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Integrated Assessment of Vitamin C Content, Acidity, and Total Titratable Acidity in Fresh Fruits and Commercial Fruit Beverages Using Classical Analytical Methods

Putri Tasnim [1], Maya Rosita[1], Dara Balqis[1], Melani Reski Amanda TB[1]

[1]Department of Food Technology, Faculty of Agricultural Technology, Universitas Serambi Mekkah, Banda Aceh, Indonesia

Email: putritasnim150@gmail.com

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ABSTRACT
Fresh fruits and fruit-derived beverages are important dietary sources of vitamin C and organic acids that contribute to nutritional quality, sensory characteristics, and product stability. The simultaneous evaluation of vitamin C content, pH, and total titratable acidity provides a comprehensive understanding of the physicochemical quality of agricultural products. This study aimed to determine these three quality parameters in selected fresh fruits and commercially processed fruit beverages using conventional laboratory analytical methods. Fresh orange, fresh guava, fresh mango juice, commercial orange beverage, commercial guava beverage, and commercial mango beverage were analyzed. The pH was measured using a calibrated pH meter, vitamin C content was determined by iodometric titration, and total titratable acidity was quantified through acid-base titration with standardized sodium hydroxide solution. The obtained data were compared to evaluate variations in nutritional and physicochemical characteristics among the analyzed samples.
All samples exhibited acidic properties, with pH values ranging from 4.00 to 5.68. Fresh guava contained the highest vitamin C concentration (50.60 mg/100 g), followed by fresh orange (26.40 mg/100 g), whereas commercial beverages generally showed lower vitamin C levels. Commercial fruit beverages exhibited lower pH values and, in several cases, higher total titratable acidity than their corresponding fresh fruits, reflecting differences associated with product formulation and processing. The findings demonstrate that pH, vitamin C content, and total titratable acidity provide complementary information for evaluating food quality and should therefore be interpreted collectively rather than independently.

This study confirms that classical analytical methods remain reliable, practical, and cost-effective tools for assessing the nutritional and physicochemical quality of fresh fruits and processed fruit beverages while supporting routine laboratory quality evaluation. This review highlights One Health as the most comprehensive framework for addressing climate-sensitive infectious diseases by integrating animal, human, and environmental health. The findings provide a multidisciplinary scientific foundation for developing evidence-based policies and sustainable adaptation strategies that strengthen livestock resilience, protect food security, and improve preparedness for future climate-related disease threats.

Keywords: *vitamin C; pH; total titratable acidity; fruit quality; iodometric titration.*

INTRODUCTION

Fruits and fruit-derived products are widely recognized as essential components of a healthy diet because they provide a diverse range of nutrients and bioactive compounds that contribute to human health and disease prevention. Among these constituents, vitamin C (ascorbic acid) is one of the most important water-soluble antioxidants naturally present in fruits and vegetables. It plays indispensable physiological roles in collagen synthesis, immune regulation, wound healing, iron absorption, and cellular protection against oxidative stress induced by reactive oxygen species. Consequently, adequate dietary intake of vitamin C has been consistently associated with improved health outcomes and a reduced risk of chronic degenerative diseases. Fresh fruits such as oranges, guavas, mangoes, tomatoes, and other horticultural commodities represent major natural sources of vitamin C, making the preservation of this nutrient a critical aspect of food quality assessment (Winarno, 2008). However, vitamin C is highly unstable and readily undergoes oxidative degradation when exposed to oxygen, elevated temperatures, light, enzymatic activity, and prolonged storage. Such degradation may occur throughout harvesting, postharvest handling, transportation, processing, packaging, distribution, and storage, resulting in substantial losses of nutritional value. Therefore, determination of vitamin C concentration has become an important indicator for evaluating both the nutritional quality and freshness of agricultural products. Among the available analytical techniques, iodometric titration remains one of the most practical and widely adopted methods because it is inexpensive, relatively accurate, simple to perform, and suitable for routine laboratory applications based on the oxidation–reduction reaction between iodine and ascorbic acid (Fitriana & Fitri, 2020). As global demand for high-quality fresh produce and processed fruit beverages continues to increase, reliable analytical approaches capable of accurately assessing nutritional quality have become increasingly important for food quality assurance, consumer protection, and educational laboratory training.

The nutritional value of fruits cannot be comprehensively assessed through vitamin C determination alone because physicochemical characteristics also play a fundamental role in defining food quality, stability, sensory attributes, and consumer acceptance. Among these characteristics, acidity is one of the most important indicators influencing flavor, texture, color stability, enzymatic activity, microbial growth, and shelf life. The hydrogen ion concentration (pH) is widely used to describe the acidity or alkalinity of food matrices and has become an indispensable parameter in food quality evaluation. Fruit products generally possess acidic pH values owing to the presence of naturally occurring organic acids such as citric, malic, tartaric, and ascorbic acids. Lower pH values generally suppress microbial proliferation, thereby enhancing product safety and extending storage stability (Angelia, 2017). Nevertheless, pH alone reflects only the concentration of free hydrogen ions and does not adequately represent the total amount of acids present within a sample. Consequently, determination of Total Titratable Acidity (TTA) has become an equally important analytical parameter because it quantifies the cumulative concentration of titratable organic acids that contribute to sourness, flavor balance, biochemical stability, and postharvest quality. The combined evaluation of vitamin C, pH, and TTA therefore provides a more comprehensive understanding of fruit quality than any single parameter alone. Such integrated physicochemical assessment is increasingly recognized as an effective approach for evaluating nutritional quality, monitoring processing effects, supporting quality control, and ensuring product consistency across fresh fruits and commercially processed beverages (Angelia, 2017).

Despite the availability of numerous analytical techniques for food quality assessment, accurately evaluating the nutritional and physicochemical characteristics of fruit products remains challenging because each analytical parameter describes only one aspect of overall quality. Modern analytical techniques such as high-performance liquid chromatography, spectrophotometry, and near-infrared spectroscopy provide highly sensitive and precise measurements; however, they require sophisticated instrumentation, extensive technical expertise, and relatively high operational costs that may limit their accessibility in routine educational or quality-control laboratories. Consequently, there remains a practical need for analytical approaches that are reliable, economical, reproducible, and sufficiently accurate for routine laboratory applications. Classical laboratory methods—including iodometric titration for vitamin C determination, direct pH measurement using a calibrated pH meter, and acid–base titration for total titratable acidity—continue to satisfy these requirements because they provide reproducible measurements using relatively simple laboratory equipment (Fitriana & Fitri, 2020; Angelia, 2017). Nevertheless, these analytical methods are frequently applied independently, potentially limiting the comprehensive interpretation of fruit quality. Therefore, integrating multiple physicochemical indicators into a single analytical framework represents a more appropriate strategy for evaluating the nutritional composition, acidity characteristics, and overall quality of agricultural products while simultaneously improving understanding of fundamental food chemistry principles.

Previous investigations have consistently demonstrated the importance of integrating vitamin C analysis with acidity measurements to characterize fruit quality. Iodometric titration has been recognized as a practical and dependable analytical method for quantifying ascorbic acid because of its rapid analytical procedure, low operational cost, and satisfactory accuracy under standard laboratory conditions (Fitriana & Fitri, 2020). However, the reliability of vitamin C determination depends heavily on proper sample handling because ascorbic acid is readily oxidized during sample preparation and storage (Fitri, 2020). Likewise, pH measurement has become an established indicator of acidity, microbial stability, and sensory quality, while TTA determination provides a more comprehensive estimate of the total concentration of organic acids than pH alone (Angelia, 2017). The use of standardized sodium hydroxide titration with phenolphthalein as an endpoint indicator remains the conventional procedure for determining total titratable acidity in fruits and beverages (Hidayati, 2024). More recently, scientific evidence has emphasized that vitamin C, pH, and TTA are closely interconnected physicochemical parameters whose relationships vary according to fruit species, maturity stage, processing conditions, storage duration, and formulation. Simultaneous assessment of these parameters provides a more reliable representation of nutritional quality, maturity, freshness, and processing effects than isolated analyses, thereby supporting food quality evaluation, postharvest research, and quality assurance programs (Sapei, 2024). These findings indicate that integrated physicochemical analysis constitutes an appropriate and scientifically supported approach for evaluating the quality characteristics of both fresh fruits and processed fruit beverages.

Based on these considerations, the present study aimed to determine vitamin C content, pH, and total titratable acidity in selected fresh fruits and commercially processed fruit beverages using conventional analytical methods routinely employed in food chemistry laboratories. Specifically, iodometric titration was applied for vitamin C determination, direct pH measurement was used to evaluate acidity, and acid–base titration was employed to quantify total titratable acidity. The novelty of this study does not arise from the development of new analytical techniques but from the integrated application of three complementary physicochemical indicators to generate a comprehensive assessment of fruit quality within a unified experimental framework. It was hypothesized that samples containing higher concentrations of organic acids, including ascorbic acid, would generally exhibit lower pH values and relatively higher total titratable acidity, reflecting the intrinsic relationships among these quality parameters. The scope of this investigation was therefore limited to the comparative laboratory evaluation of selected fresh fruits and commercial fruit beverages with the objective of improving understanding of nutritional and physicochemical quality assessment while demonstrating the continued relevance of classical analytical methods as reliable, accessible, and cost-effective tools for routine food quality evaluation and laboratory education.

RESEARCH METHOD

Materials

The study was conducted using both fresh fruits and commercially processed fruit beverages as representative agricultural products. The analyzed samples consisted of fresh oranges (*Citrus sinensis*), fresh guavas (*Psidium guajava*), commercial orange juice (Buavita Orange), and commercial guava juice (Buavita Guava). Distilled water was used for sample dilution when required. The analytical reagents included 0.01 N iodine solution for vitamin C determination, 0.1 N sodium hydroxide (NaOH) as the titrant for total titratable acidity analysis, soluble starch solution as the indicator for iodometric titration, and phenolphthalein (PP) indicator for acid-base titration.

The laboratory equipment included a laboratory blender, volumetric flasks, pipettes, Erlenmeyer flasks, filter paper, spatulas, analytical glassware, and a calibrated digital pH meter for acidity measurements.

Sample Preparation

Each fresh fruit sample was washed thoroughly before analysis. Approximately 100 g of edible tissue was weighed and homogenized using a laboratory blender to obtain a uniform sample. For samples with relatively low moisture content, 100 mL of distilled water was added prior to homogenization to achieve a 1:1 (w/v) dilution. The homogenate was subsequently filtered through filter paper to obtain a clear filtrate for vitamin C and total titratable acidity analyses. Commercial fruit beverages were analyzed directly without additional homogenization.

Determination of pH

The pH of each sample was determined using a calibrated digital pH meter. Approximately 100 g of homogenized sample was prepared as described previously. For low-moisture samples, distilled water was added at a ratio of 1:1 (w/v) before homogenization to facilitate measurement. The electrode of the pH meter was immersed directly into the homogenized sample, and the pH value was recorded after the reading had stabilized. Each sample was measured in triplicate, and the average value was reported as the final pH.

Determination of Vitamin C Content

Vitamin C (ascorbic acid) content was determined using the iodometric titration method. Twenty-five milliliters of the filtered sample were transferred into an Erlenmeyer flask, followed by the addition of several drops of starch indicator. The solution was titrated with standardized 0.01 N iodine solution until the appearance of a stable blue-violet endpoint, indicating complete oxidation of ascorbic acid. The vitamin C concentration was calculated using the following equation:

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Volume of 0.01 N iodine (mL)} \times 0.88 \times P \times 100\}}{\text{weight (g)}}$$

Where P is dilution factor. The calculated values were expressed as milligrams of ascorbic acid per 100 g of sample.

Determination of Total Titratable Acidity

Total titratable acidity (TTA) was determined by acid-base titration using standardized sodium hydroxide solution. Fifty milliliters of each sample were transferred into a 100-mL volumetric flask and diluted to the calibration mark with distilled water. The diluted solution was filtered through filter paper to obtain a clear filtrate. Twenty milliliters of the filtrate were transferred into an Erlenmeyer flask, and three drops of phenolphthalein indicator were added. The solution was titrated with standardized 0.1 N NaOH until a persistent pale pink color appeared, indicating the titration endpoint. The volume of NaOH consumed during titration was recorded. Total titratable acidity was calculated using the following equation:

$$\text{Total Titratable Acidity} = \frac{\text{ml NaOHx N NaOHx BM NaOH}}{\text{Sample weight}}$$

The calculated acidity values were expressed as the percentage of the predominant organic acid present in the analyzed sample.

Data Analysis

All physicochemical analyses, including pH measurement, vitamin C determination, and total titratable acidity analysis, were performed according to standard laboratory procedures. The pH measurements were conducted in triplicate, and the mean value was reported. Vitamin C and total titratable acidity were calculated using the corresponding analytical equations based on titration data. The results were subsequently compared among fresh fruits and commercial fruit beverages to evaluate differences in nutritional quality and physicochemical characteristics.

RESULTS AND DISCUSSION

Physicochemical Characteristics of Fresh Fruits and Commercial Fruit Beverages

The physicochemical characteristics of the analyzed agricultural products, including fresh fruits and commercially processed fruit beverages, are presented in Table 1. Three quality indicators were evaluated, namely pH, vitamin C content, and total titratable acidity (TTA), to provide an integrated assessment of the nutritional and chemical properties of each sample.

Table 1. Physicochemical characteristics of fresh fruits and commercial fruit beverages.

Sample	pH	Vitamin C (mg/100 g)	Total Titratable Acidity
Buavita Orange	4.00	0.288	0.74
Buavita Guava	4.02	24.64	1.10
Fresh Orange	5.44	26.40	0.80
Fresh Guava	4.67	50.60	0.18
Fresh Mango Juice	5.68	22.00	0.44
Buavita Mango	4.20	13.38	0.20

The analyzed samples exhibited noticeable variation in pH, vitamin C concentration, and total titratable acidity, reflecting differences in fruit species, processing conditions, and chemical composition. Overall, the pH values ranged from 4.00 to 5.68, indicating that all samples were acidic, which is characteristic of fruit products due to the presence of naturally occurring organic acids. Likewise, vitamin C concentrations and titratable acidity varied

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considerably among the analyzed samples, demonstrating that nutritional quality and acidity cannot be adequately represented by a single physicochemical parameter.

pH Characteristics of the Analyzed Samples

The pH values obtained in this study confirmed that all fresh fruits and commercial beverages belonged to the acidic food category. Fresh orange exhibited an average pH of 5.44, while fresh guava showed a lower average pH of 4.67 (Figure 1). Commercial beverages presented even lower pH values, with Buavita Orange and Buavita Guava recording average pH values of 4.00 and 4.02, respectively. Similarly, fresh mango juice exhibited a higher pH (5.68) than commercial Buavita Mango (4.20).

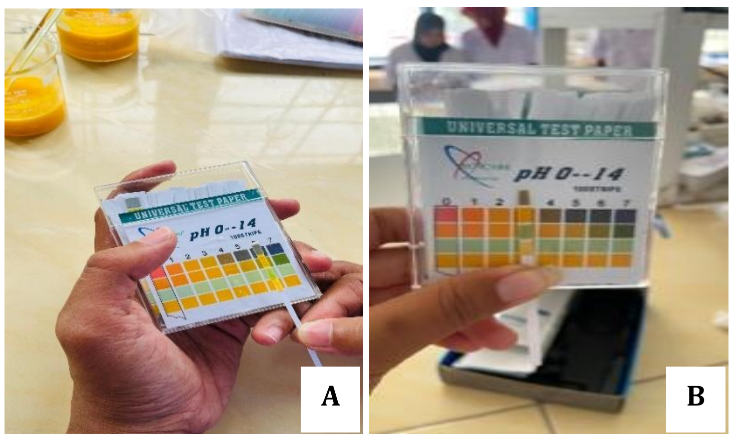

Figure 1. pH levels of guava (A) and oranges (B) measured using pH test strips (Source: research documentation)

These findings indicate that processed fruit beverages generally possess lower pH values than their corresponding fresh fruits. This observation is consistent with the formulation of commercial beverages, which often includes acidulants such as citric acid to improve flavor stability, microbial safety, and shelf life. The naturally acidic environment also inhibits microbial growth, thereby enhancing product preservation.

The acidity of fruits is primarily attributed to organic acids, including citric acid, malic acid, and ascorbic acid. Previous studies have shown that pH is an important indicator of fruit maturity, freshness, sensory quality, and storage stability. Lower pH values generally contribute to greater microbial stability and prolonged shelf life, whereas higher pH values may increase susceptibility to microbial spoilage (Angelia, 2017). Therefore, pH measurement provides valuable information regarding both the physicochemical quality and preservation characteristics of agricultural products.

Vitamin C Content

The vitamin C analysis revealed considerable variation among the analyzed samples. Fresh guava exhibited the highest vitamin C concentration (50.60 mg/100 g), followed by fresh orange (26.40 mg/100 g), Buavita Guava (24.64 mg/100 g), fresh mango juice (22.00 mg/100 g), Buavita Mango (13.38 mg/100 g), and Buavita Orange (0.288 mg/100 g).

The exceptionally high vitamin C concentration observed in fresh guava agrees with its well-established reputation as one of the richest natural sources of ascorbic acid. Fresh fruits generally contained higher vitamin C concentrations than commercially processed beverages, suggesting that industrial processing, storage, and packaging may contribute to partial degradation of ascorbic acid. Vitamin C is highly susceptible to oxidation when exposed to oxygen, elevated temperatures, light, and prolonged storage. Consequently, thermal processing and post-processing storage frequently reduce vitamin C concentration in fruit-derived products.

The markedly low vitamin C value obtained for Buavita Orange may also reflect analytical variability associated with sample preparation, dilution factors, or oxidation during analysis. Since iodometric titration depends on the reducing capacity of ascorbic acid, improper sample handling can substantially influence analytical results. Nevertheless, the overall trend supports previous findings that fresh fruits generally retain higher vitamin C concentrations than processed beverages because of reduced exposure to degradation factors (Fitriana & Fitri, 2020; Fitri, 2020).

From a nutritional perspective, vitamin C serves as a major antioxidant that protects biological tissues against oxidative damage, supports collagen synthesis, enhances immune function, and facilitates iron absorption. Therefore, maintaining high vitamin C content is an important quality objective for both fresh produce and processed fruit products.

Total Titratable Acidity

Total titratable acidity (TTA) also differed among the analyzed samples. The highest TTA was recorded in Buavita Guava (1.10), followed by fresh orange (0.80), Buavita Orange (0.74), fresh mango juice (0.44), Buavita Mango (0.20), and fresh guava (0.18). Unlike pH, which measures only free hydrogen ion concentration, TTA represents the total amount of titratable organic acids contained within the sample. Consequently, two samples may exhibit similar pH values while possessing substantially different total acidity because of differences in acid composition and buffering capacity.

The relatively high titratable acidity observed in commercial beverages may be attributed to the addition of food-grade organic acids during processing to improve flavor, product stability, and microbial preservation. Organic acids such as citric acid are commonly incorporated into fruit beverages to achieve desirable sensory characteristics and extend shelf life. Previous studies have emphasized that total titratable acidity provides a more comprehensive assessment of fruit acidity than pH alone because it measures all neutralizable acids present within the sample (Hidayati, 2024). Consequently, TTA analysis remains an essential component of routine food quality evaluation.

Relationship among pH, Vitamin C, and Total Titratable Acidity

The present study demonstrates that pH, vitamin C, and total titratable acidity are complementary rather than independent quality indicators. Although samples with higher concentrations of organic acids generally exhibited lower pH values, the relationship was not perfectly linear because pH is influenced by free hydrogen ion activity, whereas TTA reflects the cumulative concentration of all titratable acids. Likewise, vitamin C contributes only a portion of the total organic acid pool present in fruits.

Fresh guava provides an interesting example of this relationship. Despite possessing the highest vitamin C concentration, it exhibited the lowest total titratable acidity among the analyzed fruits, indicating that ascorbic acid alone does not determine overall acidity. Conversely, commercial guava beverage presented the highest TTA despite containing lower vitamin C, suggesting that additional organic acids incorporated during processing contributed substantially to total acidity.

These observations agree with previous reports indicating that vitamin C, pH, and titratable acidity should be interpreted collectively when evaluating food quality, nutritional value, maturity, and processing effects. Simultaneous determination of these parameters provides a more comprehensive characterization of agricultural products than individual measurements alone (Sapei, 2024).

Overall, the findings demonstrate that fresh fruits generally retain higher vitamin C concentrations, whereas commercially processed fruit beverages tend to exhibit lower pH values and, in several cases, higher titratable acidity due to formulation and preservation practices. Therefore, integrating vitamin C determination with pH and TTA measurements represents a practical and reliable approach for assessing the nutritional and physicochemical quality of fresh and processed fruit products.

CONCLUSION

This study demonstrated that the combined determination of pH, vitamin C content, and total titratable acidity provides a comprehensive evaluation of the physicochemical and nutritional quality of fresh fruits and commercially processed fruit beverages. The analyzed samples exhibited acidic characteristics, with pH values ranging from 4.00 to 5.68, reflecting the natural presence of organic acids. Fresh fruits generally contained higher concentrations of vitamin C than commercial beverages, indicating that processing and storage may reduce ascorbic acid content through oxidative degradation. Conversely, several processed beverages exhibited lower pH values and higher titratable acidity, likely due to the addition of food-grade organic acids to enhance product stability, flavor, and shelf life. These findings demonstrate that pH, vitamin C, and total titratable acidity should be interpreted collectively, as each parameter provides complementary information regarding food quality rather than functioning independently.

The study contributes to the existing knowledge by demonstrating the practical application of classical analytical methods, including iodometric titration, pH measurement, and acid-base titration, for the integrated assessment of agricultural products. These methods remain reliable, cost-effective, and suitable for routine laboratory analysis and educational purposes. Future studies should incorporate a larger number of fruit species, replicate analyses with statistical validation, and advanced analytical techniques such as high-performance liquid chromatography (HPLC) to improve the accuracy of vitamin C quantification and further investigate the influence of processing and storage conditions on fruit quality.

AI Declaration

The authors declare that Artificial Intelligence (AI) tools were used only as assistive instruments during the preparation of this manuscript. Specifically, ChatGPT, Grammarly, Quillbot was used to support language clarity, grammar, and formatting. The AI tool did not generate, fabricate, or manipulate research data, analysis, interpretations, or references. All AI-generated outputs were carefully reviewed, verified, and edited by the authors, who take full responsibility for the content of the manuscript. This use of AI complies with the Publication Ethics and Malpractice Statement of the ***Journal of Animal, Food and Environmental Sciences (JAFES).***

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None.

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