



Estimation and comparison of organic acids in natural fruits

Dr. Alka Gupta 

Assistant Professor, Department of Chemistry, Brahmanand College, Chhatrapati Shahu Ji Maharaj University, Kanpur, Uttar Pradesh, India

Corresponding author: Dr. Alka Gupta

Received 27 Jul 2026; Accepted 3 Sep 2026; Published 18 Sep 2026

DOI: <https://doi.org/10.64171/JAES.6.5.45-54>

Abstract

Organic acids represent a fundamental category of natural chemical compounds that define the biochemical identity of fruits, acting as the primary "flavor architects" and metabolic intermediates within the plant's life cycle. Fruits and plant-based products have been utilized for both nutritional and medicinal purposes since the earliest human civilizations, serving as a primary defense against various ailments. In the modern era, there is an emerging global trend toward increased fruit consumption as a strategic response to the rise of non-communicable diseases (NCDs) such as diabetes, cardiovascular issues, and cancer. These diseases are often linked to oxidative stress within the body, where an imbalance between free radicals and antioxidants leads to cellular damage. Fruits supply essential nutrients, particularly organic acids and polyphenols, which improve immune function and serve as natural scavengers to quench these harmful reactive oxygen species. Consequently, the chemical quantification of these acids is not merely a laboratory exercise but a vital step in understanding how dietary choices can mitigate long-term health risks in both developed and developing countries. Beyond their health benefits, the chemical complexity of fruits is centered largely on their Total Vitamin C Content (TVC), which researchers define as the sum of ascorbic acid (AA) and its oxidized form, dehydroascorbic acid (DHA). DHA can be reversibly reduced back into ascorbate in the human body, making both forms equally important for nutrition.

The scientific method used in this research paper is acid-base titration, a volumetric analysis technique where a solution of known concentration (the titrant) is added to a solution of unknown concentration. In the context of fruit acids, the analyte is the diluted fruit juice (containing organic acids like citric, malic, or ascorbic acid), and the titrant is a standardized solution of sodium hydroxide (NaOH). The effectiveness of this method is primarily rooted in its stoichiometric reliability, where the reaction between a strong base like sodium hydroxide and organic acids occurs in fixed, predictable ratios. This allows for a precise, quantitative determination of acid content, providing a numerical value that is essential for comparing the natural tartness of different fruits or accurately monitoring the stages of fruit ripeness. The overarching aim of this research is to quantitatively analyze and compare the total acid content present in a selection of different sour fruits commonly available in local markets, namely lemon, tomato, tamarind, and sweet lime. This study is designed to bridge the gap between the perceived tartness of these fruits and their actual chemical concentration through the application of standard analytical chemistry techniques. By determining the "titratable acidity" of each fruit, the experiment seeks to establish a clear chemical profile that categorizes these fruits based on their molarity and the strength of the organic acids they contain.

Keywords: Sour fruits, Organic acids, Titratable acidity, Quantitative analysis, Acid-base titration

Introduction

Fruits contain a variety of organic acids which contribute significantly to their distinctive flavor, taste, and aroma, in addition to influencing their shelf life. The balance between these acids and the sugar content determines whether a fruit is perceived as sweet or sour. The primary organic acids found in fruits include citric acid, malic acid, tartaric acid, and ascorbic acid (Vitamin C), among others. The specific acids present, and their concentrations, vary greatly among different types of fruits and even between different varieties and stages of ripeness. Currently, the most reliable and validated method for the identification and quantification of acid content in fruit juice is acid-base titration. This analytical technique involves the gradual addition of a standard solution of a strong base, such as sodium hydroxide (NaOH), to a known volume of fruit juice. The reaction reaches an equivalence point where the moles of base added exactly neutralize the moles of acid present. However, because fruits are rich in metabolizing

enzymes, the levels of these acids can fluctuate rapidly after harvesting, particularly in high-temperature environments ^[1]. The concentration of these acids is also a key indicator of fruit maturity and industrial quality. In tomatoes, the balance of citric and malic acids shifts significantly as the fruit transitions from green to ripe. This chemical "fingerprint" determines the fruit's pH and titratable acidity, which are critical parameters for the food processing industry, affecting everything from paste consistency to the shelf-stability of canned products ^[2]. When examining citrus species like lemon, orange, and sweet lime, the predominance of citric acid is well-documented. Scientific profiling demonstrates that lemons contain the highest concentration of citric acid among common citrus fruits. This high acidity is medically significant, as it has been shown to inhibit the formation of calcium oxalate crystals, thereby reducing the risk of kidney stones in patients who maintain a high-citrus diet ^[3]. In contrast, "underutilized fruits" or less common varieties often possess unique acidic profiles

that remain poorly studied. Many community-grown fruits in regions like Sri Lanka are nutritionally superior to commercially mass-produced varieties. Research suggests that exploring the acid content of these understudied species could

provide low-cost solutions to global health issues, such as iron deficiency, by leveraging the ability of organic acids to enhance mineral absorption.

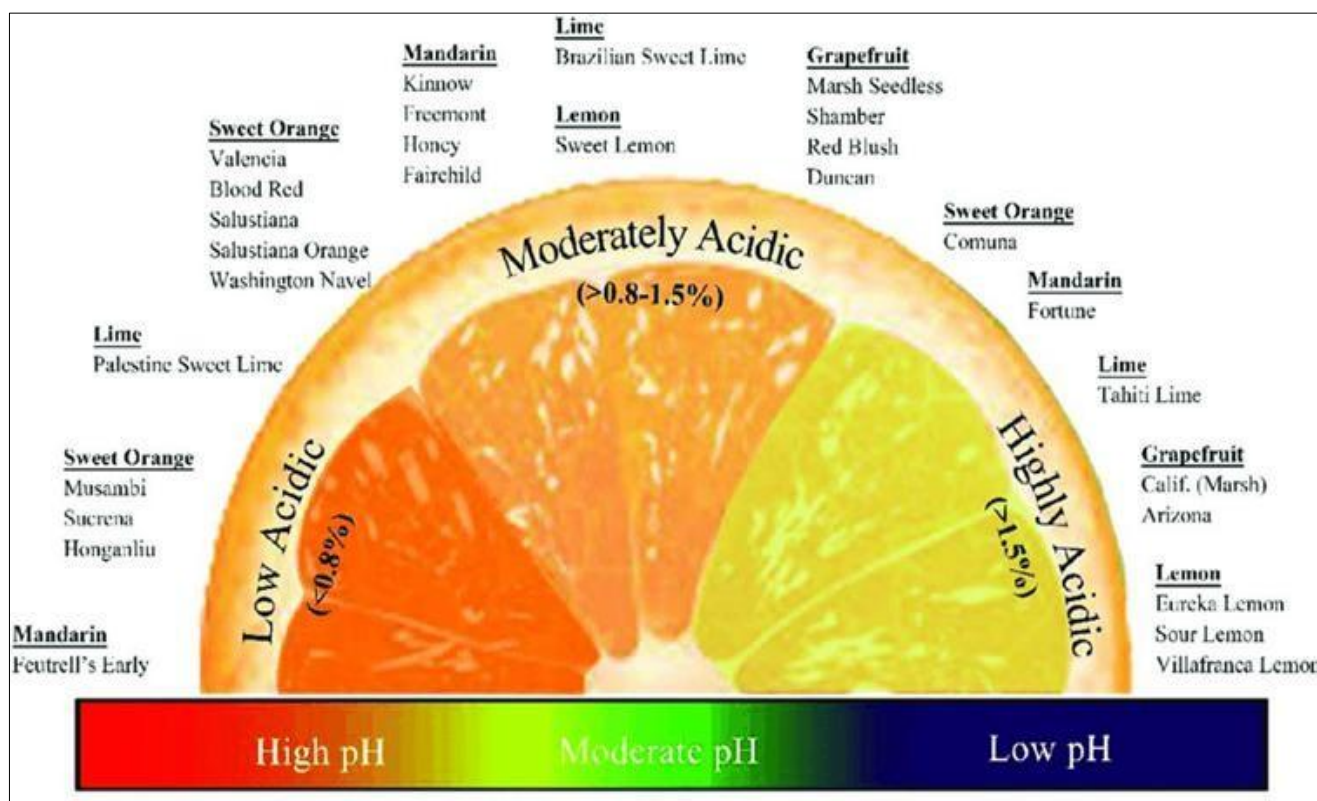


Fig 1

The methodology for measuring these compounds has evolved significantly, moving from simple sensory evaluation to complex analytical chemistry [4]. The "sugar-acid ratio" often masks the true concentration of acids. Therefore, a chemical approach is required to move beyond subjective taste and provide a reproducible, numerical value for a fruit's total acidic load. Among the various analytical choices, we observe that titrimetric methods (volumetry) remain the most favored for routine laboratory work. Despite the availability of High-Performance Liquid Chromatography (HPLC) and gas chromatography, titration is preferred because it is rapid, cost-effective, and does not require the extensive sample pre-treatment that more sensitive electronic methods often demand [5]. The findings showed that acid-base titration exhibited "excellent linearity and precision" specifically for lemon and orange samples. This confirms that for standard fruits, the volumetric reaction between organic acids and a strong base like sodium hydroxide provides a robust and internationally accepted benchmark for quality control. Environmental factors also play a subtle but significant role in the acidic makeup of fruits. The organic acid profile of a fruit can be influenced by its growing conditions whether industrial, vehicular, or residential affecting the overall antioxidant capacity and chemical stability of the produce [6]. For highly acidic fruits like tamarind, the primary constituent is tartaric acid, which presents a different chemical behavior during titration than the

citric acid found in lemons. In the presence of dicarboxylic acids like tartaric and malic acid requires a clear understanding of stoichiometry to ensure that the volume of titrant used accurately reflects the total moles of hydrogen ions neutralized at the equivalence point. Furthermore, the choice of indicator is crucial for the success of these measurements. Phenolphthalein is the most effective indicator for these weak acid-strong base reactions [7]. It provides a sharp visual transition to a faint pink at a pH of approximately 8.2, ensuring that the researcher can identify the "titratable acidity" with minimal margin for error, even in slightly colored fruit juices. In general, citrus fruits are well known for their high acid content, with lemons and limes having some of the highest concentrations.

Lemons and Oranges: The dominant acid in citrus fruits, including lemons, oranges, and sweet lemons, is citric acid. Citric acid is a weak organic acid responsible for the sharp, tangy flavor of these fruits. They also contain smaller quantities of other acids such as ascorbic acid (Vitamin C), malic acid, and oxalic acid.

Tamarind: The characteristic sour taste of the tamarind fruit (*Tamarindus indica*) is primarily due to the high concentration of tartaric acid. Tamarind also contains minor amounts of other acids like citric and malic acids, but tartaric acid is the predominant one.

Tomatoes: Tomatoes are a natural source of multiple acids, with citric acid and malic acid being the most abundant. Citric acid is typically the dominant organic acid in ripe tomatoes,

while malic acid is often more prevalent in unripe green tomatoes. Tomatoes also contain notable amounts of ascorbic acid (Vitamin C) and trace amounts of oxalic acid.

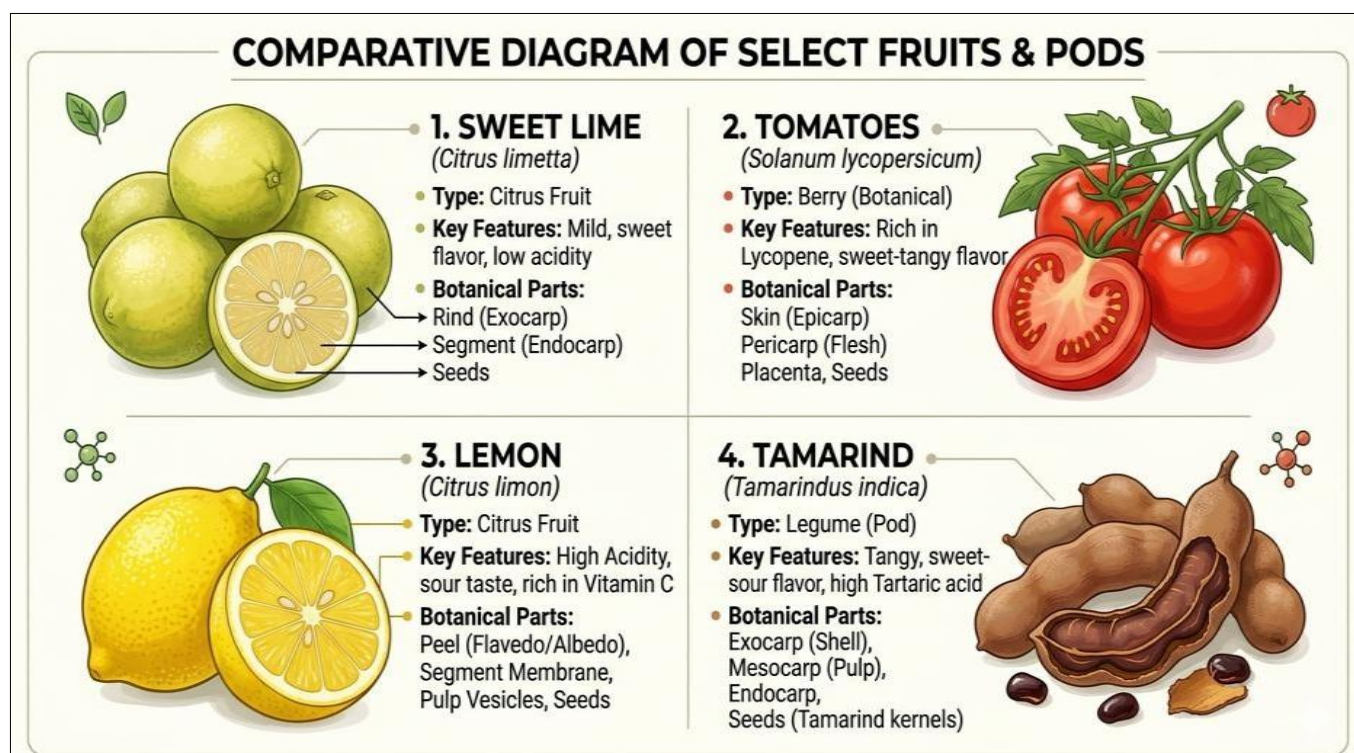


Fig 2

Organic acids act as metabolic intermediates that play a vital role in the ripening process and the overall nutritional profile of the plant. In fruits, acidity is not just a matter of flavor; it acts as a natural preservative against microbial spoilage. In study on fruit fermentation and chemistry, the most common organic acids include citric, tartaric, and malic acids [8]. While some fruits have high acid content easily detectable by taste, others have a complex balance of sugars and acids where the sourness may be masked. The concentration and type of acid vary significantly depending on the botanical origin and maturity of the fruit. In citrus fruits like lemon, sweet lime, and orange, the predominant acid is citric acid, a triprotic acid crucial for metabolic processes [9]. The lemons contain the highest concentration of citric acid compared to other citrus variants. Other fruits contain different primary acids, such as tartaric acid in tamarind, which gives it a distinctively sharp sourness. In tomatoes, the acidity is a complex mixture of citric and malic acids these levels fluctuate significantly as the fruit transitions from green to ripe, impacting both the pH and the industrial processing quality of the fruit [10].

The consumption of fruit acids has several physiological effects on the human body and is linked to various health outcomes. Organic acids like citric acid play a key role in the

Krebs cycle, helping the body produce energy, and enhance the absorption of essential minerals like iron and calcium [11]. The study on dental erosion indicate that the risk of enamel wear depends heavily on the titratable acidity and the frequency of exposure [12]. Many fruit acids also work in tandem with ascorbic acid (Vitamin C) to act as antioxidants, protecting cells from oxidative stress. Understanding these levels is vital for food science, acidity levels are a primary determinant of fruit ripeness, palatability, and overall shelf-life in the food processing industry [13]. While many organic acids exist, three primary types dominate the profile of sour fruits-

Citric Acid: The signature acid of citrus fruits like lemons, limes, and oranges. It is often the most abundant organic acid in these species, reaching high concentrations that provide a sharp, clean acidity.

Malic Acid: Commonly referred to as "apple acid," it is the predominant organic acid in apples, cherries, and stone fruits. It offers a persistent, tart flavor profile compared to citric acid.

Tartaric Acid: Highly concentrated in grapes and tamarinds, this acid is unique for its role in stabilizing fruit-based products and contributing to the distinctive "bite" found in specific varieties.

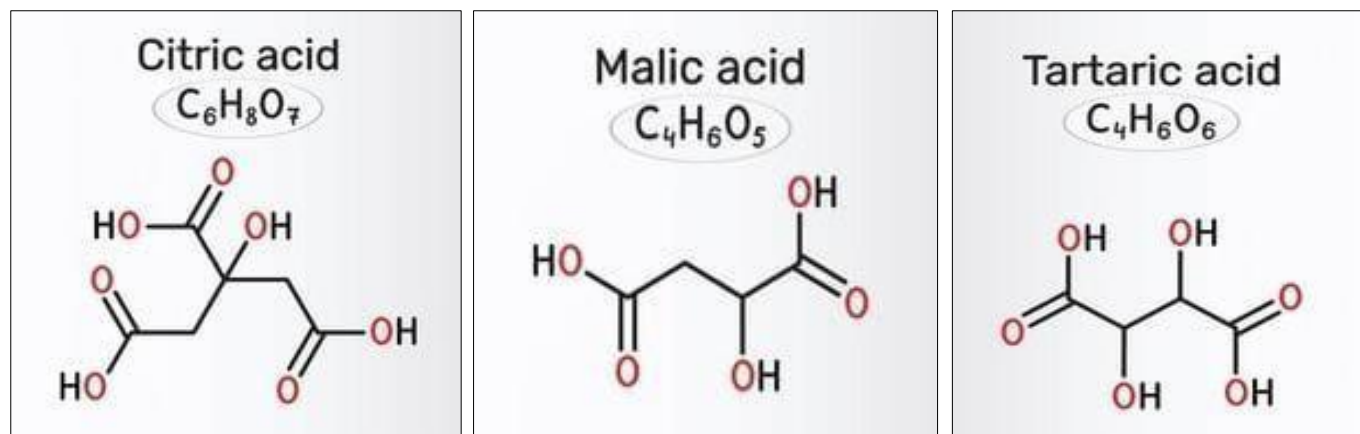


Fig 3

Neutralization Reaction: The core principle is the chemical reaction of neutralization. Acids in the fruit juice react with the added base (NaOH) to form salt and water:



For example, a diprotic acid like tartaric acid ($\text{H}_2\text{C}_4\text{H}_4\text{O}_6$), commonly found in grapes, reacts as follows:



The reaction proceeds until all the free acid molecules in the fruit sample have reacted with an equivalent number of hydroxide ions OH^- from the titrant. This point is called as the equivalence point. Acid-base titration stands as the definitive standard in food science for determining titratable acidity, which measures the total concentration of all free hydrogen ions in a solution capable of being neutralized by a base. This measurement is distinct from pH, as it evaluates the total quantity and capacity of the acid present rather than just the immediate intensity of free ions at a given moment. Beyond its technical accuracy, the method is highly valued for its visual clarity and operational simplicity^[14]. The use of an indicator like phenolphthalein provides a sharp, sensitive endpoint that is easily observable with the naked eye, shifting from colorless to pink exactly as the equivalence point is reached. This process is remarkably cost-effective, utilizing standard laboratory equipment such as burettes and flasks that are widely accessible and straightforward to use with minimal training. Ultimately, by measuring the exact volume of standardized base required to neutralize the acids in a fruit sample, titration offers a robust, reproducible, and universally accepted measurement of total acid content. This study aims to utilize this volumetric approach to calculate the molarity and total strength of acids in lemon, sweet lime, orange, tamarind, and tomato. By measuring the volume of NaOH consumed, the research seeks to establish a comparative acidity profile, providing a clear scientific understanding of the chemical composition of these common dietary staples. In summary, the

literature surrounding fruit acidity emphasizes a move toward precision and nutritional transparency. By drawing on the works of scholars like Popescu, Abeyesuriya, and Suntornsuk, this research paper aims to bridge the gap between historical medicinal knowledge and modern volumetric analysis.

Experimental

Materials

This research paper on determining acid content in various sour fruits requires specific equipment for accurate titration, a range of chemical reagents, and the necessary-fruit samples. Burette (50 mL) used for precise dispensing of the sodium hydroxide solution during titration. Pipette (10 mL or 25 mL) for accurately measuring the volume of the extracted fruit juice samples. Conical flasks (250 mL) are the reaction vessel where the titration takes place. Beakers (various sizes) used for general chemical preparation and holding liquids. Measuring cylinder (100 mL) for approximate measurement of water or other solvents. White tile or white paper placed underneath the conical flask to clearly observe the color change at the endpoint of the titration. Mortar and pestle or juicer for crushing fruits and extracting the juice. Filter paper and funnel/muslin cloth is used to separate the pulp and seeds from the juice, ensuring a clear sample for testing. Weighing balance for accurate measurement of solid chemicals like sodium hydroxide pellets (if preparing solution from solid) and potentially the mass of fruit samples. Distilled water dispenser essential for preparing solutions and cleaning glassware, as tap water can contain minerals that interfere with results. Sodium hydroxide (NaOH) solution (standardized 0.1 M) is the titrant (the base of known concentration) used to neutralize the acid in the fruit juice. Glass funnels for safe and spill-free pouring of liquid. Retort stand with clamp for securely hold the burette in a vertical position. Phenolphthalein indicator is a pH-sensitive dye that changes from colorless to a pale pink when the solution becomes basic, signaling the titration endpoint. A selection of common sour fruits collected fresh. Examples may include lemons, limes, oranges, grapefruits, kiwis, and green apples.

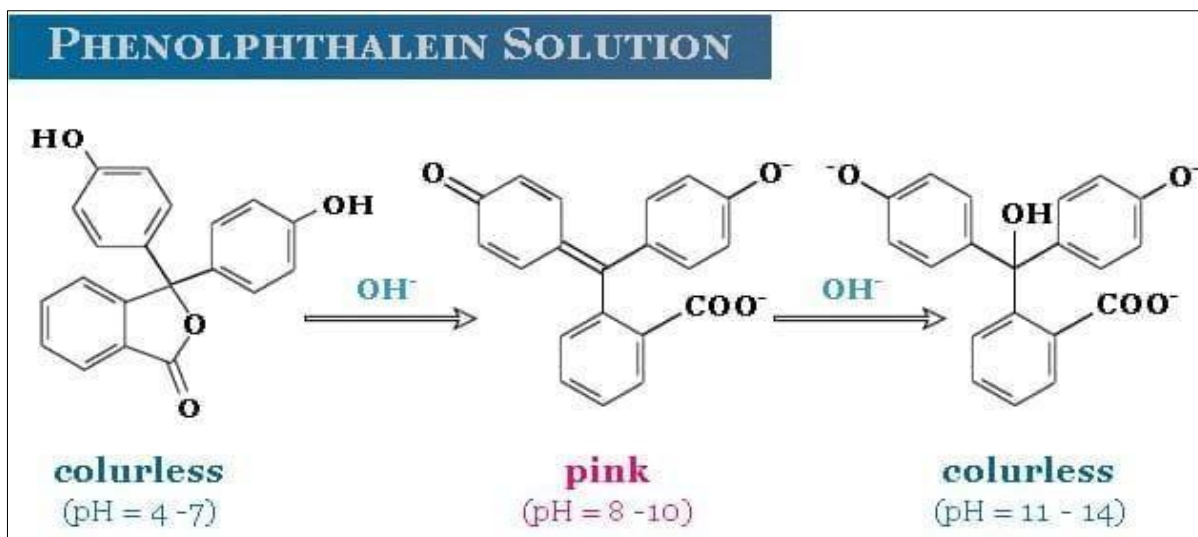


Fig 4

Method

Sample collection and preparation

The integrity and consistency of the fruit samples are paramount to obtaining reliable and comparable results. This section details the systematic approach to selecting and preparing the fruit juice for analysis. Fruits were sourced from a local market, focusing on uniformity to minimize

experimental variance. The selection criteria included ensuring that all fruits of a specific type were of a similar size, appearance, and ripeness level. Only undamaged, fresh specimens were chosen to prevent the influence of decay or bruising on the acid content. A consistent number of fruits of each type (e.g., three lemons, three oranges, etc.) were collected to provide enough volume for replicate testing.

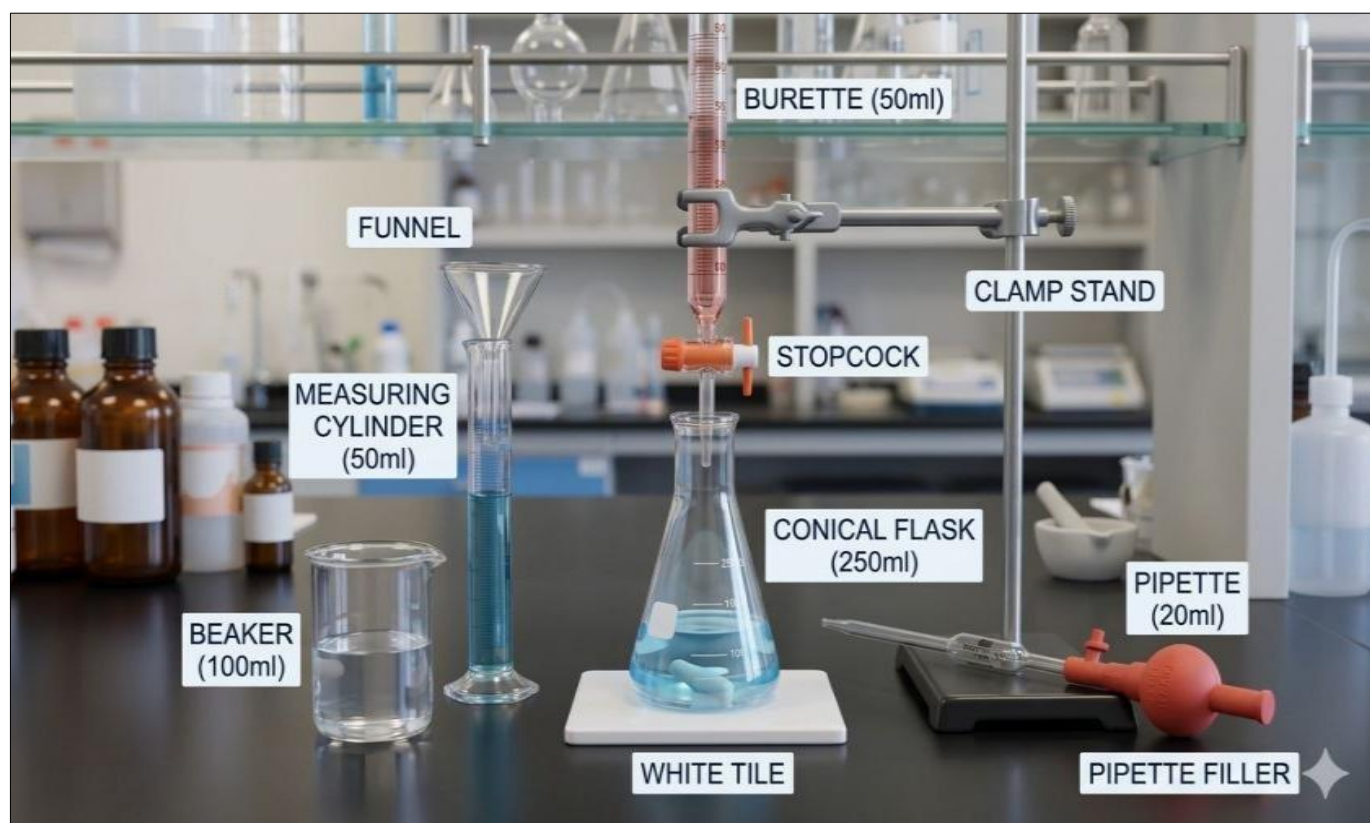


Fig 5

Immediately after collection, the fruits were thoroughly washed with clean water to remove any surface contaminants and dried. The edible portions were then processed to extract the juice. For smaller, firmer fruits, a clean mortar and pestle

or a manual citrus juicer was used. The extracted juice, which contained pulp and seeds, was filtered using a fine muslin cloth followed by filter paper to obtain a clear, homogenous liquid. This filtration is crucial; solid pulp can interfere with the visual

detection of the phenolphthalein endpoint during titration. The collected, filtered juice from each fruit type was considered the stock sample. Before titration, a precise volume (e.g., 10 mL or 25 mL) of this clear juice was carefully pipetted into a clean conical flask and diluted with a small amount of distilled water. Dilution helps ensure the volume inside the flask is sufficient to swirl effectively during titration, without affecting the total amount of acid present in the measured volume of the initial juice sample. The prepared samples were then ready for the titration procedure.

Titration procedure

Rinse a clean burette with distilled water and then filled with a small amount of the 0.1 M NaOH solution. Fill the burette with NaOH, ensuring there are no air bubbles in the tip, and record

the initial volume reading. Using a clean 10 ml pipette, transfer exactly 10 ml of the filtered fruit juice into a 125 ml conical flask. Add approximately 10–20 ml of distilled water to the flask to facilitate easier viewing of the color change. Add around 2–3 drops of phenolphthalein to the juice. Note that for highly colored juices like orange, the change might appear as a darker shade or a shift toward pinkish- orange. Slowly add the NaOH from the burette into the flask while constantly swirling the juice. As the endpoint approaches, add the NaOH drop by drop until a faint pink color persists for at least 30 seconds. Record the final burette reading. The difference between the initial and final readings provides the volume of NaOH required for neutralization. Repeat the titration at least three times for each fruit sample to ensure the results are concordant and to calculate an accurate average volume.

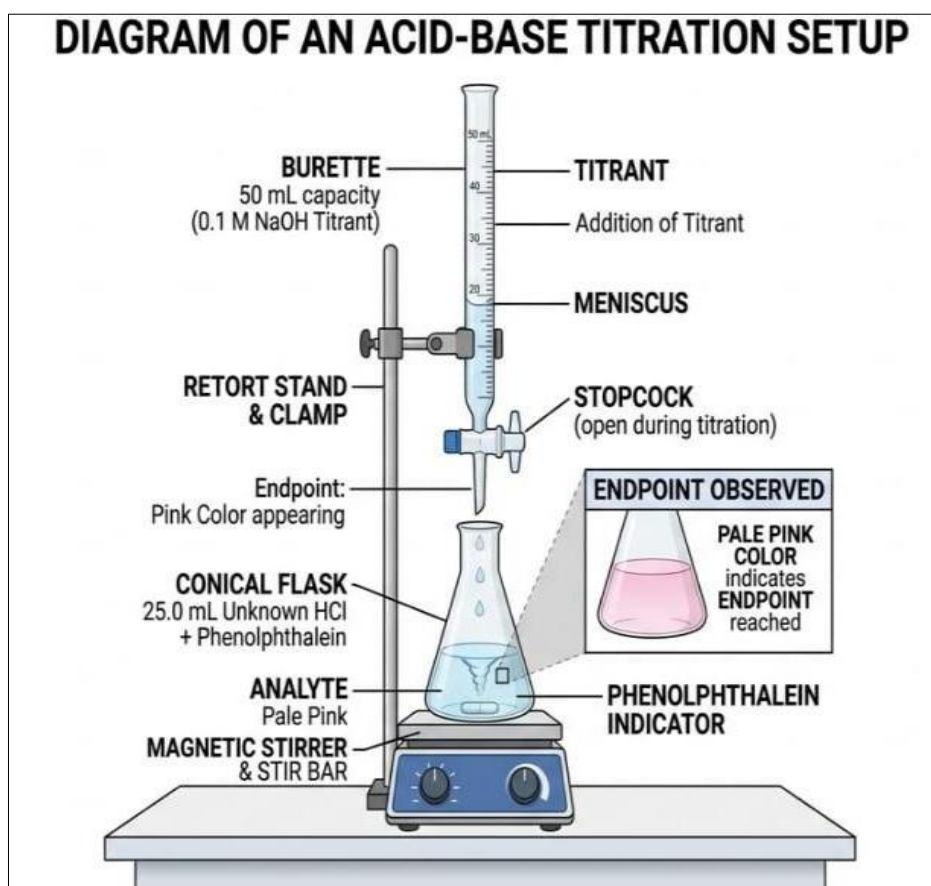


Fig 6

Observation

The following tables present the quantitative data recorded during the titration of various fruit juices (lemon, tamarind, tomato, and sweet lemon) against a standard 0.1 N (or M) sodium hydroxide solution using phenolphthalein as an indicator. All titrations were performed in triplicate for

accuracy and find average volume of NaOH used (ml).
Standard Solution Used: 0.1 N Sodium Hydroxide (NaOH)
Indicator: Phenolphthalein
Volume of Fruit Juice Taken for Each Titration: 250 ml
Number of Trials: Three (Triplicate readings)

Table 1: Titration data for various fruit juices (lemon, tamarind, tomato, and sweet lemon)

S. No.	Name of Fruit Juices	Name of Acids	Volume of Juice taken (ml)	Average Volume of NaOH Used (ml)
1	Lemon Juice	Citric acid	25.0	17.7
2	Tamarind Juice	Tartaric acid	25.0	6.0
3	Tomato Juice	Citric acid & Malic Acid	25.0	8.0
4	Sweet Lime Juice	Citric acid	25.0	4.0

Calculations

Indicator used: Phenolphthalein

Titration follows the principle: **Acid + Base → Salt + Water**

Using the law of equivalence: $N_1 \times V_1 = N_2 \times V_2$

Where-

N_1 = Normality of fruit acid

V_1 = Volume of fruit juice (ml)

N_2 = Normality of NaOH (0.1 N)

V_2 = Average volume of NaOH used (ml)

Volume of juice (V_1) = 25.0 ml

Titrant (NaOH) used (N_2) = 0.1N

Formula used:

$$N_1 = \frac{N_2 \times V_2}{V_1}$$

Strength (g/L) = $N_1 \times$ Equivalent Weight

Result and Discussion

This research paper determine and compare the acid content of selected sour fruits—lemon, tamarind, tomato, and sweet lime using acid–base titration with standard sodium hydroxide solution. The quantitative analysis allowed the estimation of acidity in terms of percentage of predominant organic acid present in each fruit juice. All titrations were performed in triplicate, and average values were considered to improve accuracy and reliability of the results. The experimental results clearly indicate that the selected fruits differ significantly in their acid content. This variation is influenced by the type of organic acid present, the natural composition of the fruit, and its degree of sourness. Citrus fruits such as lemon and sweet lime mainly contain citric acid, while tamarind contains tartaric acid, and tomato contains a mixture of citric and malic acids, expressed in this study as citric acid equivalents. The percentage acidity calculated for each fruit reflects their commonly perceived taste characteristics, thereby validating the experimental approach.

Table 2: Strength of fruit juice in the form of acid content

S. No.	Fruits	Average Volume of NaOH (ml)	Normality (N)	Acid Content (g/l)
1	Lemon	17.7	0.0708	4.53
2	Tamarind	6.0	0.024	1.80
3	Tomato	8.0	0.032	2.05
4	Sweet Lemon	4.0	0.016	1.02

Lemon juice required the highest average volume of sodium hydroxide during titration, indicating a comparatively higher concentration of acid. Based on the calculations, the percentage acidity of lemon juice was found to be approximately 0.45% (as citric acid). This result confirms that lemon is the most acidic among the fruits studied. The high citric acid content explains its strong sour taste and its extensive use in food preservation, beverages, and culinary applications. The obtained value is consistent with the general understanding that lemon juice has a high acidity level among natural fruit juices. Tamarind juice showed a moderate requirement of sodium hydroxide, indicating a lower acid concentration compared to lemon but still significant. The percentage acidity of tamarind juice was calculated to be approximately 0.18% (as tartaric acid). Although tamarind tastes intensely sour, this is partly due to the type of acid present and the presence of other compounds, rather than just the total acid concentration. The results demonstrate that tamarind has a notable but lower acidity than lemon, aligning well with its traditional culinary use as a souring agent rather than a direct acidic additive. Tomato juice required an intermediate volume of sodium hydroxide, reflecting a moderate acid content. The acidity,

expressed as citric acid equivalent, was found to be approximately 0.20%. Tomatoes contain a mixture of organic acids, primarily citric and malic acids, which together contribute to their mild sour taste. The relatively lower acidity compared to lemon explains why tomatoes are less sour and are widely consumed as vegetables and in cooked forms. The result highlights the balanced acidic nature of tomato juice.

Sweet lime juice consumed the least volume of sodium hydroxide among all the samples tested. The percentage acidity was calculated to be approximately 0.10% (as citric acid). Despite belonging to the citrus family, sweet lime contains much lower acid levels, which accounts for its mild and pleasant taste. This result supports its common consumption as a refreshing fruit rather than a sour one. The low acidity makes sweet lime suitable for individuals who prefer fruits with minimal sourness.

The results clearly establish the following order of acidity among the selected fruits:

Lemon > Tomato ≈ Tamarind > Sweet Lime

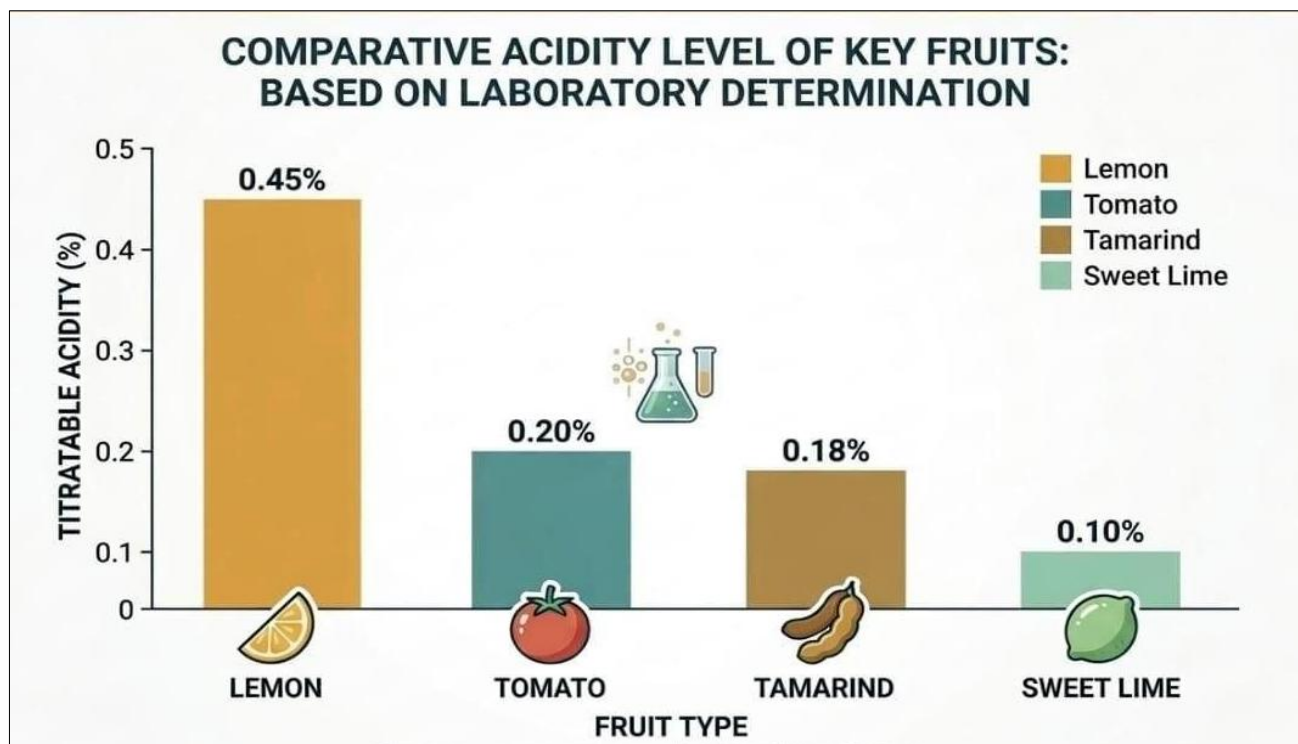


Fig 7

This trend aligns well with everyday experience and culinary usage. Fruits with higher acidity, such as lemon, are commonly used for flavor enhancement, preservation, and beverages, whereas fruits with lower acidity, such as sweet lime, are consumed primarily for refreshment. The consistency between experimental results and practical observations strengthens the validity of the study.

Applications

Food Processing and Preservation

Acidity is one of the most effective natural hurdles against food spoilage. High acid content lowers the pH level of food products, creating an environment that inhibits the growth of pathogenic bacteria and molds. In the processing of jams, jellies, and preserves, the tartaric and citric acids found in these fruits are necessary for pectin gelation. Without precise acid levels, fruit preserves would fail to "set" correctly. This research provides the benchmarks needed for thermal processing and vacuum packaging to extend the shelf life of processed foods without relying solely on synthetic chemicals.

Pharmaceutical and Nutraceutical Industry

The pharmaceutical industry utilizes fruit-derived organic acids as excipients and stabilizers. Citric acid, for instance, acts as a buffering agent to maintain the pH stability of liquid medications, preventing the active ingredients from breaking down. Additionally, the effervescent effect in "fizzy" tablets (such as Vitamin C or antacids) is produced by the reaction between these fruit acids and carbonates. In the nutraceutical sector, this research helps in formulating supplements that utilize natural acidity to improve the bioavailability of minerals like iron and calcium in the human gut.

Cosmetics and Personal Care

In the cosmetics industry, the acids found in lemon and tomato are classified as Alpha Hydroxy Acids (AHAs). These are prized for their keratolytic properties, meaning they help in chemical exfoliation by dissolving the "glue" between dead skin cells. This research is instrumental for formulators developing skin-brightening serums, anti-acne creams, and chemical peels. Furthermore, fruit acids are used to balance the pH of shampoos and soaps to match the natural acid mantle of human skin, reducing irritation and enhancing the efficacy of hair care products.

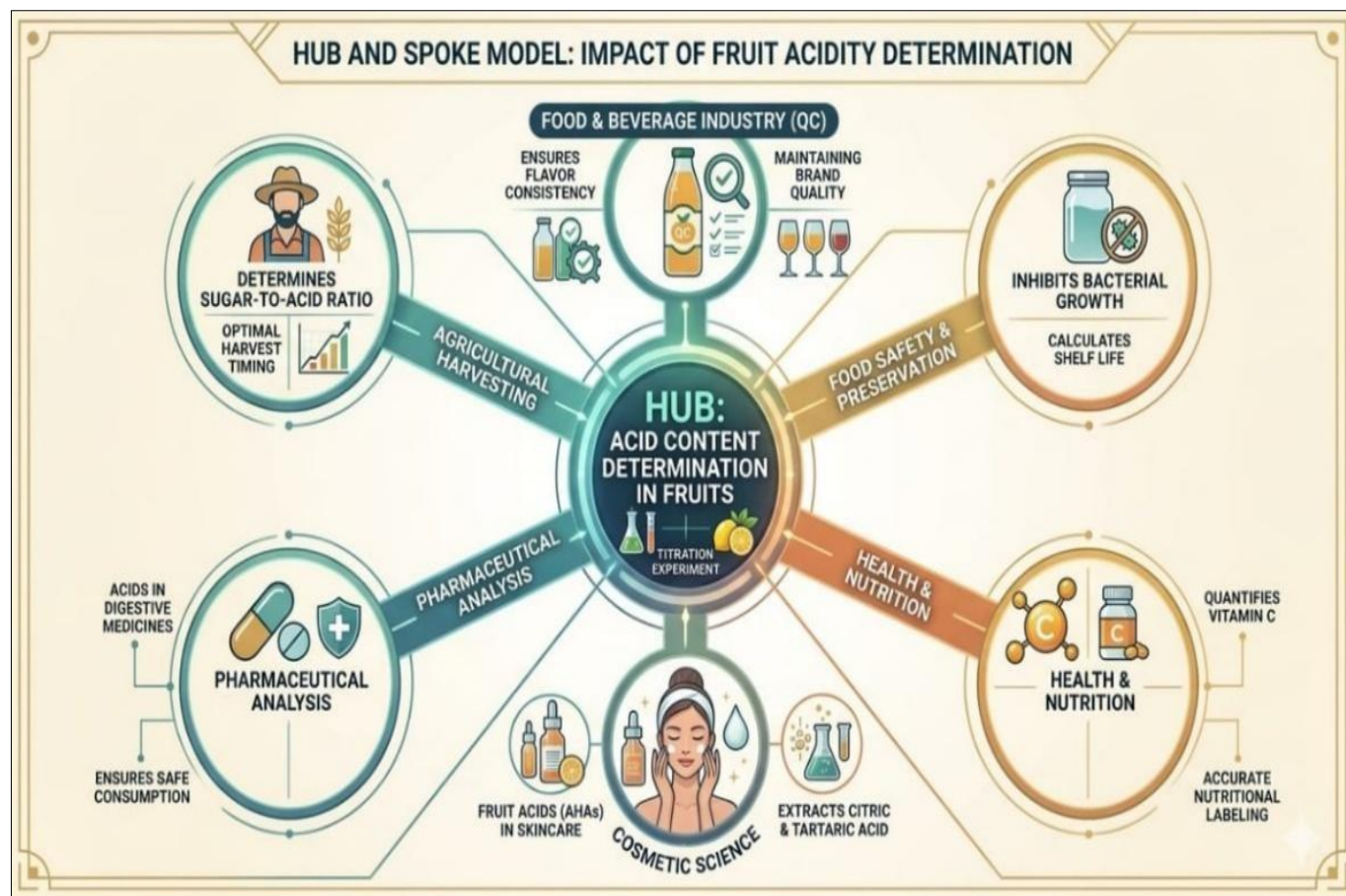


Fig 8

Health, Nutrition, and Clinical Research

From a nutritional standpoint, the organic acid content of these fruits plays a significant role in metabolic health. For example, the citric acid in lemons and sweet limes is known to increase urinary citrate levels, which helps prevent the formation of calcium oxalate kidney stones. This research provides clinical data on the "citrate-to-sugar" ratio in fruits, helping dietitians design therapeutic diets. Additionally, the antioxidants often bound to these organic acids help in neutralizing free radicals, contributing to overall cellular health and anti-inflammatory responses.

Conclusion

The present research paper, entitled "Determination of Acid Contents in Some Sour Fruits," was conducted with the objective of estimating and comparing the acidity of commonly consumed fruits—lemon, tamarind, tomato, and sweet lime—using a standard acid–base titration method. The experimental findings clearly demonstrated that the selected fruits vary considerably in their acid content. Among all the samples analyzed, lemon juice exhibited the highest acidity, confirming its rich content of citric acid and its characteristic sharp sour taste. Tomato and tamarind juices showed moderate acidity, while sweet lime possessed the lowest acid content, explaining its mild and pleasant flavor despite being a citrus fruit. The observed order of acidity—lemon > tomato ≈ tamarind > sweet lime was consistent with common sensory experience and culinary usage. The results strongly supported the initial

hypothesis that lemon would contain the highest level of acid and that sweet lime would show comparatively low acidity. The use of triplicate titrations improved the reliability of the data, and the consistency of results across trials confirmed the effectiveness of titration as a quantitative analytical technique for estimating acid content in fruit juices. Although minor experimental limitations such as endpoint detection and natural variation in fruit composition were present, they did not significantly affect the overall trend or validity of the results. The study highlights that acidity in fruits is influenced not only by the quantity of acid present but also by the type of organic acid and the presence of other constituents.

In conclusion, this investigation provides a clear comparative understanding of acid content in selected sour fruits and demonstrates the practical application of chemical principles in food analysis. The study also emphasizes the importance of acidity in determining the taste, nutritional value, and culinary use of fruits. Thus, the research successfully bridges theoretical chemistry with real-life applications and lays a foundation for further studies on food chemistry and quality analysis.

References

1. Pal D, Sharma A. Comparative titrimetric determination of acidity in fruits. *Food Science Research Journal*. 2017;8(2):210-215.
2. Mohammed AS, et al. Determination of citric acid levels in various drinks using standard titration. *International Journal of Scientific Research Publications*. 2014;4(12):1-5.

3. Dioha IJ. Ascorbic Acid (Vitamin C) protocol for iodometric titration across different temperature regimes. *International Journal of Pure and Applied Sciences*. 2011;4(2):112-118.
4. Pithava P, Pandey S. Determination of Acid Content by Titration including 192.12 g/mol molar mass calculations for citric acid. *International Journal of Pharmaceutical Sciences and Research*. 2018;9(6):2450-2456.
5. Mohammed AS, et al. Quantitative Assessment study comparing citric acid content in lemons, oranges, and grapes. *ResearchGate*, 2022.
6. Humayun S, et al. Effect of Citric and Malic Acid on Shelf Life and organoleptic taste differences. *Journal of Food Quality*. 2020;2020:44-51.
7. Amar S. Comparative Studies of Malic Acid and Citric Acid Contents in Mango during ripening. *Journal of Agricultural Sciences*. 2021;13(4):112-119.
8. Ranganna S. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*. Tata McGraw-Hill, New Delhi, 1986, 1112.
9. Sharma BK. *Instrumental Methods of Chemical Analysis*. Goel Publishing, Meerut, 2000, 450.
10. Yadav AK, Singh SV. Comparative analysis of citric acid content in citrus fruits. *Journal of Food Chemistry*. 2014;148:75-80.
11. FSSAI. *Manual of Methods of Analysis of Foods: Fruit and Vegetable Products*. Food Safety and Standards Authority of India, 2016;1:22-45.
12. IFU. Method Number 3: Determination of titratable acidity in the global beverage industry. *International Federation of Fruit Juice Producers*, 2005.
13. Kumar R, et al. Organic acid profile in tamarind pulp. *International Journal of Food Properties*. 2018;21(1):33-42.
14. Singh R, Meena A. Malic and citric acid quantification in tomato using titration method. *Journal of Analytical Chemistry in Food*. 2019;11(2):24-29.