

Developmental Analysis of Sugar-Acid Ratio and Ripening Characteristics in Guimaras Mangoes

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Abstract: - This study evaluates the developmental changes in physical and chemical attributes of Guimaras mangoes during ripening, focusing on the sugar-acid ratio and maturity indicators. As mangoes ripen, starch hydrolyzes into sugars, causing a sharp decrease in titratable acidity and a substantial rise in total soluble solids (TSS). Optimal ripening involves increasing total sugars and carotenoids, resulting in yellow-orange pulp color, while fruit firmness decreases due to pectin degradation. Results indicate that maximum sensory quality and sweetness, characterized by high sugar-acid ratios, are achieved when fruit is allowed to reach full maturity (typically 110+ days after flowering) before ripening.

Key-Words: - *Mangifera indica*, ripening characteristics, ripening characteristics, sugar-acid ratio, titratable acidity, total soluble solids

Received: May 27, 2025. Revised: August 14, 2025. Accepted: September 19, 2025. Published: April 9, 2026.

1 Introduction

The Guimaras mango renowned for its exceptional sweetness, fiber less flesh, and vibrant color, is a premier agricultural product of the Philippines, benefiting from a unique, protected, and climate-specific growing environment. A developmental analysis of its sugar-acid ratio is crucial to understanding the complex biochemical changes—specifically the conversion of starch into sugars and the reduction of organic acids—that occur from maturity to ripening, directly impacting consumer quality (Amber, 2021 & Dick, 2025).

This study investigates the physiological and biochemical transformations occurring during the postharvest ripening of Guimaras mangoes, which are highly sensitive to handling and storage conditions (Kaur, 2026 & Yin, 2025). As a climacteric fruit, mango undergoes a sharp increase in respiration and ethylene production, triggering rapid softening and flavor development. Analyzing these, alongside changes in total soluble solids (TSS), provides a comprehensive overview of the ripening profile.

The sugar-acid ratio, a fundamental index for evaluating mango maturity and flavor, changes dynamically as the fruit matures (Ghimere, 2025 & Zhai, 2026). While starch levels are high at the mature-green stage, they decrease during ripening

due to hydrolysis, leading to an increase in sugar content (Kyaing, 2023 & Wang, 2025). Concurrently, titratable acidity (TA) decreases, and the balance between these sugars and acids defines the final eating quality.

This research aims to determine the optimal harvest time by analyzing the chemical compositions such as reducing sugars, titratable acidity, and pH—at different developmental stages. Understanding the kinetics of these parameters is vital for identifying the precise, optimal maturity stage that guarantees the best organoleptic characteristics (sweetness, aroma, and texture) for export and domestic markets.



Figure 1. Guimaras Mangoes

Ultimately, this analysis provides essential data to enhance postharvest practices for Guimaras

mangoes, helping to manage the ripening process, reduce spoilage, and maintain high standards of quality. (Megha, 2022 & Singh, 2025) By establishing a clear, science-backed timeline of development, producers can ensure the consistent, superior taste that defines this premium, locally protected product

2 Developmental Changes in Sugar-Acid Ratio

The Guimaras mango, primarily of the Carabao variety, is globally recognized for its extreme sweetness, with some fruits reaching a Brix content of 21.3° or higher. Its developmental profile during ripening is characterized by a rapid conversion of starch to sugars and a simultaneous decline in organic acids, resulting in a significantly elevated sugar-acid ratio that defines its "world's sweetest" status. The sugar-acid ratio is the primary indicator of flavor quality in Guimaras mangoes. This ratio increases dramatically as the fruit transitions from the mature-green stage to full ripeness).

2.1 Sugar Accumulation (Brix)

At the mature-green stage, total soluble solids (TSS) are typically low, ranging from 7-11° Brix.

During ripening, starch is hydrolyzed into soluble sugars (sucrose, glucose, and fructose), causing TSS to rise to 18-21° Brix in fully ripe Guimaras mangoes

2.2 Acidity Decline

Acidity starts high (roughly 2.71%) and drops sharply as organic acids (primarily citric and malic) are consumed during respiration. In fully ripe fruit, titratable acidity can fall to as low as 0.04% to 0.31%.

2.3 The Resulting Ratio

The sugar-acid ratio typically ranges from 23 to 50 in high-quality mangoes, but exceptional varieties like those from Guimaras can exceed these standards significantly at the final edible stage.

3 Factors Influencing Quality

Harvesting too early results in poor color and low sugar content, while late harvesting can lead to jelly seed (internal breakdown) and reduced shelf life.

The sweetness of Guimaras mangoes is specifically linked to the island's sandy soil, which provides excellent internal drainage, and favorable climatic conditions. Cultural practices, such as bagging and proper nursery management, are critical for maintaining the high export quality of the fruit.

4 Key Ripening Characteristics

Ripening in Guimaras mangoes follows a climacteric pattern, meaning they undergo a sharp increase in respiration and ethylene production after harvest

Table 1. Key Ripening Characteristics

Characteristic	Mature-Green Stage	Fully Ripe Stage
Pulp Color	White to pale yellow	Deep yellow to orange-yellow
Firmness	Highly firm (high penetrometer resistance)	Soft (due to pectin and starch degradation)
Peel Color	Dark green to light green	Full yellow or orange yellow
Aroma	Neutral "grassy" or	Strong aromatic profile (esters, ketones, terpenoids)

3.1 Hot Water Treatment (HWT)

This process is a mandatory requirement for export-bound Guimaras mangoes to control post-harvest diseases and ensure uniform ripening.

Mature-green mangoes are immersed in heated water at 52 deg C to exactly 10 minutes. The heat effectively kills fungal spores responsible for anthracnose and stem-end rot, which are the leading causes of fruit decay and flavor degradation during transit. Beyond disease control, HWT improves final peel color (making it a more vibrant yellow) and helps remove fresh latex stains that can burn the skin. While it costs approximately \$550 per kilo to perform, it is essential for maintaining the "Guimaras" brand standard in international market

3.2 Advanced Post Harvest Facilities

Guimaras recently deployed its second Integrated Mango Post-Harvest Facility in Sibunag, which modernizes these processes:

3.2.1 Automation

Minimize fruit mishandling during the treatment process, ensuring consistent quality.

3.2.2 Extended Shelf-Life

Treated fruits maintain their acceptability and yellow color for up to 6–9 days longer than untreated fruit.

3.3 Harvesting Efficiency Tools

To prevent physical damage that could lead to rapid acid fermentation, Guimaras farmers use specialized harvesting tools

3.3.1 V-Sigpao Mechanical Fruit Picker

Designed to cut the pedicel (stem) in a way that reduces latex overflow, preventing "sap burn" which spoils the fruit's appearance and increases rot risk.

3.3.2 Mango Power Y-Sprayer

Enhances the efficiency of pre-harvest treatments to ensure fewer pests reach the post-harvest stage.

4 Problem Formulation

The core problem regarding the developmental analysis of sugar-acid ratios and ripening in Guimaras mangoes lies in maintaining consistent, high-quality, and market-standard edible characteristics across varied harvest maturities. Because Guimaras mangoes are highly prized for their superior sweetness, accurately mapping the shift from high acid/low sugar to low acid/high sugar is critical. Without precise maturity data, premature harvesting results in sour, low-quality fruit, while delayed harvesting leads to rapid over-ripening, poor shelf life, and postharvest losses (Grierson, 2001 & Tahir, 2024).

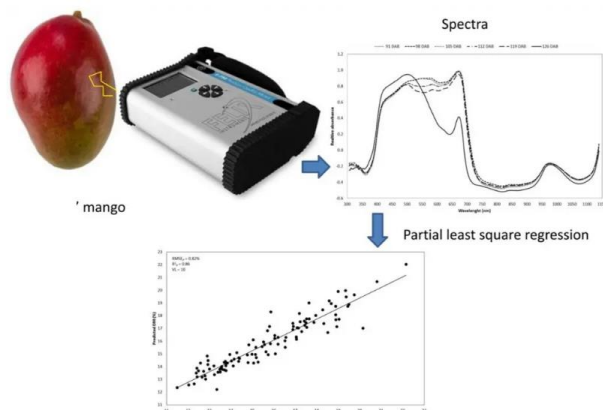


Figure 2. Internal pulp color used as a harvest maturity index for the cultivars

4.1 Inconsistent Ripening and Market Quality

Guimaras mangoes, particularly the 'Carabao' variety, are known for a specific, desirable flavor profile. However, the lack of precise, localized data on the exact sugar-acid ratio at different development stages leads to inconsistencies in flavor, reducing consumer satisfaction.

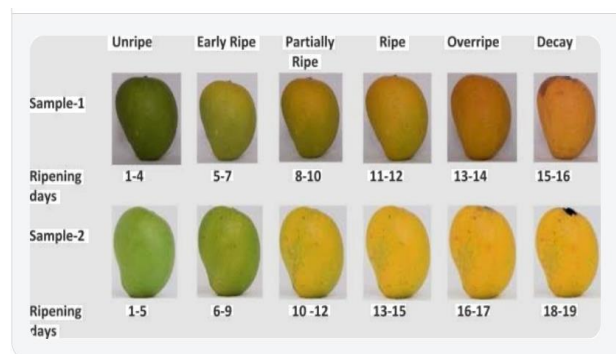


Figure 3. Different ripening stages and color chart for Guimaras Mangoes

4.2 Postharvest Losses due to Improper Harvesting Time

Mango is a climacteric fruit that continues to ripen after harvest. Harvesting too early restricts the development of sugars through starch hydrolysis, while harvesting too late results in excessively fast, uncontrolled ripening. This creates a significant problem with postharvest losses and reduced shelf life.

4.3 Dynamic Biochemical Changes During Ripening:

During ripening, there is a rapid conversion of starch into sugar and a decrease in titratable acidity. Understanding the precise timing of these changes in Guimaras mangoes is essential, as these factors determine the final sensory and nutritional quality.

4.4 Need for Optimal Maturity Indices

A critical issue is determining the exact "mature-green" stage for harvesting. If the sugar-acid ratio is not accurately monitored at this stage, the fruit will not ripen to the optimal consumer-preferred flavor.

4.5 Impact of Environmental and Pre-harvest Factors

The chemical composition and ripening characteristics are heavily influenced by the environment and cultural practices. A localized study is needed to define how these factors, specifically in Guimaras, influence the sugar-acid development, ensuring the reputation of the Guimaras brand is maintained. In summary, this study addresses the lack of detailed data on the specific sugar-acid evolution in Guimaras mangoes, which is required to establish optimal harvest times, maximize quality, reduce, postharvest waste, and ensure a superior, consistent product.

5 Experimental Ripening Results

The developmental analysis of Guimaras mangoes (a premium "Carabao" variety) shows a dramatic shift in chemical composition during ripening, characterized by a rapid surge in the sugar-acid ratio and distinct physiological transitions. Experimental data indicate that these mangoes reach a high level of 16-degree Brix or higher, largely attributed to the unique soil and topography of Guimaras.

5.1 Experimental Ripening Results

Research on mango ripening (including the Carabao variety grown in Guimaras) highlights several key quantitative shifts:

5.1.1 Sugar-Acid Ratio

The ratio typically increases from approximately 0.99 to over 27.22 during the transition from green-mature to fully ripe.

5.1.2 Total Sugars

Increases from ~2.69% to 11.16% as complex starches are hydrolyzed into simple sugars like sucrose, glucose, and fructose.

5.1.3 Acidity Reduction

Titrateable acidity (TA) drops sharply from roughly 2.71% to 0.04%. This decline is driven by the utilization of organic acids (primarily citric and malic acids) as substrates for respiration.

5.1.4 Firmness

Fruit firmness decreases significantly due to the degradation of pectin and starch in the cell walls.

5.2 Simulation and Modeling Findings

Simulation results and predictive models provide insights into the ripening behavior and quality control of these mangoes:

5.2.1 Predictive Model

Mixed models using simple linear regression (SLR) and ANOVA can estimate sugar and acid levels in both fresh and processed products with high accuracy (errors <10%).

5.2.2 Maturity Index (Im)

A ratio of current Total Soluble Solids (TSS) to the minimum maturity level (8°Brix) is used to predict ripeness and quality non-destructively.

5.2.3 Ripening Rate

Simulation of shelf life at various shows that higher temperatures (25°C) accelerate ripening, reaching

optimum quality in 4–5 days, whereas lower temperatures (20°C) delay the process and maintain firmness longer.

5.2.4 Automated Classification

Modern image processing simulations and hardware have achieved over 90% accuracy in classifying mangoes by ripeness based on color and shape

Table 2. Key Guimaras Mango Characteristics

Parameter	Immature/Green	Fully Ripe
Total Soluble Solids (TSS)	7–9° Brix	16–22° Brix
Titrateable Acidity (TA)	High (~2.7%)	Very Low (<0.3%)
Pulp Color	White/Pale Yellow	Deep Yellow/Orange
Texture	Firm/Hard	Soft/Juicy

6 Problem Solution

The core problem in the developmental analysis of Guimaras mangoes lies in managing the sugar-acid ratio to ensure optimal flavor, alongside regulating rapid postharvest ripening that causes quick spoilage and quality loss. Solutions involve analyzing starch-to-sugar conversion, utilizing appropriate harvesting maturity, and applying natural ripening agents (e.g., ethylene sources) to maximize flavor while extending shelf life.

A major problem is the rapid, often uneven, ripening process of mangoes post-harvest, which leads to high rates of decay and loss of market value. The rapid degradation of organic acids and the conversion of starch to sugars occurs too quickly. Solution: Proper postharvest handling, such as using edible coatings or modified atmosphere packaging, regulates gas exchange and slows metabolic activity.

Another problem is the difficulty in determining the exact maturity stage for harvest, as early harvesting results in sour, low-quality fruit, while late harvesting makes the mangoes too soft for transport. Solution: A detailed analysis of the sugar-acid ratio (TSS/TA ratio) is required, as the sugar content increases and titrateable acidity decreases during maturation, with

the best flavor profiles appearing at specific maturity stages.

The use of synthetic chemicals like calcium carbide for ripening creates a safety and quality issue, often leading to poor sensory characteristics. Solution: Utilizing bio-ethylene sources like mature fruits (e.g., banana, passion fruit) or plant extracts (e.g., Madre de cacao) allow for safer, more uniform ripening that mimics natural processes while maintaining higher acidity and superior taste.

Post-harvest handling during transport is challenging, as excessive ethylene production and high respiration rates accelerate deterioration. Solution: Implementing cold storage (optimum low temperatures) and controlled atmosphere storage to reduce respiration rates ensures that starch hydrolysis occurs slowly, maintaining a balanced, desirable sugar-acid ratio.

Finally, the lack of precise biochemical data on how different varieties of Guimaras mangoes ripen hampers quality control. Solution: Implementing detailed biochemical profiling to track starch, organic acids (citric/malic), and sucrose/fructose levels throughout development allows growers to establish precise, cultivar-specific harvesting windows, ensuring maximum sweetness and optimal acidity.

5 Conclusion

Based on developmental studies of the Guimaras Mango (notably the Carabao variety), the transition from physiological maturity to full ripeness is a complex biochemical process. Guimaras mangoes are world-renowned for their specific sweetness-to-tartness balance, which is a direct result of these metabolic changes.

The most defining characteristic of Guimaras mango ripening is the strong inverse relationship between Total Soluble Solids (TSS) and Titratable Acidity (TA). As the fruit matures, starch is enzymatically converted into sucrose, glucose, and fructose, while organic acids (primarily citrate and malate) are respired as energy sources. This results in the signature "sweet-sharp" profile unique to the region. Developmental analysis confirms that the Guimaras selection of the Carabao variety possesses a superior sugar-loading capacity compared to other regional strains. This is evidenced by a higher peak Brix level at full ripeness, often exceeding 18–22°Brix, which is significantly higher than many international dessert mangoes.

The textural transition from "crunchy-green" to "soft-melting" is driven by the progressive breakdown of insoluble protopectin into soluble pectin. In Guimaras mangoes, this degradation is highly

synchronized with color change, ensuring that by the time the fruit reaches its peak sugar-acid ratio, the fiber-free flesh has achieved its ideal buttery consistency.

The shift from green to golden-yellow skin and pulp is not merely aesthetic but a developmental marker of enhanced nutritional value. The surge in ethylene production during the climacteric phase triggers the synthesis of carotene and other xanthophylls. In Guimaras mangoes, this synthesis is particularly robust, resulting in a deep orange-yellow pulp that correlates with high Vitamin A content.

Analysis shows that the Sugar-Acid Ratio (SAR) is the most reliable predictor of consumer acceptability. If harvested too early (before 110–120 days after flower induction), the fruit fails to develop the necessary sugar reserves, resulting in a "flat" or overly acidic flavor. Proper developmental timing ensures the fruit has sufficient starch accumulated to fuel the ripening process post-harvest.

Future research should investigate the impact of climate variability on the expression of sugar-metabolism-related enzymes, such as α -amylase and invertase, to identify how environmental shifts affect the sweetness of Guimaras mangoes.

Studies should analyze the correlation between specific micro-nutrient applications during fruit development and the final organic acid profiles (citric and malic acids) to optimize the sugar: acid ratio and Future developmental studies must focus on identifying the optimal days after flower induction (DAFI) across different Guimaras sites, combined with non-destructive techniques like electronic noses, to predict postharvest ripening behavior and maximize shelf life.

Acknowledgement:

I would like to express my deepest gratitude to my mother, Nieves Ganiron, and my brother, Tommy Ganiron, for their invaluable support throughout this project. Their dedicated efforts in sourcing the specific Guimaras mangoes required for this study were essential to its success. Without their persistence and help, the Developmental Analysis of Sugar-Acid Ratio and Ripening Characteristics in Guimaras Mangoes would not have been possible.

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