Amerta Nutrition
e-ISSN: 2580-1163 (Online)
p-ISSN: 2580-9776 (Print)
Suganya and Kalpana | Amerta Nutrition Vol. 9 Issue 2 (June 2025). 319-328

RESEARCH STUDY
English Version
OPEN ACCESS

Solanum betaceum (Tamarillo): A Potential Antioxidant Rich Indigenous Fruit of India

Solanum betaceum (Terong Belanda): Buah Asli India yang Kaya Antioksidan

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ARTICLE INFO

Received: *23-07-2024*
Accepted: *19-03-2025*
Published online: *20-06-2025*

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DOI:
10.20473/amnt.v9i2.2025.319-328

Available online at:
https://e-journal.unair.ac.id/AMNT

Keywords:
Tamarillo, Tree tomato, Solanum betaceum, Antioxidant activity, Metabolic syndrome

ABSTRACT

Background: *Solanum betaceum*, commonly known as tamarillo, a nutritious fruit rich in vitamin C, dietary fibre, and an essential antioxidant that protects cells from free radical damage, contributing to overall health.
Objectives: The study aimed to achieve the confirmation of antioxidant activity of fruit followed by functional group and components identification.
Methods: Fiber content was determined enzymatically. Phytochemicals were screened using polar solvent extracts, with Gas Chromatography-Mass Spectrometry identifying metabolites and Fourier Transform Infrared Spectroscopy characterizing secondary metabolites. Antioxidant capacity was measured by DPPH (2,2-diphenyl-1-picrylhydrazyl) assay.
Results: Fresh tamarillo fruit exhibited a high content of dietary fiber (47.3 g/100 g), Vitamin C (27 mg/100 g), and β-carotene (832 mcg/100 g) the major nutrients accounts for the antioxidant. Phytochemical screening revealed the highest abundance of phenolic compounds, flavonoids, terpenoids, and quinones in the methanol extracts. Identification of functional groups used to confirm the presence of bioactive components: $OH_{alcoholic/phenolic}$ (3300-2900 cm-1), $C{=}C_{aromatic}$(1600-1450cm-1), $C\text{-}H_{aromatic}$(680-470 cm-1). with Gas Chromatography-Mass Spectrometry analysis identified various metabolic components, including beta-Bisabolene, Hexadecanoic acid methyl ester, Palmitic acid, Pentadecanecarboxylic acid, Heneicosane, Eicosane, Dotriacontane, Myrtenyl formate, and Isobutyric acid. The DPPH free radical scavenging assay demonstrated tamarillo fruit's potent antioxidant activity, with an IC50 value of (22.1 µg/mg mL^{-1}) significantly lower than the control (p-value<0.001).
Conclusions: These findings revealed a broad spectrum of beneficial properties in tamarillo. Presence of vitamin C and dietary fibre confirms the antioxidant activity and it makes tamarillo a promising fruit for the prevention of cancer and other degenerative diseases.

INTRODUCTION

Tamarillo (*Solanum betaceum*), also named as the tree tomato or tamarillo eggplant, is cultured worldwide, thriving in subtropical and tropical climates. It is commercially grown in countries such as Australia, Brazil, New Zealand, and in the tropical highlands of Southeast Asia and Indonesia. In India, tamarillo is also cultivated in the hill regions of Tamil Nadu. This subtropical species flourishes at elevations of 1,000–3,000 m in equatorial regions and 300–1,000 m in cooler subtropical areas. Its growth improves better in the temperatures between 18–22°C with yearly rainfall of 600–800 mm. Despite its increasing global presence, tamarillo remains a relatively understudied fruit in India. The fruit can be eaten by juices, salads, cake toppings and other culinary preparations including preserves including jam, jelly, sauces and pickles[1]. Hence the tamarillo fruit can be available all-round the year. Consuming fruits regularly not only strengthens the immune system but also helps prevent metabolic disorders. Tamarillos are exceptionally nutritious, containing carotenoids of 96mg βCE/g, anthocyanins, phenolic compounds of 95 mg /100 g of Gallic acid Equivalents, and flavonoids of 21 mg /g of dry weight. These compounds are renowned for their antioxidant and anti-inflammatory properties. Phenolic compounds play a pivotal role in enhancing anti-inflammatory effects through their antioxidant activity. Specifically, flavonoids effectively neutralize reactive oxygen species (ROS) produced by neutrophils and macrophages, while also inhibiting ROS-generating enzymes, thereby exhibiting pronounced antioxidant and anti-inflammatory potential. Additionally, tamarillos are rich in essential minerals while being low in calories. Previous research has indicated that consuming tamarillos may offer protection against various diseases, including cancer, due to their potent antioxidant effects[2].

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Tamarillo was found to contain moderate amounts of carbohydrates, protein, and total dietary fiber, alongside high levels of antioxidant activity and antioxidant vitamins. Its strong scavenging effects were allocated to its superior total phenolic content (TPC). Additionally, tamarillo demonstrated particular cytotoxicity against liver hepatoma (HepG2) and non-hormone-dependent breast cancer (MDA-MB-231) cell lines, while exhibiting no toxicity toward normal mouse fibroblast cells (3T3). These discoveries indicate that tamarillo holds potential as an anti-cancer agent due to its non-toxic nature toward normal cells. This study suggests that tamarillo is a promising source of natural antioxidants and a cytotoxic agent against specific cancer cell lines[3].

This research aims to bridge this knowledge gap by exploring the chemical composition and antioxidant potential of tamarillo using a combination of advanced analytical techniques. Gas Chromatography Mass Spectrometry offers a powerful tool for identifying and quantifying the metabolite compounds present in tamarillo. Gas Chromatography Mass Spectrometry can be used to analyze these plant metabolites in a single analysis. The technique involves converting the metabolites, including amino acids and organic acids (OAs), into volatile derivatives using a process called derivatization. Fourier Transform Infrared Spectroscopy is ideal for providing rapid, non-destructive insights into the functional groups of chemical compounds present in tamarillo. Similarly, Gas Chromatography Mass Spectrometry is particularly well-suited for tamarillo analysis due to its ability to precisely identify the bioactive components of tamarillo which helps better understanding to maximize the potential of Tamarillo health benefits. These techniques together offer complementary advantages, making them uniquely effective for comprehensive metabolite profiling of tamarillo. Furthermore, the incorporation of an antioxidant assay allows for the evaluation of tamarillo's potential health benefits. By assessing its free radical scavenging activity, may gain valuable knowledge regarding its possible role in preventing oxidative stress-related diseases. The findings from this study can contribute to promoting tamarillo consumption and its possible utilization in the food and nutraceutical productions. This study on tamarillo, which investigates its phenolic and bioactive components along with its antioxidant potential for the first time, provides valuable insights. The findings aim to highlight tamarillo as an origin of antioxidants and suggest its power as a functional food for disease management.

METHODS

Collection of Plant and Sample Preparation

Red varieties of Tamarillo (*Cyphomandra betacea*) fruits were procured from Uppatty village, Gudalur, The Nilgiris, a hill station in India. Fresh, fully ripened, red fruits were collected and keep in reserve at ambient temperature. The fruits were authenticated by the Botanical Survey of India, Tamil Nadu Agricultural University, Coimbatore, India. The fruit sample was also received Institutional Human Ethical Clearance to conduct the study.

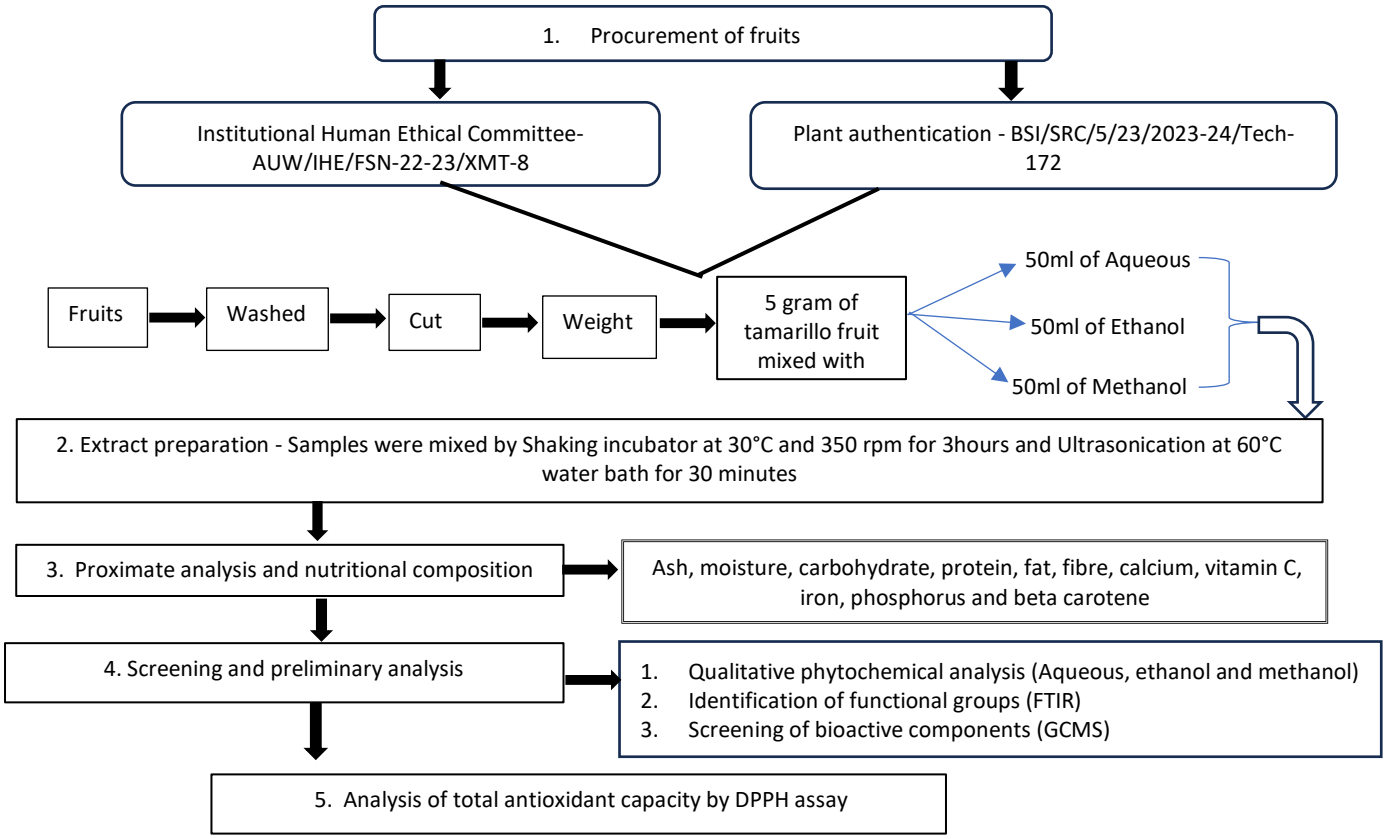

Figure 1. Methodology (Flow diagram)

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Extract Preparations

The fruits were washed, chopped into uniform pieces, weighed and divided into three portions for extractions with aqueous, ethanol and methanol. Five grams of fruits were mixed with 50 ml of each solvent (aqueous, ethanol, methanol) in shaking incubator at 30°C and 350 rpm for 3 hours. The extracts obtained were used to identify the phytochemicals. Since methanol was the better solvent extraction from the qualitative phytochemical analysis, the methanol extract underwent further ultrasonic extraction in a 60°C water bath for 30 minutes to be used for antioxidant assay a component identification by Gas Chromatography Mass Spectrometry[4].

Presence of Phytochemicals

Qualitative analysis for the presence of phytochemicals were identified with aqueous, ethanol and methanol extraction in tamarillo. 5 g of the fruit was soaked with 50 ml of aqueous, ethanol and methanol separately. The mixture was kept in the shaking incubator for three hours for concentrated sample extraction. The sample extract was passed into and out of a Whatman No. 40 filter paper to take off the particulates. Qualitative screening for each sample was follow out as per standard guidelines. Presence of alkaloids (Dragendroff's test), and Carbohydrates (Barfoed's test, Seliwanoff's Test and starch test), Glycosides (bromine water and biuret test), Flavonoids (lead acetate and ferric chloride test), Phenolic compounds (Iodine test, ferric chloride and lead acetate) were identified as the procedure by modified procedures of phytochemical screening[5].

Functional group Identification by Fourier Transform Infrared Spectroscopy

The functional groups of Tamarillo fruit sample were analyzed using a technique called Fourier Transform Infrared Spectroscopy. FTIR (Fourier Transform Infrared Spectroscopy) is ideal for providing rapid, non-destructive insights into the functional groups of chemical constituents present in tamarillo. It even allows for semi-quantitative comparisons between samples. To prepare the sample for analysis, one gram was mixed with 80% ethanol, shook well and then filtered. Each sample was measured three times (triplicates) in a specific range (4000-600 cm-1) employed by a specialized instrument (Vertex 70 FTIR spectrometer). Data processing software corrected for background interference and water vapor. The key fingerprint region (1800-800 cm-1) was then analyzed. The resulting extract was centrifuged and stored at a cool temperature (5°C) for further analysis[6].

Analysis of Components by Gas Chromatography Mass Spectrometry

Gas Chromatography Mass Spectrometry is particularly well-suited for tamarillo analysis due to its ability to precisely identify the bioactive components of tamarillo which helps better understanding to maximize the potential of Tamarillo health benefits. In order to identify the different chemical compounds within the tamarillo extracts, Gas Chromatography-Mass Spectrometry technique was used. The Gas Chromatography Mass Spectrometry analysis was employed in a specific setup: A capillary column named Elite-1 (made of Dimethyl poly siloxane) was used to separate the components. Helium gas served as the carrier, propelling the specimen through the column at a continuous run rate. Sample was injected in small volumes (2 microliters) at a 10:1 split ratio. Specific temperatures were maintained for the injector (250°C) and the ion source (280°C) throughout the process. The oven temperature itself followed a programmed ramp, starting at 110°C and holding for 2 minutes, then increasing gradually to 200°C, followed by a steeper rise to 280°C. Finally, it held steady at 280°C for an additional 9 minutes. The mass spectrometer collected data at specific intervals (every 0.5 seconds) and analyzed fragments within a range of 45 to 450 Daltons (Da), a unit of measurement for molecular mass. The entire process lasted approximately 36 minutes to complete[7].

Proximate Analysis and Nutritional Composition

The moisture rate and dried substance was measured. Ash content was discovered by gravimetric analysis followed by incineration in a muffle furnace at 600°C for 3 hours, as per AOAC method 942.05. Protein content of tamarillo fruit was evaluated using a conversion factor of 6.25 on nitrogen content measured by the Kjeldahl method as stated by AOAC method 978.04 (AOAC, 2005). Five grams of the sample mixed with 15ml of concentrated sulfuric acid and it was taken in the digestion flask with small amount of digestion mixture as a catalyst. The flask was heated gently on a heating mantle until the solution became colorless, indicating complete digestion. The digested sample was then transferred to a distillation unit to recover ammonia. During distillation, the ammonia released was captured in a receiving suspension. The resulting suspension was titrated with 0.1N hydrochloric acid until a colour change indicated the endpoint. The procedure was repeated to determine the nitrogen content, which was likely to quantify the protein mass in the fruit sample[8]. The energy value of tamarillo was estimated using a Bomb Calorimeter[9]. Carbohydrate was estimated using Anthrone method. Soxhlet method with petroleum ether (60-80°C) was used based on fat solubility in organic solvents. Dietary fiber was estimated using an enzymatic method. Sample were defatted with petroleum ether mixed with phosphate buffer and pH-adjusted using NaOH or HCl. Enzymatic hydrolysis was performed sequentially with α-amylase, papain and amyloglucosidase under controlled conditions. Soluble fiber was precipitated using ethanol, while insoluble fiber was washed with water, ethanol and acetone. Both residues were dried at 105°C, cooled and weighed. The percentages of soluble and insoluble dietary fiber were calculated as per the AOAC method. Vitamin C was measured by a dye method that reduced (2,6-dichlorophenol indophenol). Carotene was obtained with petroleum ether and colour intensity compared to a standard solution using a colorimeter. Calcium content in tamarillo determined by dye method using potassium permanganate. Iron and Phosphorus were estimated by colorimetric method.

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Efficiency of Antioxidant

The total antioxidant capacity of tamarillo fruit extract was determined using the DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging assay, as described by[10]. Various concentrations of the extract (ranging from 20 to 100 ppm) were mixed with a methanolic solution of DPPH and incubated in the dark for 30 minutes. The reduction in absorbance was recorded at 517 nm using a UV spectrophotometer. A (3 mL) DPPH solution was used as a blank for comparison. Ascorbic acid was employed as a positive control, and a calibration curve was generated using triplicate optical density (OD) readings of both the extract and the control to quantify antioxidant activity. Each measurement was conducted in triplicate, and measurement of DPPH radical scavenging activity was quantified for both the tamarillo extract and ascorbic acid standards, following the study of [11].

Antioxidant scavenging activities % = Ac − As / Ac × 100

Where, Ac denotes the measure of absorbance of the control solution, and as represents the measure of absorbance of the standard solution (used for calibration).

Statistical Analysis

The proximate and nutrient analysis were conducted in triplicate and the outcome exhibited as mean and standard deviation. For the antioxidant activity, a one-way ANOVA was carried out to assess significant differences ($p < 0.001$) between the standard and tamarillo fruit sample. The investigation included calculations of mean, standard deviation and p value. The statistical analysis was carried out using IBM SPSS statistical software version 25.

RESULTS AND DISCUSSIONS

Phytochemical Profile of Tamarillo

A qualitative analysis of fresh tamarillo fruit suspension exhibited the existence of many phytochemicals. Tamarillo is rich in a variety of phytochemicals, each with its own unique health benefits. Notably, the methanol extract exhibited appreciable amounts of alkaloids, flavonoids, glycosides, terpenoids and phenolic compounds. Conversely, saponins were entirely absent in all tamarillo extracts investigated. Aqueous and ethanol extracts also contained a range of phytochemicals, including sterols, anthraquinones, anthocyanins, proteins and carbohydrates. Polyphenols, a class of antioxidants, can counteract reactive oxygen species and secure the cells from oxidative harm. Flavonoids, another group of antioxidants, possess antibacterial and antiviral properties in addition to their antioxidant effects. Carotenoids, responsible for the fruit's vibrant colour have nutraceutical properties and offer various health benefits. Anthocyanins, a type of flavonoid can prevent lipid oxidation, reducing the threat of cardiovascular diseases[12]. The synergistic effects of these phytochemicals make tamarillo a nutritious and health-promoting fruit. These findings align with earlier research by[3] who emphasized the potential health benefits associated with these compounds. Terpenoids, for instance, have been linked to the retardation of various diseases, including cancer. Flavonoids offer protection against oxidative cell damage and may aid in managing diabetes. Sterols contribute to cholesterol reduction and immune system regulation while glycosides are known to boost the immune system.

Identification of Functional Group Using FTIR

The FT-IR spectrum was utilized to identify the primary functional groups present in the vital components of tamarillo. This analysis confirmed the presence of various compounds, including aromatics, nitro compounds, carboxylic acids, alkanes, and phenols[3]. In the methanol suspension of Tamarillo fruit, the FT-IR spectra of the consecutive functional groups feasibly used to prove the presence of bioactive components such as: $OH_{alcoholic/phenolic}$ (3300-2900 cm-1), $C{=}C_{aromatic}$(1600-1450cm-1), $C\text{-}H_{aromatic}$(680-470cm-1).

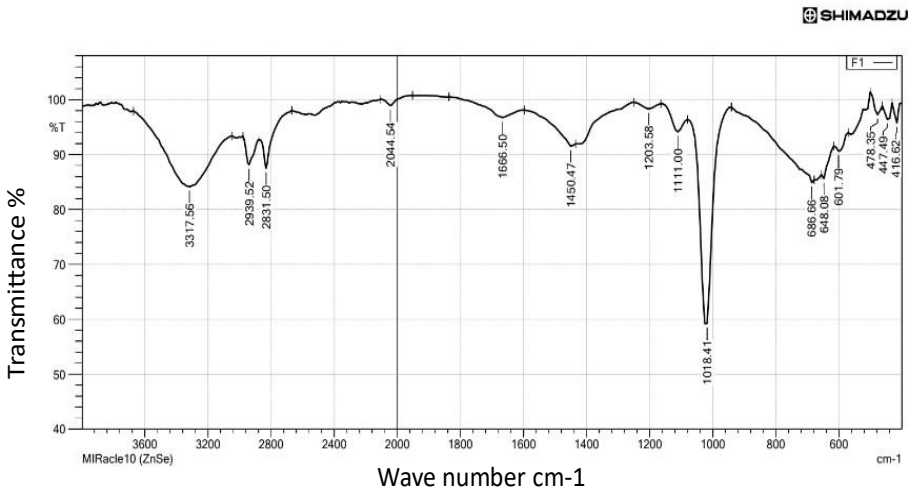

Figure 2. FTIR spectra of methanol extract of tamarillo fruit

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The FTIR spectra of tamarillo presented the composition at the observation all over 2970 to 879 cm¯1. The diverse area displays more peaks recognise set off observations ranges for offering different regions; the medium and sharp bands of 3695 cm¯1 for O-H stretching alcoholic group, presence of medium-strength C-H stretching vibrations around 3000-2840 cm^{-1} indicates alkenes in the sample. The strong C=O stretching bands observed in the 1745-1710 cm^{-1} region suggest the presence of carboxylic acids, aliphatic ketones or aldehydes. The strong N-O stretching band observed in the 1600-1300 cm^{-1} region suggests the presence of nitro compounds, 1400-1000 cm¯1 strong O-H bending carboxylic acid groups which was on par with a study by[13]. Fourier-Transform Infrared (FTIR) spectroscopy revealed distinct chemical composition variations in the tamarillo samples, particularly within the 1800–1600 cm^{-1} wavenumber range. While the overall spectral fingerprint remained consistent, the intensity of specific bands differed. These intensity variations corresponded to changes in specific functional groups as evidenced by characteristic peaks at distinct wavenumbers: 3317 cm^{-1} (O–H stretch in water) and bonded with phenols which confirms the antioxidant activity of the fruit, 2939 cm^{-1} (C–H stretch in fatty acids), 1666 cm^{-1} (C=O stretch in methyl esters), 1630 cm^{-1} (asymmetric stretch of carboxylate), 1450 cm^{-1} (symmetric stretch of carboxylate), and 1018 cm^{-1} (C=O and C–C stretch in acids)[14]. Notably, the region between 1300 and 800 cm^{-1} exhibited significant changes, resembling the fingerprint region of citrus pectin, suggesting the existence of high methoxyl pectin in tamarillo. The FTIR results also displayed some similarities with the characteristic peaks of inulin (3270–2929 cm^{-1} and 1025–985 cm^{-1})[15].

Identification of Metabolite Components by Gas Chromatography Mass Spectrometry

The Gas Chromatography Mass Spectrometry analysis of tamarillo revealed the presence of 9 important bioactive components that possess various beneficial properties for human health. These compounds have the potential to prevent the development of numerous pathologies, making tamarillo a valuable source of natural compounds with therapeutic applications. In this study, Gas Chromatography Mass Spectrometry analysis of the methanol extract of tamarillo fruit revealed the presence of various compounds, including beta-Bisabolene and fatty acids like hexadecanoic acid (palmitic acid).

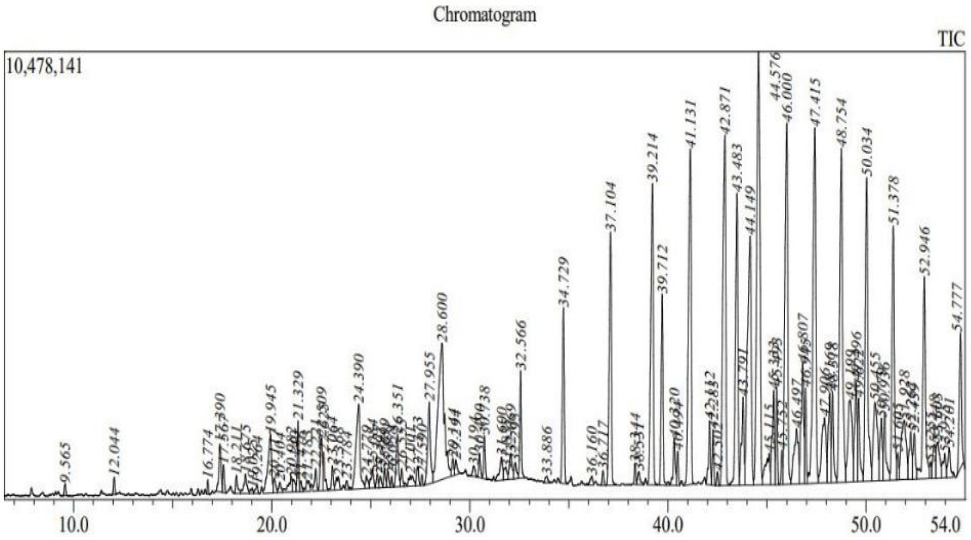

Figure 3. GC-MS chromatogram of the methanol extract of tamarillo fruit

The analysis identified a range of compounds, with beta-Bisabolene eluting first (18.2 minutes) and Dotriacontane eluting last (40 minutes)[16]. Notably, cis-9-hexadecenoic acid, a fatty acid with reported antimicrobial, antioxidant, and anti-inflammatory properties, was detected in tamarillo at a retention time of 27-28 minutes. Eicosane is a 20carbon poly unsaturated fatty acid act as a cell membrane, maintain integrity and fluidity, energy storage, anti- inflammatory properties, role in glucose metabolism.

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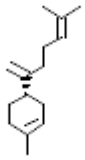
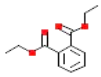
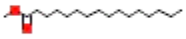
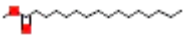
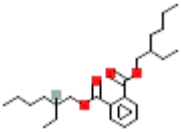
Table 1. Identifying the key components found in tamarillo through GC-MS analysis

Compound name	RT (min)	Area	Molecular Formula	Chemical Structure	Bioactivity
beta-Bisabolene	18.2	3019048	C15H24		Beta-Bisabolene improve and absorbs Beta-carotene, found in tamarillo can makes the nutraceutical products.
1,2-Benzenedicarboxylic acid,	26	118380	C12H14O4		Indirect additives
Hexadecanoic acid, methyl ester	27	3388534	C17H34O2		Antimicrobial activity, antibacterial, antioxidant, antitumor, chemopreventive
n-Hexadecanoic acid Palmitic acid Pentadecanecarboxylic	28	69530053	C16H32O2		Maintain integrity and fluidity, glucose metabolism
Heneicosane, Eicosane	30-40	11645351	C26H46		Anti-inflammatory drugs
Bis(2-ethylhexyl) phthalate	39	28533016	C24H38O4		Thyroid and energy balance and metabolism
Dotriacontane	42	81515253	C32H66		Antimicrobial, antioxidant, antispasmodic, antibacterial, and antiviral.

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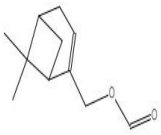
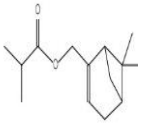
Compound name	RT (min)	Area	Molecular Formula	Chemical Structure	Bioactivity
Myrtenyl formate			C11H16O2		Also known as monoterpenoids. Used in the treatment of neurodegenerative disorders.
Isobutyric acid, 2-pinen-10-yl ester			C14H22O2		Anti-inflammatory, treatment of prostate cancer

Beta-Bisabolene is a substance that helps improve how well the body absorbs Beta-carotene, which is a nutrient found in many fruits and vegetables. Hence daily consumption of tamarillo as salad, juice, sauces and desserts are preferred for better health. This can make nutraceutical products, which are supplements that offer health benefits which were more effective. Tamarillo can also use to prepare jam, jelly, pickle and more culinary preparations. This describes the substances can acts as a antimicrobial activity (killing germs) and antioxidant (protecting cells from damage). Hexadecanoic acid, methyl ester is like hemolytic (damaging red blood cells) or antiandrogenic (reducing the effects of male hormones), can have negative consequences. 5-Alpha reductase inhibitors are specific molecules that block the conversion of testosterone to a more potent form. There are also terms that describe the strength of an effect (potent) and whether it might help prevent disease (chemopreventive and antitumor). n-Hexadecanoic acid and Palmitic acid is one of the most important building blocks of a cell's membrane is a molecule that plays multiple roles. This molecule helps to keep the membrane strong and flexible (maintaining integrity and fluidity). It can also be used by the cell for energy storage.

Bis(2-ethylhexyl) phthalate helps for the proper functioning of our thyroid gland is crucial for maintaining a healthy balance of energy in our bodies. This gland produces hormones that regulate metabolism, the process by which our bodies convert food into usable energy. Dotriacontane group of terms describes various properties a substance might have that could be beneficial for health such as antimicrobial and antibacterial both refer to the ability to fight germs, but antimicrobials have a broader range and can also target fungi or viruses. Antioxidant describes a substance that protects cells from damage caused by unstable molecules. Antispasmodic refers to the ability to relax muscles, which can be helpful in relieving cramps or spasms. Finally, antiviral describes a substance that can fight viruses, the infectious agents responsible for diseases like the common cold or the flu. Monoterpenoids, also known as simply monoterpenes, are a group of natural compounds found in many plants. Some monoterpenoids have been shown to have pain-relieving (analgesic) and anti-inflammatory properties, which could be helpful in managing conditions like arthritis. Scientists are exploring the application of monoterpenoids for the treatment of neurodegenerative disorders, which are conditions that cause progressive damage to the nervous system. Isobutyric acid, 2-pinen-10-yl ester combination of properties suggests a potentially powerful compound. It has anti-inflammatory effects, which can help reduce swelling and pain. It also acts as a bronchodilator, opening up airways in the lungs, potentially beneficial for conditions like asthma. Furthermore, it exhibits pain-relieving properties, and research suggests it might even be useful in the treatment of prostate cancer[16].

Nutritional and Proximate Content of Tamarillo

A triplicate analysis was conducted to determine both proximate components and nutrient. Fresh tamarillo exhibited high moisture content (81%) in the samples suggested that they have high perishability[17] and also which can be impacted by storage and processing methods[11]. Ash content (10.2g/100g) reflects quantity of total mineral profile. Low carbohydrate content (7.2 g/100g) translated to low energy value. Notably, the high dietary fiber content (47.3g/100g) offers potential benefits for digestive health and may reduce the risk of coronary heart disease (CHD) and some type of tumours[12]. The analysis also revealed high iron levels, crucial for red blood cell formation and overall growth. Tamarillo demonstrated remarkable ability to retain phosphorus and boasted the highest vitamin C content (27.6mg/100g) amongst the samples. Vitamin C is an necessary antioxidant molecule in plants, and fruits are the major origin of vitamins[10]. Ascorbic acid (vitamin C), a vital nutrient primarily acquired from fruits and vegetables, plays a dual role in disease prevention (e.g., scurvy) and functions as a biological antioxidant[18]. Furthermore, the presence of beta-carotene (832.6mcg) suggested tamarillo may be a valuable source for individuals at risk of vitamin A deficiency. Carotenoids, like beta-carotene, also exhibit antioxidant properties, enabling them to neutralize free radicals and peroxyl radicals**.** β-carotene perform as a prohibition against lipoprotein oxidation and differentiated to β-cryptoxanthin, doubled antioxidant activity had been found. In addition, benefits over reducing the harm of cancers, cardiovascular disease and rising immune response are evident in studies[19]. A study stated that Tamarillo consumption during pregnancy can prevent Anaemia after delivery and it replenish the iron stores[21]. A study by Vasco, 2009 the antioxidant capacity, was significantly greater (p-value<0.05) in the purple-red

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variety compared to the golden-yellow variety of tamarillo[22]. According to the study total phenolic, total flavonoids and antioxidant activity of tamarillo were significantly higher than tomato[2].

Antioxidant activity of tamarillo fruit

The IC50 value, which stands for the "half maximal inhibitory concentration" is a measure used to find out the concentration of a tamarillo fruit sample requisite to hinder 50% of a specific radical. This value is commonly used to assess the antioxidant activity of various samples, such as plant extracts or compounds. The lower the IC50 value, the more effective the sample is at inhibiting the radical, indicates that it elevates the efficiency of antioxidant activity. The antioxidant activity of Tamarillo fruit with methanol extract was performed on the results shown in Table 2. According to study tamarillo fruit extracts that acquire IC50 values ranging from 50 to 100 mg / mL is accounted to exhibit intermediate antioxidant activity[23]. Meanwhile, extracts with IC50 value ranging between 10 to 50 mg / mL is accounted to retain powerful or strong antioxidant activity.

Table 2. Antioxidant activity of tamarillo fruit

Concentration	Standard (Ascorbic acid)	Tamarillo	p-value
20µL	65.6	70	
40µL	68	72.6	
60µL	71.1	74.4	
80µL	73.4	76	0.001
100µL	74.68	80	
IC50	58.5	22.1	
Mean±SD	70.45±3.68	74.6±3.75	

Values mean ±SD (Standard Deviation - determinants in triplicates). IC50 value and p value indicates significant differences (p-value=0.001) based on paired sample T test.

The DPPH assay revealed that the methanol extract of fruit exhibited stronger free radically scavenging movement compared to a standard ascorbic acid solution. This suggests that tamarillo possesses potent antioxidant capacity, exceeding even well-known antioxidant sources like tomatoes. Hence it showed the significant difference between the standard and tamarillo fruit extract of (p-value<0.001) with 95% confidence interval. The elevated antioxidant capacity of tamarillo forms a quality onset of natural dietary supplemention[24]. According to study the high activity is likely due to the presence of various phytochemicals, including phenolic compounds like hydroxycinnamoyl acids and rosmarinic acid, which have been demonstrated to possess superior scavenging abilities[25]. Naturally occurring antioxidants are known to slow the progress of more chronic diseases by neutralizing free radicals. Research have highlighted that tamarillo fruit possesses strong antioxidant properties, likely attributed to its more content of phenolic compounds, vitamin C, and carotenoids, all of which are potent antioxidants. In this study, the antioxidant capacity of the extracts was measured using IC50 values, which showed a positive correlation with antioxidant activity. The tamarillo fruit extract demonstrated appreciably rise in DPPH radical scavenging activity and reducing power compared to standard ascorbic acid used. This superior performance is likely due to tamarillo's rich content of vitamin C, phenolic compounds, and carotenoids, as supported by its nutritional profile. Additionally, tamarillo is a rich source of dietary fibber and bioactive components, making it a promising fruit for functional product development[11].

The study effectively makes use of Fourier Transform Infrared Spectroscopy to identify the specific functional groups and Gas Chromatography Mass Spectrometry to detect a range of metabolites in tamarillo fruit. Screening of phytochemical highlights the differences in phytochemical profiles among aqueous, ethanol, and methanol extracts suggesting that different solvents may be optimal for extracting specific compounds. This investigation confirms the antioxidant activity of tamarillo fruit through functional group and component identification. It addresses a gap by focusing on tamarillo, which is relatively understudied in India despite its global presence, encouraging consumption and potential applications based on its nutraceutical properties. Looking forwarded the limitation of the study primarily focuses on red varieties of Tamarillo but lacks detailed comparisons with other varieties. While it identifies various phytochemicals qualitatively, quantitative analysis would provide more precise information about compound abundance. Using ascorbic acid as a positive control is beneficial however, including a negative control would strengthen results by providing a baseline for comparison. Relying solely on in vitro antioxidant assays (like DPPH) does not fully represent complex biological systems; thus, in vivo studies are needed to confirm health benefits such as cancer prevention or disease pathology prevention claims.

CONCLUSIONS

This investigation highlights the nutritional and biologically active in potential of tamarillo fruit, emphasizing its high dietary fiber, essential nutrients, and rich bioactive compounds that promote digestive health, immunity, and antioxidant activity when comparing with tomato from the previous study. The presence of phenolic compounds, flavonoids, and terpenoids further

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enhances its antimicrobial, anti-inflammatory, and antioxidant properties. Therefore, tamarillo can be suggested as part of a daily diet to enhance human health with its strong antioxidant capacity and health-promoting benefits, tamarillo holds promise as a nutraceutical fruit, though further research is needed to validate its effects, improve storage methods, and explore its use in functional foods.

ACKNOWLEDGEMENT

The authors would like acknowledge to the Advance Research Laboratory, Avinashilingam Institute to carried out the experimental studies and extend their gratitude to the Department of Adi Dravidar Welfare, Tamil Nadu, India for the Scholarship provided to the entire Doctoral degree program.

CONFLICT OF INTEREST AND FUNDING DISCLOSURE

All authors declare that they have no conflict of interest. There was no funding for conduct of this study.

AUTHOR CONTRIBUTIONS

AS: Framing of methodology, analysing and interpretation of data, preparing the draft manuscript, statistical analysis.

CAK: Conduct supervision and guidance, provides opinion and reviewing, input and suggestions for writing manuscripts, editing and validating.

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