risk of crop failure and an earlier delivery to the consumer, thereby enhancing the marketability of tamarillo The fragile lateral branches can break easily when loaded with fruits, so premature harvest helps to reduce this risk and allows storage of fruits for up to 20 days at room temperature. Tamarillos can be stored for about 12–14 weeks at 3.5–4.5°C. A cold

water dipping process, developed by the New Zealand Department of Scientific and Industrial Research also allows further storage of 6–10 weeks. At higher temperatures, postharvest diseases multiply rapidly. One of the main causes of postharvest loss is bitter rot caused by a *Colletotrichum* sp. Applications of postharvest fungicides greatly reduce the number of fruits affected. Another alternative for postharvest disease control is to dip the fruit in water at 5°C for 10 min. Temperatures below 7°C will reduce softening, weight loss, TA reduction, and color change, among other postharvest handling characteristics that might impact quality. On the other hand, extremely low temperatures (between 0 and 2°C) raise the danger of chilling injury and worsen stem and calyx discoloration.

1.24. PROCESSING AND VALUE ADDITION

Pomegranate can be used in both savory and sweet dishes, and it can even be eaten raw. Fruits can be used to make preserves because of their high pectin content. However, if they are left untreated, they will oxidize and eventually fade. The yellow fruit is preferred for industrial production. As it turns out, it can be utilized in the same way as tomatoes are used in many other cuisines. Simply slice the tomatoes in half, sprinkle them with sugar, then consume the pulp and flesh by scooping it out. Chopped bacon and cream cheese go on top of sandwiches. Diced fruits, bread crumbs, butter, and seasonings are used as a stuffing for roast lamb. Dessert in the form of a pie sliced tree tomatoes, either on their own or accompanied by an apple, are available. They may be filled with water or sugar syrup, then packed into plastic containers with 50% sugar syrup and quickly frozen for later use as pie fillings or puddings. In a blender or on the stove, puree the peeled fruits, remove the seeds, and freeze in containers. Before blending, add some lemon juice to the purée to enhance the flavor even further. Several slices of fresh tree tomato are placed on top of the gelatin, milk, sugar, and lemon juice-cooked fruits. Cooking tree tomatoes with sugar, lemon zest, and juice results in a jam or chutney; the tomatoes can also be cooked with onions and apples for chutney, depending on the desired consistency. Chutney for the commercial market is made in an Auckland, New Zealand, facility. Pectin in the fruit makes it simple to turn into jelly, but the fruit quickly oxidizes and discolors if not treated further. Using whole, peeled fruits and sugar, a thick sauce is cooked to serve with ice cream. The peeled fruits can be used for tomatoes in tomato sauce. Tamarillo jelly can be made from tomatoes with a 50°C Brix sugar concentration, sucrose, and 2% pectin.

CHAPTER 2

LITERATURE SURVEY

Tamarillo is a unique fruit with a distinctive flavor and an interesting history. Despite being native to South America, it is very popular in New Zealand. Tamarillo thrives in a subtropical climate but can also be grown in areas where citrus crops are cultivated. While it is grown in various countries, commercial cultivation is mainly in New Zealand and some parts of South America. It does not typically bear fruit in low-lying tropical regions. The plant grows rapidly and produces fruit in approximately 18 months, reaching a height of about two meters and living for around seven years. Propagation is commonly done using seeds or cuttings, with trimming techniques varying depending on the method used. Tamarillo plants are sensitive to wind and should be planted in sheltered areas or protected by windbreaks. The fruit has a glossy skin and is rich in vitamins, minerals, fiber, and antioxidants, with a low-calorie content. It can be consumed fresh or used to make juices, concentrates, jams, gelatins, and desserts. If processing facilities and suitable transportation are available, tamarillo can be exported as pulp or concentrate. This fruit offers an opportunity to diversify fruit production in subtropical regions, as high-quality fruits can fetch premium prices in niche markets in Europe, North America, and Japan.

Tamarillo is primarily cultivated for its edible fruits and is also grown as a decorative plant outdoors to a lesser degree. The tamarillo fruit has been described as noticeably beautiful and its scent as unique and appealing. It is versatile in the kitchen and can be enjoyed raw in salads or desserts, but it is usually preferred cooked. The flesh of the tamarillo can be consumed fresh or used to create a variety of sweet and savory dishes and condiments. Tamarillos have a tangy and usually sweet flavor with a bold and intricate taste that varies depending on the variety. The fruit can be stewed for use in cereals, pies, or crumbles, added to stews, or turned into a tasty chutney, particularly good with a hint of chili. In Jamaica and the West Indies, the fruit is believed to have positive effects in the treatment of liver disorders. Tamarillo plays a significant role in Rwanda's exotic fruit industry, and the fruit is traditionally recommended for individuals with stomach ailments. It is processed into jams, juices, jellies, or canned syrup, and is also used in combination with dairy products like yogurt, milkshakes, and ice cream. The fruit contains a high level of pectin, making it

especially suitable for making jams and preserves. It is also utilized for canning in syrup and for producing pulp, chutney, sauce, baby food, and in combination with dairy products. The fruit can be used similarly to a regular tomato, but it has less moisture, so more liquid is needed in most cooked dishes.

"This fruit is rich in antioxidants and vitamins A, C, B6, and E. Tamarind has high levels of vitamins A and C compared to other fruits (Table 2). Its ascorbic acid content is similar to citrus fruits, while its vitamin A levels fall between that of tomatoes and carrots. The color of tamarind comes from its high levels of carotenoids and anthocyanins, which also contribute to its biological, medicinal, and preventive properties. Researchers like Osorio et al. have found that tamarillo fruits are valuable due to their natural pigments with antioxidant potential, confirmed by spectroscopic analyses. The primary antioxidants in the fruit pulp are phenols. Both the fruit flesh and seeds are consumed together, with seeds making up one-third to one-half of the fruit's weight (50-80 g). An analysis of tamarillo seeds showed a total carbohydrate content of 43.87 percent, protein content of 22.63 percent, fat content of 21.13 percent, and ash content of 3.15 percent. The most common fatty acids in tamarind seed oil are linoleic acid (70.47 percent), oleic acid (14.93 percent), palmitic acid (9.41 percent), stearic acid (2.23 percent), and linolenic acid (1.73 percent). In addition, lignoceric acid (0.23 percent), phellonic acid (0.22 percent), and arachidic acid (0.23 percent) are also present in the oil. Tamarind fruits are low in calories."

The growth and development of fruits involve changes in their morphology, anatomy, and physiology, while the ripening of fruits is characterized by significant changes in texture, color, juice composition, softness, organic acids metabolism, and the development of compounds responsible for flavor and taste. A simple sigmoid growth curve is typically followed during development, while ripening is non-climacteric. An increase in fresh weight and volume occurs rapidly and linearly between the sixth and sixteenth week before growth ceases, although the dry weight of the fruit continues to increase until reaching a maximum in the twentieth week after anthesis. Tamarillos are considered commercially mature at 21-24 weeks after anthesis, indicated by color, firmness, juice content, and soluble solids content. Changes in skin and pulp color occur as the fruit develops, with purple coloration appearing on the skin around 15 weeks and the disappearance of green chlorophyll between 18 and 22 weeks. Tamarillos are non-climacteric fruits, showing a decrease in respiratory rate as they

age. Ethylene production in these fruits remains low until the onset of senescence when it abruptly increases along with the respiratory rate.

Fruits of red cultivars remain green until around the sixteenth week after anthesis when a violet color starts at the apical end before spreading throughout the fruit. In the nineteenth week, the green base color turns yellow, and the violet color transitions to red. Fruits of yellow cultivars undergo a similar color change pattern, ending in a light orange color without the red pigmentation around the seeds. Skin color changes are due to chlorophyll degradation and an increase in anthocyanins and carotenenes. The concentration of anthocyanins in the skin peaks during the violet state and decreases thereafter.

Immature fruits have a high starch content that decreases to less than 1% in ripe fruits, accompanied by an increase in soluble solids and sugars. Citric acid is the primary organic acid in tamarillos, increasing during active growth but decreasing in mature fruits. Malic acid levels remain relatively low throughout fruit development. Pectin content decreases during fruit development, resulting in increased pectin solubilization during ripening. The soluble solids content of tamarillos typically reaches 10-12°B during ripening, while titratable acidity declines, leading to an increase in the SSC/TA ratio and improved sensory flavor. Stems also change color when fruits ripen, turning yellow due to water loss and chlorophyll degradation. An SSC value above 12% qualifies tamarillos for raw consumption or industrial processing.

2.1.HARVESTING AND PRODUCTION

The tree usually begins to bear fruit when it is 1 1/2 to 2 years old and continues to produce for another 5 or 6 years. With proper nutrition, it may bear fruit for up to 11-12 years. Since the crop does not all ripen at once, multiple harvests are necessary. Tamarillos are harvested when they are fully colored, with red cultivars being best picked when they are violet in color. Other indicators of fruit maturity include firmness, juice content, and soluble solids. The color of the stem in combination with the skin color has also been suggested as a maturity indicator. Fruit can be harvested when they are starting to change color and then treated with ethylene to promote ripening. This early picking and postharvest ripening reduces the risk of crop failure, increases early availability, and concentrates harvesting, allowing for harvest to be advanced by up to 1 month. Fruits are cut with a stem of about 12.5 cm attached and collected in

bags. A single tree can yield over 30 kg of fruit per year, while a regular orchard can produce 15-17 tons per hectare.

2.2.ORIGINS AND CULTIVATION OF TAMARILLO

Tamarillo has a rich history rooted in South and Central American cultures. Indigenous peoples of these regions have long utilized the fruit for its nutritional properties and medicinal benefits. Tracing the historical cultivation and consumption of tamarillo provides insights into its cultural significance and traditional uses.

2.3.CULTIVATION PRACTICES

The cultivation of tamarillo involves specific agricultural practices tailored to its tropical origins. From soil requirements to climate considerations, understanding the optimal conditions for tamarillo cultivation is essential for maximizing yield and quality. Additionally, exploring modern cultivation techniques and challenges faced by tamarillo growers sheds light on the fruit's commercial production.

2.4.MACRO-NUTRIENT COMPOSITION OF TAMARILLO

2.4.1.Carbohydrates

Tamarillo is predominantly composed of carbohydrates, with simple sugars such as glucose and fructose being the primary constituents. Analyzing the carbohydrate profile of tamarillo elucidates its role as a source of energy and its implications for blood sugar regulation.

2.4.2.Proteins

While tamarillo is not a significant source of protein, it still contains essential amino acids necessary for various physiological functions. Examining the amino acid composition of tamarillo provides insights into its nutritional value and potential contributions to dietary protein intake.

2.4.3.Fats

Tamarillo contains minimal amounts of fat, primarily in the form of healthy unsaturated fats such as omega-3 and omega-6 fatty acids. Investigating the lipid profile of tamarillo highlights its role in promoting heart health and overall well-being.

2.4.4.Fiber

One of the standout features of tamarillo is its high fiber content, which includes both soluble and insoluble fiber. Exploring the fiber content and composition of tamarillo underscores its importance for digestive health, satiety, and blood cholesterol management.

2.5.NUTRITIONAL VALUE OF TAMARILLO

2.5.1.Vitamins

Tamarillo is rich in various vitamins, particularly vitamin C and vitamin A. Analyzing the vitamin content of tamarillo reveals its antioxidant properties and potential benefits for immune function, skin health, and vision.

2.5.2.Minerals

In addition to vitamins, tamarillo contains essential minerals such as potassium, magnesium, phosphorus, and calcium. Investigating the mineral composition of tamarillo elucidates its role in supporting electrolyte balance, bone health, and muscle function.

2.6.HEALTH BENEFITS OF TAMARILLO

The antioxidant properties of tamarillo play a crucial role in protecting against oxidative stress and inflammation. Exploring the mechanisms of antioxidant action in tamarillo provides insights into its potential role in preventing chronic diseases such as cancer, cardiovascular disease, and neurodegenerative disorders.

2.6.1.Heart Health

Tamarillo's fiber, potassium, and antioxidant content contribute to its cardiovascular benefits. Examining the impact of tamarillo consumption on cholesterol levels, blood pressure regulation, and arterial health sheds light on its role in promoting heart health and reducing the risk of cardiovascular disease.

2.6.2.Digestive Health

The high fiber content of tamarillo makes it particularly beneficial for digestive health. Investigating the effects of tamarillo fiber on bowel regularity, gut microbiota

composition, and digestive disorders provides a comprehensive understanding of its digestive health benefits.

2.6.3. Weight Management

Tamarillo's fiber content and low-calorie density make it a valuable addition to weight management diets. Exploring the satiety-promoting effects of tamarillo fiber and its potential role in reducing calorie intake and promoting weight loss offers insights into its practical applications for individuals seeking to manage their weight.

2.6.4. Immune Support

The vitamin C content of tamarillo plays a crucial role in supporting immune function. Investigating the mechanisms of vitamin C action in tamarillo and its potential benefits for immune response modulation provides a scientific basis for its traditional use as an immune-boosting fruit.

2.7. CULINARY VERSATILITY OF TAMARILLO

2.7.1. Traditional Uses

Tamarillo is a versatile ingredient in various culinary traditions, from savory dishes to sweet treats. Exploring traditional recipes and cooking methods involving tamarillo offers insights into its cultural significance and culinary applications.

2.7.2. Modern Culinary Trends

In addition to traditional uses, tamarillo is gaining popularity in modern cuisine, particularly in gourmet cooking and health-conscious recipes. Investigating innovative tamarillo recipes and culinary trends highlights its potential for culinary creativity and culinary tourism.

2.7.3. Nutritional Considerations in Cooking

Understanding the impact of cooking methods on the nutritional composition of tamarillo is essential for maximizing its health benefits. Exploring the effects of cooking, processing, and storage on tamarillo nutrients offers practical guidance for preserving its nutritional value in culinary applications.

Secondary metabolites are organic compounds produced by plants that are not directly involved in their growth, development, or reproduction. Instead, these

compounds often serve various ecological functions, such as defense against herbivores, attraction of pollinators, and resistance to pathogens. Secondary metabolites found in tamarillo encompass a diverse array of chemical classes, including alkaloids, flavonoids, phenolic compounds, terpenoids, and glycoalkaloids. Each class of secondary metabolites in tamarillo contributes to its unique flavor, aroma, color, and potential bioactivity.

Alkaloids are nitrogen-containing compounds known for their diverse pharmacological properties. In tamarillo, alkaloids such as solanidine and tomatidine have been identified. These alkaloids exhibit cytotoxic effects against cancer cells and may also possess anti-inflammatory and antioxidant properties. However, their concentrations in tamarillo are relatively low compared to other alkaloid-rich plants within the Solanaceae family.

Flavonoids are a class of polyphenolic compounds that contribute to the pigmentation of fruits and flowers. Tamarillo contains various flavonoids, including quercetin, kaempferol, and rutin. These flavonoids possess antioxidant activity, which helps protect cells from oxidative damage caused by free radicals. Additionally, they exhibit anti-inflammatory, antimicrobial, and cardiovascular protective effects, making them beneficial for human health.

Phenolic compounds are another group of antioxidants present in tamarillo. These include phenolic acids such as chlorogenic acid and caffeic acid, as well as other polyphenols like resveratrol. Phenolic compounds contribute to the fruit's bitterness and astringency while offering potential health benefits such as reducing the risk of chronic diseases like cancer, diabetes, and cardiovascular disorders.

Terpenoids are a diverse class of compounds synthesized from isoprene units and are abundant in plants. Tamarillo contains terpenoids such as β -carotene, lycopene, and phytosterols. β -carotene is a precursor of vitamin A and is essential for vision, immune function, and skin health. Lycopene is a red pigment with potent antioxidant properties, known for its potential role in reducing the risk of prostate cancer and cardiovascular disease. Phytosterols, structurally similar to cholesterol, help lower blood cholesterol levels and may reduce the risk of heart disease.

Glycoalkaloids are nitrogen-containing compounds found predominantly in the Solanaceae family, known for their bitter taste and potential toxicity. Tamarillo contains

glycoalkaloids such as solanine and tomatine, albeit in lower concentrations compared to other Solanaceae species like potatoes and tomatoes. These compounds serve as natural defenses against pests and pathogens but may pose health risks if consumed in large amounts.

In addition to their potential health benefits, secondary metabolites from tamarillo have attracted interest for their industrial applications. For example, the pigments derived from tamarillo, such as lycopene and β -carotene, are used as natural colorants in food and cosmetic products. The antioxidant properties of tamarillo extracts make them valuable ingredients in dietary supplements and functional foods aimed at promoting health and wellness.

The extraction and purification of secondary metabolites from tamarillo involve various techniques such as solvent extraction, chromatography, and spectroscopy. These methods allow researchers to isolate specific compounds of interest and evaluate their bioactivity and potential applications. Furthermore, advances in biotechnology offer opportunities to enhance the production of desired secondary metabolites through genetic engineering and metabolic engineering of tamarillo plants or microbial systems.

However, despite the promising health benefits and industrial potential of tamarillo secondary metabolites, further research is needed to fully understand their mechanisms of action, safety profiles, and potential interactions with other compounds. Additionally, efforts to optimize extraction methods, scale up production, and ensure sustainable sourcing of tamarillo resources are essential for maximizing the commercial viability and societal impact of these valuable natural compounds.

Recent scientific research has unveiled the diverse array of bioactive compounds present in tree tomatoes, which contribute to their potential health benefits. These bioactive compounds, collectively known as secondary metabolites, include alkaloids, flavonoids, phenolic compounds, terpenoids, and glycoalkaloids. Accumulating evidence suggests that tree tomato possesses antioxidant, anti-inflammatory, antimicrobial, anticancer, cardioprotective, and neuroprotective properties, making it a promising candidate for various therapeutic applications.

This review aims to provide a comprehensive overview of the bioactivity of tree tomatoes, focusing on their phytochemical composition, biological activities,

mechanisms of action, and potential therapeutic applications. Furthermore, it discusses the challenges and opportunities for further research and the development of tree tomato-derived products for nutraceutical, pharmaceutical, and cosmeceutical purposes.

2.8.PHYTOCHEMICAL COMPOSITION OF TREE TOMATO

Alkaloids are nitrogen-containing compounds known for their diverse pharmacological properties. Tree tomatoes contain several alkaloids, including solanidine and tomatidine. These alkaloids exhibit cytotoxic effects against cancer cells and may also possess anti-inflammatory and antioxidant properties (Mhlongo *et al.*, 2018) .

Flavonoids are polyphenolic compounds known for their antioxidant and anti-inflammatory properties. Tree tomatoes contain various flavonoids, including quercetin, kaempferol, and rutin. These flavonoids contribute to the fruit's color and offer potential health benefits such as reducing the risk of chronic diseases like cancer and cardiovascular disorders (Yahia *et al.*, 2018).

Phenolic compounds are antioxidants found in abundance in tree tomatoes. These include phenolic acids such as chlorogenic acid and caffeic acid, as well as other polyphenols like resveratrol. Phenolic compounds contribute to the fruit's bitterness and offer potential health benefits such as reducing oxidative stress and inflammation (Fuentes *et al.*, 2015).

Terpenoids are a diverse class of compounds synthesized from isoprene units. Tree tomatoes contain terpenoids such as β -carotene, lycopene, and phytosterols. These compounds exhibit antioxidant properties and may contribute to the fruit's color and flavor. Additionally, they offer potential health benefits such as reducing the risk of cancer and cardiovascular diseases (Castro *et al.*, 2016).

Glycoalkaloids are nitrogen-containing compounds found predominantly in the Solanaceae family. Tree tomatoes contain glycoalkaloids such as solanine and tomatine, albeit in lower concentrations compared to other Solanaceae species like potatoes and tomatoes. These compounds serve as natural defenses against pests and pathogens (Jiménez *et al.*, 2019)

2.9.BIOLOGICAL ACTIVITIES OF TREE TOMATO

2.9.1.Ant-ioxidant activity

Tree tomato exhibits significant antioxidant activity attributed to its high content of flavonoids, phenolic compounds, and carotenoids. Antioxidants scavenge free radicals and prevent oxidative damage to cells, thereby reducing the risk of chronic diseases such as cancer, cardiovascular disorders, and neurodegenerative diseases

2.9.2.Anti-inflammatory Activity

Several studies have demonstrated the anti-inflammatory properties of tree tomato extracts. Flavonoids and phenolic compounds present in tree tomatoes inhibit pro-inflammatory cytokines and enzymes, thereby alleviating inflammation and associated symptoms. These anti-inflammatory effects make tree tomatoes potentially beneficial for conditions such as arthritis and inflammatory bowel diseases (Rodríguez *et al.*, 2011)

2.9.3.Antimicrobial Activity

Tree tomato extracts possess antimicrobial properties against a wide range of pathogenic microorganisms, including bacteria, fungi, and viruses. These antimicrobial effects are attributed to the presence of bioactive compounds such as alkaloids, flavonoids, and phenolic compounds. Tree tomato extracts have shown inhibitory activity against foodborne pathogens and antibiotic-resistant bacteria, highlighting their potential as natural antimicrobial agents (Quispe, C., *et al.* , 2017)

2.9.4.Anticancer Activity

Several studies have investigated the potential anticancer effects of tree tomato extracts against various cancer cell lines. The cytotoxic effects of tree tomato extracts are attributed to their alkaloids, flavonoids, and phenolic compounds, which induce apoptosis (programmed cell death) and inhibit the proliferation of cancer cells. Additionally, tree tomato extracts exhibit anti-angiogenic properties, suppressing the formation of new blood vessels that supply nutrients to tumors .

2.9.5.Cardioprotective Activity

Tree tomato extracts have shown promising cardioprotective effects in preclinical studies. Flavonoids and phenolic compounds present in tree tomatoes exert antioxidant and anti-inflammatory effects, which help prevent cardiovascular diseases

such as atherosclerosis, hypertension, and myocardial infarction. Additionally, tree tomato extracts improve lipid metabolism and endothelial function, contributing to their cardioprotective properties (Hurtado *et al.*, 2014)

2.9.6.Neuroprotective Activity

Emerging evidence suggests that tree tomato extracts possess neuroprotective properties, potentially beneficial for neurological disorders such as Alzheimer's disease and Parkinson's disease. Flavonoids and phenolic compounds present in tree tomatoes exhibit antioxidant and anti-inflammatory effects, which protect neurons from oxidative stress and neuroinflammation. Additionally, tree tomato extracts enhance cognitive function and promote neurogenesis (the formation of new neurons) in preclinical models (Barrera *et al.*, 2016)

2.9.7.Mechanisms of Action

The bioactive compounds present in tree tomatoes exert their therapeutic effects through various mechanisms of action:

Antioxidant compounds scavenge free radicals and inhibit oxidative stress, thereby protecting cells from damage and reducing the risk of chronic diseases.

Anti-inflammatory compounds suppress the production of pro-inflammatory cytokines and enzymes, alleviating inflammation and associated symptoms.

Antimicrobial compounds inhibit the growth and proliferation of pathogenic microorganisms, preventing infections and promoting health.

Anticancer compounds induce apoptosis (programmed cell death) and inhibit the proliferation of cancer cells, thereby suppressing tumor growth and metastasis.

Cardioprotective compounds improve lipid metabolism, endothelial function, and antioxidant defenses, reducing the risk of cardiovascular diseases.

Neuroprotective compounds protect neurons from oxidative stress and neuroinflammation, enhancing cognitive function and promoting neurogenesis.

Given its diverse biological activities, tree tomato holds promise for various therapeutic applications. Some potential uses of tree tomato-derived products include:

Nutraceuticals: Tree tomato extracts can be formulated into dietary supplements or functional foods with antioxidant, anti-inflammatory, and cardioprotective properties. These products may help promote overall health and prevent chronic diseases.

Pharmaceuticals: Bioactive compounds isolated from tree tomatoes can serve as lead compounds for the development of novel pharmaceutical drugs. For example, anticancer compounds may be formulated into chemotherapy drugs, while neuroprotective compounds may be used for the treatment of neurological disorders.

Cosmeceuticals: Tree tomato extracts can be incorporated into skincare products and cosmetics for their antioxidant and anti-aging properties. These products may help reduce oxidative damage to the skin, improve complexion, and prevent premature aging.

Functional Ingredients: Tree tomato extracts can be used as functional ingredients in various food and beverage products to enhance their nutritional value and health benefits. For example, tree tomato juice may be fortified with antioxidants to boost immune function and protect against oxidative stress.

2.10. CHALLENGES AND OPPORTUNITIES

Despite the promising therapeutic potential of tree tomato, several challenges need to be addressed for its widespread utilization:

Standardization: There is a need for standardized extraction and purification methods to ensure consistent quality and bioactivity of tree tomato-derived products.

Safety: The safety profile of tree tomato extracts needs to be thoroughly evaluated, especially regarding potential toxicity and adverse effects.

Bioavailability: The bioavailability of bioactive compounds in tree tomato extracts needs to be optimized to ensure their efficacy in vivo.

Sustainability: Sustainable cultivation practices need to be implemented to ensure the long-term availability of tree tomato resources without harming the environment.

Regulatory Considerations: Regulatory approval and compliance with safety and quality standards are essential for the commercialization of tree tomato-derived products.

Despite these challenges, there are also significant opportunities for further research and development:

Exploring Synergistic Effects: Studying the synergistic interactions among different bioactive compounds in tree tomatoes may lead to the development of more potent and effective therapeutic formulations.

Clinical Trials: Conducting well-designed clinical trials to evaluate the efficacy and safety of tree tomato-derived products in humans is essential for their validation and acceptance in mainstream healthcare.

Personalized Medicine: Tailoring tree tomato-based therapies to individual genetic and metabolic profiles may enhance their efficacy and minimize adverse effects.

Biotechnological Approaches: Harnessing biotechnological tools such as genetic engineering and metabolic engineering may allow for the production of tree tomato varieties with enhanced bioactivity and nutritional value.

Value-Added Products: Exploring innovative applications of tree tomato extracts in sectors such as pharmaceuticals, cosmetics, and nutraceuticals can create new market opportunities and economic benefits.

2.11.ANTI-CANCER ACTIVITY

Research on the potential anticancer activity of tree tomatoes (*Solanum betaceum*) is still ongoing and relatively limited compared to other fruits and vegetables. However, preliminary studies suggest that tree tomatoes contain bioactive compounds such as antioxidants, polyphenols, carotenoids, and flavonoids, which are known for their potential anticancer properties.

Antioxidants play a crucial role in neutralizing free radicals and reducing oxidative stress, which is linked to the development of cancer. Carotenoids, such as lycopene and beta-carotene found in tree tomatoes, have been studied for their ability to inhibit the growth of cancer cells and reduce the risk of certain types of cancer, including prostate and breast cancer.

Additionally, flavonoids present in tree tomatoes have been associated with anti-inflammatory and anticancer effects. Some studies have suggested that flavonoids

may help inhibit the growth of cancer cells, induce apoptosis (programmed cell death), and prevent the formation of blood vessels that supply tumors with nutrients.

While these preliminary findings are promising, more extensive research, including in vitro and in vivo studies and clinical trials, is needed to fully understand the anticancer potential of tree tomatoes and their bioactive components. Furthermore, it's essential to consider tree tomato consumption as part of a balanced diet and a healthy lifestyle, rather than a standalone cancer treatment. Always consult with a healthcare professional for personalized medical advice and treatment options.

CHAPTER 3

AIM AND SCOPE OF THE PRESENT INVESTIGATION

The research aims to explore the phytochemical composition of tree tomatoes (*Solanum betaceum*) and their potential anti-cancer activity, with a focus on implications for food formulation. Tree tomato, a tropical fruit belonging to the Solanaceae family, is rich in bioactive compounds such as antioxidants, polyphenols, carotenoids, and flavonoids. These compounds have been studied for their potential health benefits, including anti-inflammatory, antioxidant, and anti-cancer properties. Antioxidants like vitamin C and E help neutralize free radicals and reduce oxidative stress implicated in cancer development, while carotenoids such as lycopene and beta-carotene are associated with a reduced risk of prostate and breast cancer. Flavonoids such as quercetin and kaempferol exhibit anti-inflammatory and anti-cancer effects through mechanisms like inhibiting cancer cell proliferation and inducing apoptosis.

Tree tomato (*Solanum betaceum*) is a tropical fruit rich in bioactive compounds.

Bioactive compounds include antioxidants, polyphenols, carotenoids, and flavonoids.

Antioxidants like vitamins C and E help neutralize free radicals and reduce oxidative stress implicated in cancer development.

Carotenoids such as lycopene and beta-carotene are associated with a reduced risk of prostate and breast cancer.

Flavonoids such as quercetin and kaempferol exhibit anti-inflammatory and anti-cancer effects through mechanisms like inhibiting cancer cell proliferation and inducing apoptosis.

The research aims to explore the anti-cancer potential of tree tomatoes and their implications for food formulation.

CHAPTER 4

METHODOLOGY

4.1 PREPARATION OF TAMARILLO JAM

4.1.1 *INGREDIENTS USED:*

Tamarillo, palm sugar.

4.1.2 *PRE- PREPARATION METHOD:*

- Cut the tips of the tree tomatoes
- Slit at the bottom and blanch for 3-4 minutes
- Grind the tree tomatoes and de-seed the puree with strainer.
- Now tree tomato puree is ready

4.1.3 *PREPARATION:*

- Add palm sugar in a pan and allow it to melt, then add the puree to it.
- Bring to a boil over medium heat, stirring often.
- Reduce heat and simmer, stirring occasionally, until mixture has consistency of thick paste. Then cool to room temperature

4.1.4 *Formulation 1:*

Our 1st try was done with tamarillo puree and white sugar as. It was with seeds. It has a crunchy texture, the seed was hard to chew.

Materials used	Formulation 1
Tree tomato	200g
sugar	170g

Table no. 1 – formulation 1

4.1.5 *Formulation 2:*

Our 2nd try was with tamarillo puree and white sugar but de-seeded this time to improve the texture of the jam.

Materials used	Formulation 2
Tree tomato	250g
sugar	190g

Table no. 2 – formulation 2

4.1.6 Formulation 3:

Third formulation was done by substituting white sugar with jagerry with equal amount of tamarillo puree.

Materials used	Formulation 2
Tree tomato	250g
jagerry	250g

Table no. 3 – formulation 3

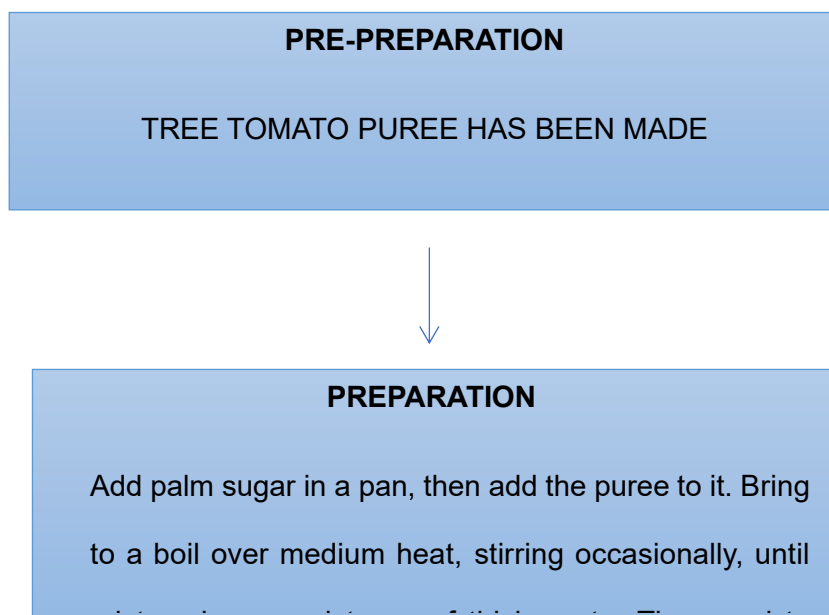
4.1.7 Formulation 4:

Fourth formulation was done by using palm sugar with equal amount of tamarillo puree.

Materials used	Formulation 2
Tree tomato	250g
Palm sugar	250g

Table no. 4 – formulation 4

4.1.8 FLOW CHART OF JAM PREPARATION



4.2 THIN LAYER CHROMATOGRAPHY (TLC):

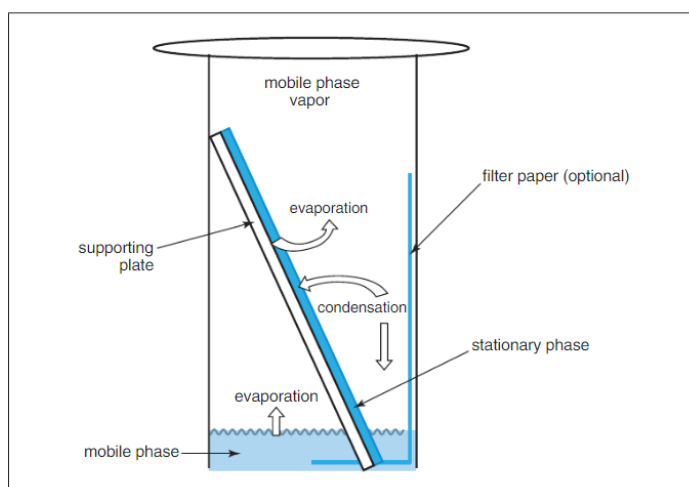


Fig no. 3 - Tlc set up

Thin layer chromatography (TLC) is a chromatography technique used to separate non-volatile mixtures. It involves a stationary phase (usually a thin layer of silica gel or alumina) and a mobile phase (a solvent mixture). The sample is spotted near the

bottom of the plate and placed in a developing chamber with the mobile phase. As the mobile phase moves up the plate by capillary action, components of the mixture separate based on their affinity for the stationary phase and mobile phase. Polar absorbents can be used as the stationary phase in Thin Layer Chromatography (TLC), a solid-liquid chromatography technique, whereas a single solvent or a combination of solvents can be used as the mobile phase.



Fig no. 4 - Process of TLC

SOLVENT MOBILE PHASE:

PHASE -1: Ethyle acetate and methanol

PHASE-2: hexane and ethyl acetate and acetic acid

PHASE-3: hexane and ethyle acetate and acetic acid.

PHASE-4: chloroform and methanol and hexane

Solute used was methanol tree tomato extract.

4.3 GAS CHROMATOGRAPHY/MASS SPECTROMETRY:

Gas Chromatography-Mass Spectrometry, or GCMS for short, is a potent analytical method for separating, identifying, and quantifying constituents in a mixture. It blends the detection and identification powers of mass spectrometry with the separation capabilities of gas chromatography. This method is frequently applied in many different disciplines, including forensics, environmental analysis, medicines, and food and beverage testing.

GC-MS analysis of the whole plant extract of *Evolvulus alsinoides* was performed using the equipment Thermo GC-Trace Ultra Version: 5.0, Thermo MS DSQ II. The equipment has a DB 35 – MS Capillary Standard non-polar column with dimensions of 30 mm × 0.25 mm ID × 0.25 µm film. The carrier gas used is Helium with a flow of 1.0 ml/min. The injector was operated at 250 °C and the oven temperature was programmed as follows: 60 °C for 15 min, then gradually increased to 280 °C at 3 min.

4.4 DNA FRAGMENTATION:

DNA fragmentation research has become pivotal in various fields, including genetics, forensics, and medical diagnostics. This phenomenon, characterized by the breakdown of DNA molecules into smaller fragments, offers insights into cellular processes, disease mechanisms, and evolutionary patterns. Understanding DNA fragmentation has profound implications, from unraveling the intricacies of apoptosis to developing novel diagnostic tools for cancer detection. For instance, studies by Kumar et al. (2018) have elucidated the role of DNA fragmentation in cancer progression, shedding light on potential therapeutic targets. This introduction sets the stage for further exploration into the multifaceted realm of DNA fragmentation and its far-reaching implications.

DNA FRAGMENTATION: (Wyllie, 1980)

Procedure:

- Colo 320 cells were plated in 6 well plate and kept in CO₂ incubator to attain confluency.
- 1ml of Sample was added in to the well (IC₅₀ concentration) and incubated for 24 hrs. After this, cells were harvested using TPVG

- Centrifuge cells at 200xg at 4°C for 10 min.
- Add to the pellet 0.5 ml of TTE Solution and Vortex Vigorously. This procedure allows the release of fragmented chromatin from nuclei, after cell lysis (due to the presence of Triton X- 100 in the TTE solution) and disruption of the nuclear structure (following Mg ++ chelation by EDTA in the TTE Solution).
- To separate fragmented DNA from intact chromatin, centrifuge tubes at 20,000xg for 10 min at 4°C.
- Carefully remove the supernatants and add 500µl of TTE solution into the pellet.
- Add 500µl of Ice-cold NaCl and vortex vigorously. The addition of the Salt should be able to remove histones from DNA.
- Add 700µl of ice-cold isopropanol and vortex vigorously.
- Allow precipitation to proceed overnight at -20°C.
- After, precipitation, recover DNA by pelleting for 10 min at 20,000x g at 4°C.
- Rinse the pellets by adding 500-700µl of ice-cold 70% ethanol.
- Centrifuge tubes at 20,000x g for 10 min at 4°C.
- Dissolve DNA by adding to each tube 20-50 µl of TE buffer and place the tubes at 4°C.
- Mix the samples of DNA with loading buffer .The addition of loading buffer to samples allows to load in wells more easily and to monitor the run of samples.
- Run the electrophoresis in standard TE buffer after setting the voltage to the desired level. During electrophoresis it is possible to monitor the migration of samples by following the migration of bromophenol blue dye contained in the loading dye.
- Stop the electrophoresis when the dye reaches about 3 cm from the end of the gel.
- To visualize DNA, place the gel on a UV Trans illuminator.

4.5 Quantification of Total phenolic content

The Folin-Ciocalteu reagent method (Mc Donald et al., 2001) was used to determine total phenol. After mixing 0.1 ml of Folin-Ciocalteu reagent (1N) with a 100 µl plant extract sample, it was incubated at room temperature. After adding 5 ml of Na₂CO₃,

the mixture was allowed to sit at room temperature for 30 minutes. Using a UV-VIS spectrophotometer (Biospectrometer, Eppendorf, Germany) set to 760 nm, the total phenolic content was calculated. The unit of measurement for total phenol was gallic acid equivalent (mg/g of the extracted component), with gallic acid serving as the standard.



Fig no. 5 sample placed at 96 well plate for reading

4.6 Anti cancer activity

Cell line and culture:

MCF 7 Cell line was obtained from National Centre for Cell Sciences, Pune (NCCS). The cells were maintained in DMEM supplemented with 10% FBS, penicillin (100 U/ml), and streptomycin (100 µg/ml) in a humidified atmosphere of 5% CO₂ at 37 °C.

***In Vitro* assay for anti cancer activity: (MTT assay) (Mosmann, 1983)**

Cells (1×10^5 /well) were plated in 24-well plates and incubated in 37°C with 5% CO₂ condition. After the cell reaches the confluence, the various concentrations of the samples were added and incubated for 24hrs. After incubation, the sample was removed from the well and washed with phosphate-buffered saline (pH 7.4) or DMEM without serum. 100µl/well (5mg/ml) of 0.5% 3-(4, 5-dimethyl-2-thiazolyl)-2,5-diphenyl-tetrazolium bromide (MTT) was added and incubated for 4 hours. After incubation,

1ml of DMSO was added in all the wells .The absorbance at 570nm was measured with UV- Spectrophotometer using DMSO as the blank. Measurements were performed and the concentration required for a 50% inhibition (IC₅₀) was determined graphically. The % cell viability was calculated using the following formula:

$$\% \text{ Cell viability} = \text{A570 of treated cells} / \text{A570 of control cells} \times 100$$

Graphs are plotted using the % of Cell Viability at Y-axis and concentration of the sample in X-axis. Cell control and sample control is included in each assay to compare the full cell viability assessments.

4.7 QUALITY ANALYSIS

This done by the review of 100 consumers having our product tamarillo jam by sensory evaluation. The data has been taken as appearance, texture, flavour, aroma, mouthfeel. This tells the experience of customers after having our product.

CATEGORY	MEAN±STANDARD DEVIATION
APPEARANCE	9.44±0.987
TEXTURE	9.73±0.446
FLAVOUR	9.56±0.977
AROMA	9.62±0.8012
MOUTH FEEL	9.65±0.914
OVER ALL ACCEPTABILITY	9.57±0.923

Table No. 5 – Sensory Evaluation

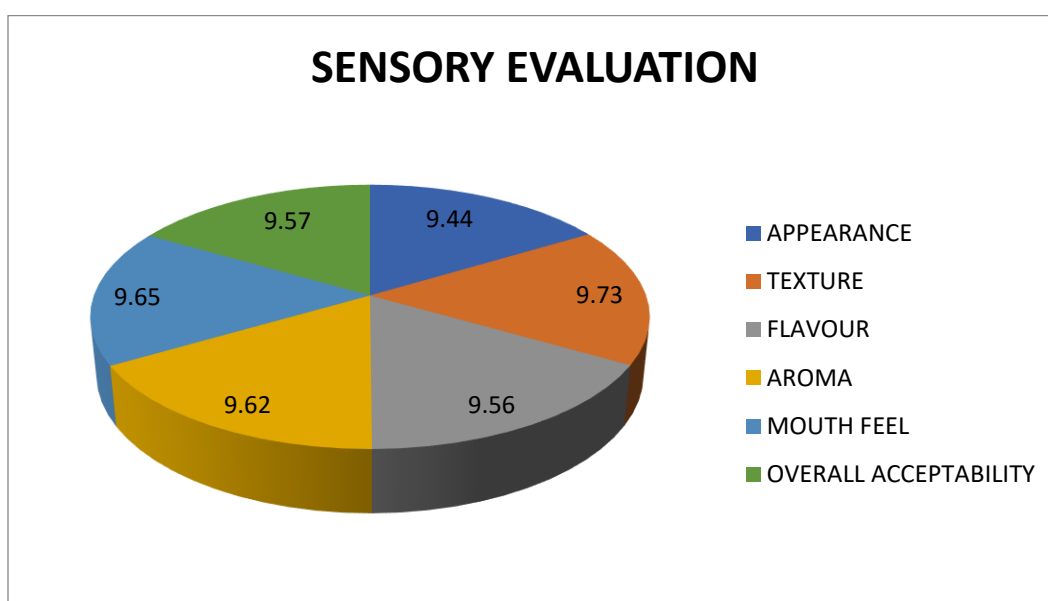


Fig no. 6 – sensory evaluation

1. INTERPRETATION : The above pie chart tells about the sensory evaluation results given by 100 consumers.

QUESTIONNAIRE :

1. Appearance :

Rating range (1-10)	No. of responses
Below 10	28
10	72

Table No. 6 – Appearance

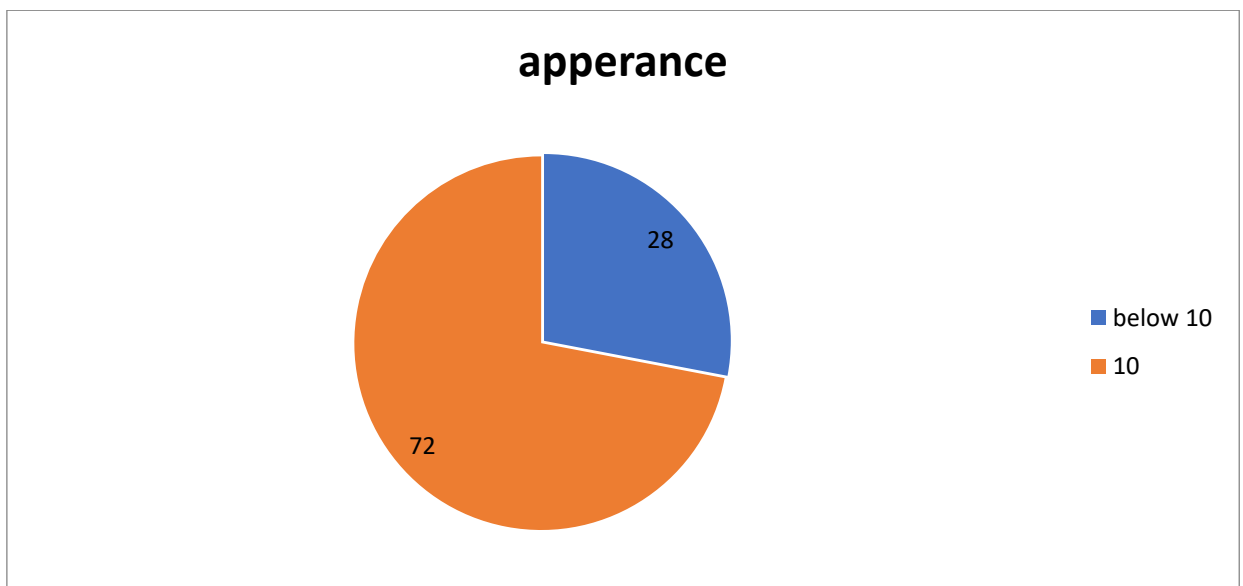


Fig no. 7 - Appearance

Intrepratation:

72 people are fully satisfied with our product and 28 members have responses below 10.

2. Texture :

Rating range (1-10)	No. of responses
Below 10	22
10	78

Table no. 7 - Texture

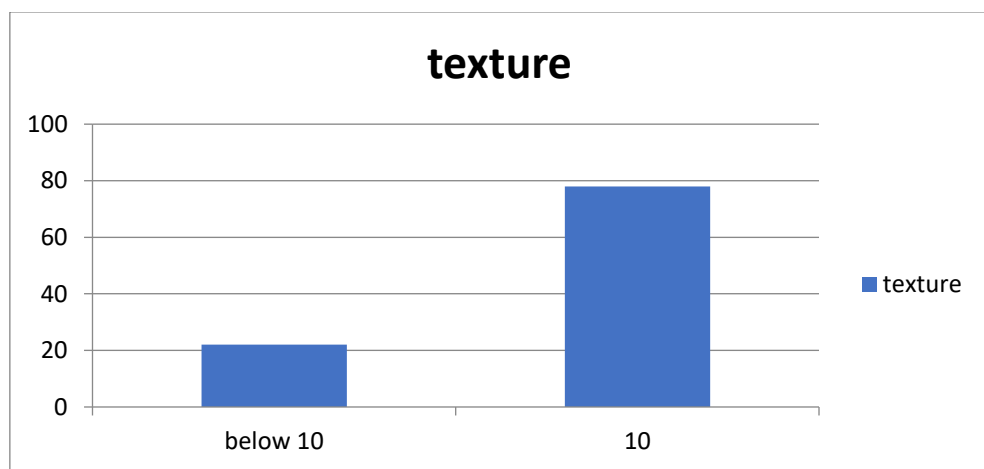


Fig no. 8 - Texture

Intrepratation:

78 people are fully satisfied with our product and 22 members have responses below 10.

3. Flavour

Rating range (1-10)	No. of responses
Below 10	19
10	81

Table no. 8 – flavour

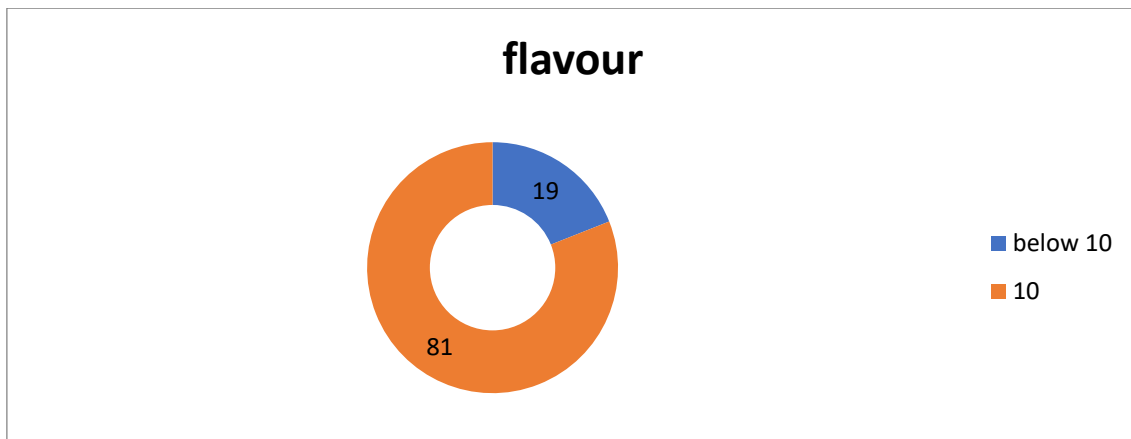


Fig no. 9 - Flavour

Intrepratation:

81 people are fully satisfied with our product and 19 members have responses below 10.

4. Aroma

Rating range (1-10)	No. of responses
Below 10	26
10	74

Table no. 9 - Aroma

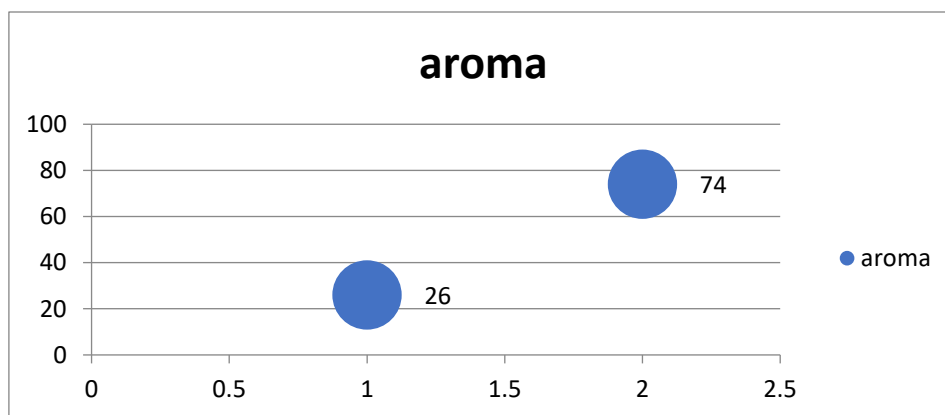


Fig no. 10 - Aroma

Intrepretation:

74 people are fully satisfied with our product and 26 members have responses below 10.

5. Mouth feel:

Rating range (1-10)	No. of responses
Below 10	18
10	82

Table no. 10 - Mouth feel

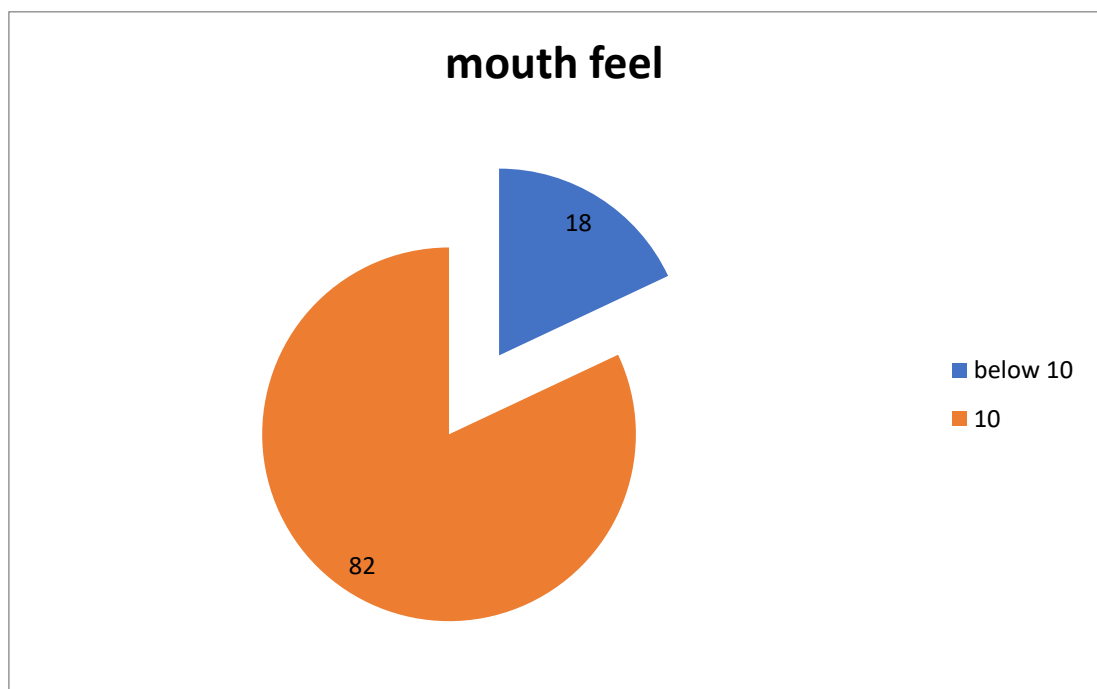


Fig No. 11 – Mouth Feel

Intrepretation:

82 people are fully satisfied with our product and 18 members have responses below 10

6. Overall acceptability:

Rating range (1-10)	No. of responses
Below 10	25
10	75

Table no. 11 - Overall acceptability

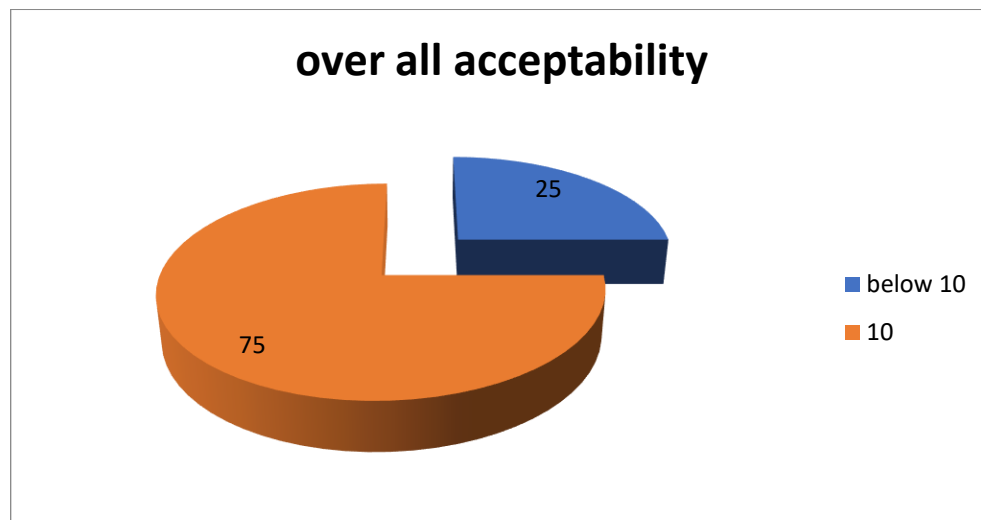


Fig No. 12 – Overall Acceptability

Intrepratation:

75 people are fully satisfied with our product and 25 members have responses below 10.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 SEPERATION OF COMPONENTS IN THIN LAYER CHROMATOGRAPHY



Fig No. 13 – VIEW OF SEPERATED PHYTOCHEMICAL PIGMENTS

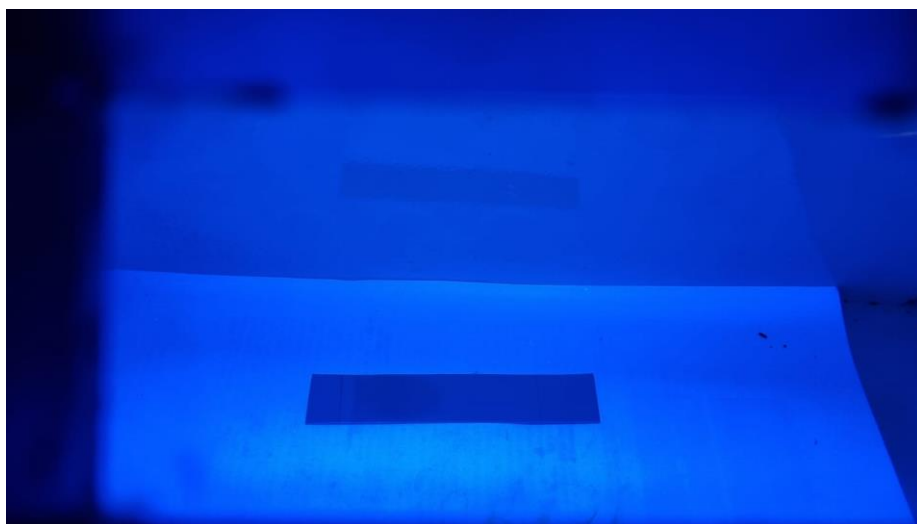


FIG NO. 14 - TLC VIEWED UNDER UV LIGHT

The presence of phytochemical as not been determined since the pigments separated are very light and colours are not properly visible.

5.2 GAS CHROMATOGRAPHY/MASS SPECTROMETRY

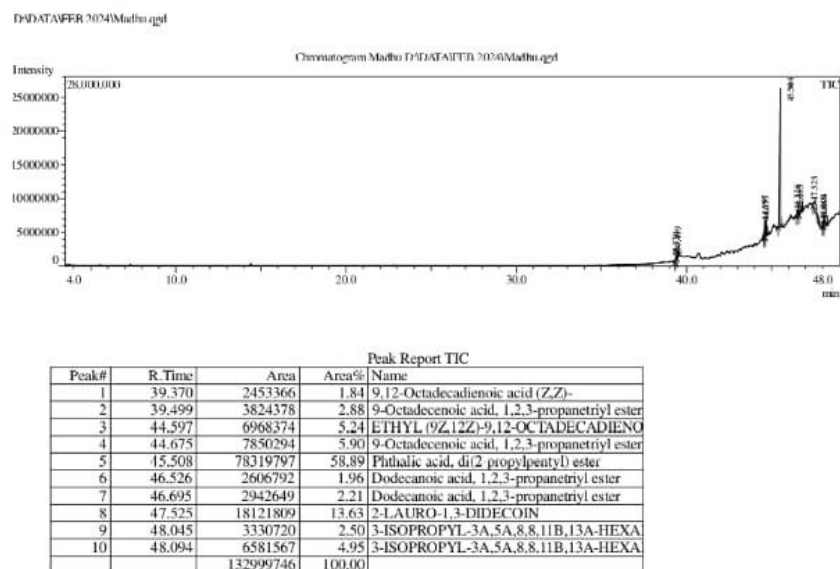
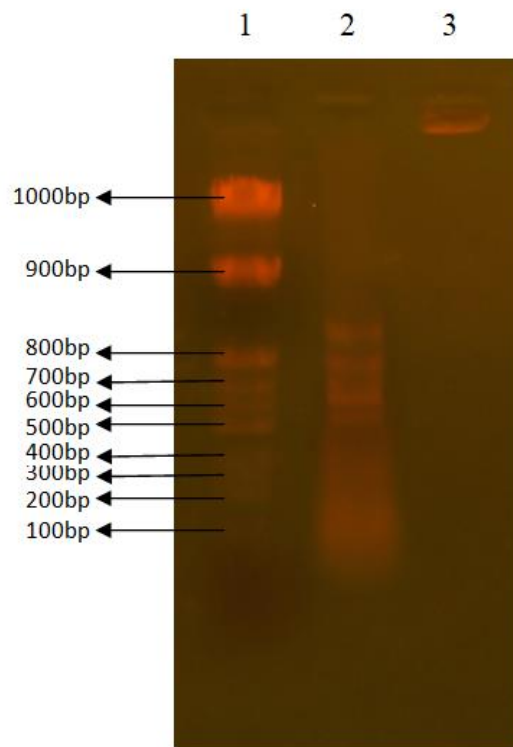


Fig No.15-Gc/Ms

5.3 DNA FRAGMENTATION

RESULT:

DNA fragmentation of MET sample in MCF7 cells



Lane 1: Marker
Lane 2: MET Sample
Lane 3: Control

Fig No. 16 – Fragmented Dna

Interpretation: The control DNA is diffused and no clear fragments were seen. The sample DNA shows fragments

5.4 ANTI CANCER ACTIVITY

Anticancer effect of Sample MET on MCF-7 cell line

S.No	Concentration (µg/ml)	Absorbance (O.D)	Cell viability (%)
1	1000	0.272	28.07
2	500	0.354	36.53
3	250	0.436	44.99
4	125	0.511	52.73
5	62.5	0.582	60.06
6	31.2	0.667	68.83
7	15.6	0.738	76.16
8	7.8	0.817	84.31
9	Cell control	0.969	100

Table No. 12 – Anti Cancer Concentrations

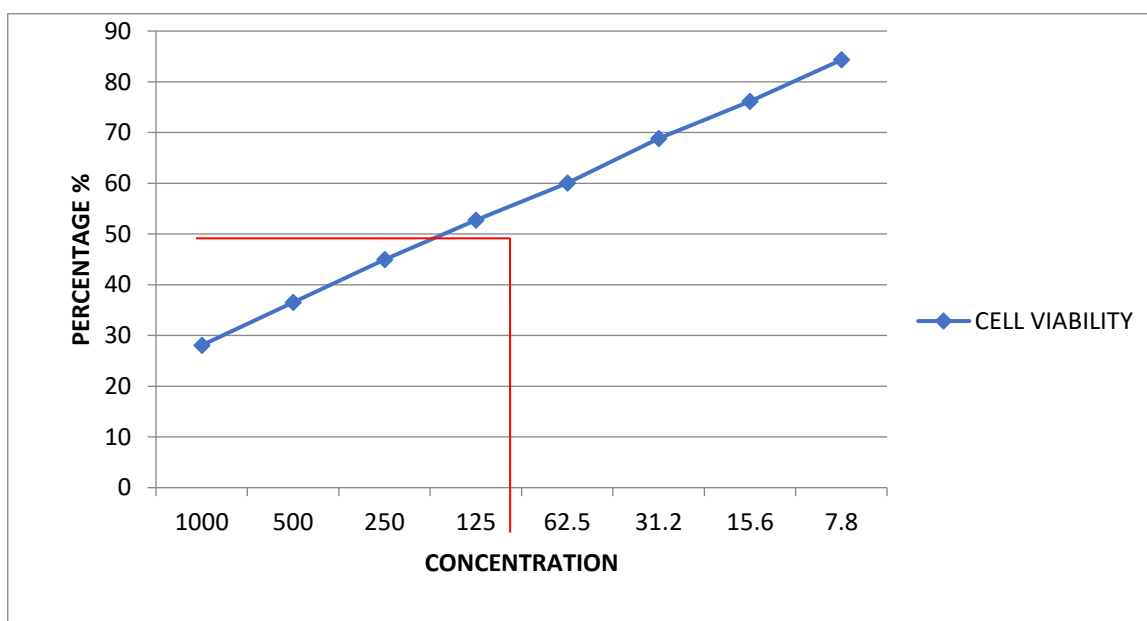


Fig No. 17 – Anti Cancer Graph

5.5 MCF 7 cells

Sample MET

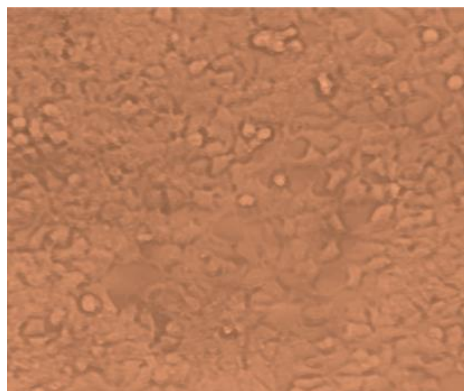


Fig No. 18 – MCF 7 Cells

125 $\mu\text{g/ml}$

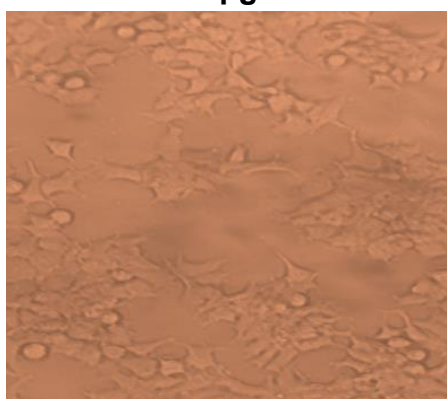
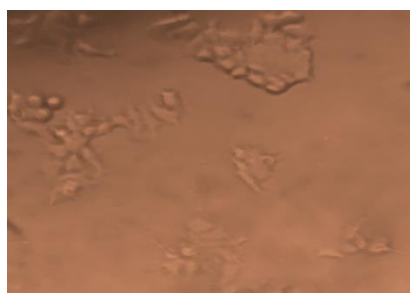
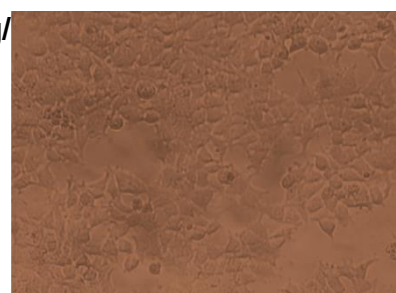


Fig No. 19 – MCF 7 Cells



7.8 $\mu\text{g/ml}$

1000 $\mu\text{g/ml}$



5.5 TOTAL PHENOLIC CONTENT

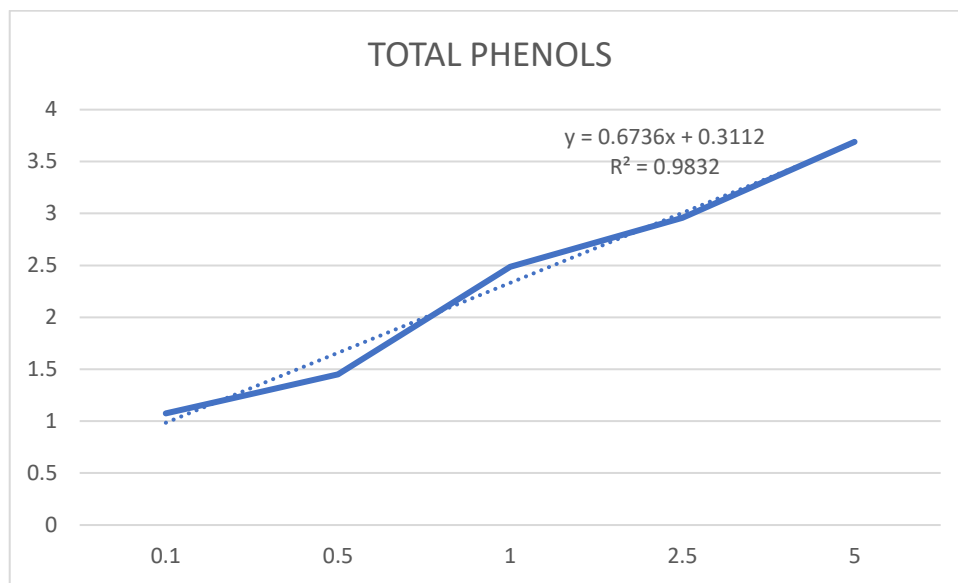


Fig No. 22 Phenolic Component Graph

$$Y = 0.6736x + 0.3112$$

$$0.084 = 0.6736x + 0.3112$$

$$= 0.6736x + 0.3112 - 0.084$$

$$X = \frac{0.2272}{0.6736}$$

$$= 0.337 \text{ MG/G}$$

5.6 NUTRITIVE ANALYSIS OF TAMARILLO JAM

Test Results:

The above sample tested as received, and results are as follows:

S. NO	PARAMETERS	METHOD	UNITS	RESULTS
1	Energy (By Calculation)	FAO Method	kcal/100g	333
2	Carbohydrates (By difference)	CTL/SOP/FOOD/262 - 2014	g/100g	80.0
3	Total Fat	AOAC 20 th Edn.2016, 920.39	g/100g	BDL(DL:0.1)
4	Protein (Nx 6.25)	AOAC 20 th Edn.2016, 986.25	g/100g	3.16
5	Total Sugars	FSSAI Manual 2015- Beverages, Sugar and confectioneries	g/100g	32.9
6	Dietary fibre	AOAC 20 th Edn.2016, 985.29	g/100g	BDL(DL:1.0)
7	Sodium as Na	AOAC 20 th Edn.2016, 969.23	mg/100g	16.8
8	Iron as Fe	AOAC 20 th Edn.2016, 999.11	mg/100g	1.75

Note : BDL - Below Detection Limit; DL - Detection Limit;

The energy value for 100g of our jam is 333kcal, carbohydrate is 80g, 3.16 g of protein, 32.9 g of total sugars, 16.8g of sodium and 1.75 of iron. Our products is fat free and contains palm sugar healthier and better option of jam to consume has is has no preservatives and artificial colours or chemical.

CHAPTER 6

SUMMARY AND CONCLUSION

The preparation of tamarillo jam involved several formulations using different sugars and de-seeding methods to improve texture and taste. The sensory evaluation of the jam indicated high satisfaction among consumers in terms of appearance, texture, flavor, aroma, mouthfeel, and overall acceptability.

Additionally, various analytical techniques such as Thin Layer Chromatography (TLC), Gas Chromatography-Mass Spectrometry (GC-MS), DNA fragmentation analysis, quantification of total phenolic content, and anti-cancer activity assessment (MTT assay) were employed to study different aspects of the jam, including its chemical composition, potential health benefits, and anti-cancer properties. Overall, the jam formulation and evaluation process demonstrated a comprehensive approach to product development and quality assessment

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