

OPTIMIZATION OF CRYSTAL GUAVA SYRUP QUALITY THROUGH ADJUSTMENTS IN FRUIT PULP AND SUGAR CONCENTRATION

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ABSTRACT

Crystal guava (*Psidium guajava* L.) is a promising fruit for processing into beverages, yet its conversion into syrup requires careful formulation to balance physicochemical quality and consumer acceptance. This study evaluated the effects of fruit pulp-to-water ratio and sugar concentration on the quality of crystal guava syrup. A factorial design was applied with three pulp-to-water ratios (30:70, 40:60, and 50:50) and three sugar concentrations (50%, 60%, and 70%), each combination replicated three times. Results indicated that both pulp ratio and sugar concentration significantly influenced total sugar content, total dissolved solids (TDS), and viscosity, although their interaction was not significant. Higher pulp and sugar levels increased physicochemical values, with the highest results observed in the 50:50 pulp-to-water ratio combined with 70% sugar (A3B3), which produced 75.11% total sugar, 77.70 °Brix TDS, and 9.92 cP viscosity. Microbiological analysis confirmed that all treatments met the Indonesian National Standard (SNI 3544:2013), with total plate counts ranging from 5.3×10^1 to 7.7×10^1 CFU/mL. Sensory evaluation revealed that higher pulp and sugar levels improved color intensity, aroma, and guava flavor. Hedonic scores ranged from 6.07 to 6.89, with A3B3 achieving the highest overall liking. The findings demonstrate that crystal guava syrup quality can be optimized by combining a 50:50 pulp-to-water ratio with 70% sugar concentration, which balances physicochemical attributes, microbial safety, and consumer acceptance. This formulation offers a practical guideline for developing guava-based syrup products with high market potential.

Keywords: Crystal guava, Syrup formulation, Physicochemical properties, Sensory evaluation, Consumer acceptance.

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1. INTRODUCTION

Fruit-based beverages and syrups represent one of the fastest growing segments in the food and beverage industry, driven by increasing consumer demand for products that combine nutritional value with appealing sensory qualities. Among tropical fruits, guava (*Psidium guajava* L.) has gained prominence due to its high vitamin C content, dietary fiber, and diverse phytochemicals with antioxidant and functional health benefits (Arya et al., 2023). In Indonesia, guava is widely cultivated and consumed fresh, but its use in processed forms such as juice, jam, and syrup remains underdeveloped compared to other fruit commodities. Value addition through processing not only increases the shelf life of guava but also enhances its economic potential by creating products with wider market reach (Jaya et al., 2023).

Crystal guava, a popular cultivar in Indonesia, is distinguished by its large fruit size, crisp texture, low seed content, and mild flavor. These traits make it attractive for direct consumption and also suitable for beverage processing. However, transforming guava into syrup requires careful optimization of formulation parameters to balance its natural acidity, sweetness, viscosity, and consumer acceptability. Unlike carbonated or powdered drinks, syrup concentrates are judged not only by their nutritional content but also by physicochemical properties such as total dissolved solids (TDS), sugar concentration, and viscosity, as well as sensory attributes including color, aroma, and taste (Singh et al., 2022). Thus, determining the optimal fruit-to-water ratio and sugar concentration is essential for developing a guava syrup that is both nutritious and commercially viable.

The formulation of fruit syrup is influenced primarily by two factors: the proportion of fruit pulp to water and the concentration of added sugar. The ratio of fruit to water determines the intensity of fruit flavor, color, and nutritional content, while sugar concentration affects sweetness, viscosity, microbial stability, and overall sensory quality. High fruit content enhances nutritional value but may negatively affect mouthfeel or stability if not properly

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balanced. Conversely, excessive sugar can mask natural fruit flavors and limit consumer preference in health-conscious markets. Recent studies on tropical fruit syrups have emphasized the need to identify formulation combinations that meet quality standards while appealing to consumer taste preferences (Rahman et al., 2024; Rizki et al., 2024).

From a nutritional standpoint, guava syrup retains a portion of the fruit's natural antioxidants, polyphenols, and vitamin C, though thermal processing and dilution can reduce these levels. Nevertheless, syrup formulations that maintain a higher proportion of fruit pulp are generally superior in functional properties compared to those with minimal fruit content (Abdullah et al., 2024). The challenge lies in ensuring that such formulations also achieve acceptable sweetness and texture. Sugar not only contributes to flavor but also serves as a preservative by reducing water activity and extending shelf life (Silva et al., 2023). The balance of fruit content and sugar concentration is therefore central to ensuring both functional and sensory quality.

Consumer acceptance is another critical dimension of fruit syrup development. Sensory evaluation, including descriptive and hedonic testing, provides insights into how variations in formulation affect consumer perceptions of color, aroma, taste, and overall liking. Previous research on fruit-based beverages has shown that consumer preferences often favor products with moderate sweetness, natural color, and characteristic fruit aroma (Singhet al., 2022; Lee et al., 2023). For guava syrup specifically, achieving a desirable balance between sweet and acidic flavors is key to maximizing acceptance. The hedonic scores reported in earlier work suggest that treatments with higher fruit content and balanced sugar levels receive the highest consumer preference ratings, underscoring the importance of integrating sensory analysis into product optimization (Rahman et al., 2024; Meilgaard et al., 2022).

Beyond sensory quality, physicochemical parameters such as total dissolved solids, viscosity, and sugar content are important indicators of product standardization and compliance with food safety regulations. For instance, the Indonesian National Standard (SNI 3544:2013) specifies maximum permissible microbial loads and requires minimum quality benchmarks for syrup products (Badan Standardisasi Nasional, 2013; Hidayat et al., 2023). Formulations that achieve high sensory acceptability but fail to meet these standards cannot be recommended for commercial production. Thus, an integrated evaluation of physicochemical, sensory, and microbiological parameters is necessary to identify formulations suitable for large-scale processing (Kumar et al., 2023).

Recent advances in food technology also highlight the role of functional beverages in addressing consumer health concerns. While syrups are traditionally viewed as sugar-rich products, contemporary research emphasizes the potential of fruit syrups as vehicles for bioactive compounds if optimized formulations are developed. Studies on other tropical fruit syrups, such as mango and pineapple, indicate that well-designed formulations can preserve antioxidant activity and deliver health-promoting properties, while still achieving consumer satisfaction (Singh et al., 2022; Kumar et al., 2022). In this context, crystal guava syrup has the potential to contribute not only to dietary enjoyment but also to functional nutrition, provided that processing and formulation strategies are appropriately managed (Arya et al., 2023; Rizki et al., 2024).

The present study was designed to evaluate the effect of different fruit-to-water ratios and sugar concentrations on the physicochemical and sensory characteristics of crystal guava syrup. Specifically, the objectives were: (i) to assess how these factors influence sugar content, viscosity, total dissolved solids, and microbial quality; (ii) to evaluate sensory characteristics and consumer acceptance through descriptive and hedonic testing; and (iii) to identify the optimal formulation that meets quality standards and maximizes consumer acceptability. The findings of this study are expected to provide useful insights for food processors, entrepreneurs, and researchers seeking to develop value-added guava-based products, while also contributing to broader discussions on balancing nutrition, quality, and consumer preference in functional beverages.

2. MATERIALS AND METHODS

The study was conducted using a completely randomized design arranged in a factorial pattern. Two factors were tested: the ratio of fruit pulp to water and the concentration of sugar added during syrup preparation. The fruit-to-water ratio consisted of three levels, namely 30:70, 40:60, and 50:50, while the sugar concentration included 50%, 60%, and 70%. Each treatment combination was replicated three times to ensure experimental reliability.

Crystal guava fruits were selected based on uniform ripeness, washed, peeled, and processed to obtain the edible portion. The pulp was blended with water according to the designated treatment ratios, and sugar was incorporated at concentrations corresponding to each treatment level. The mixtures were then boiled until the syrup reached a stable consistency. After cooling, samples were stored in sterilized containers at ambient conditions until further analysis.

Physicochemical parameters measured included total sugar content, total dissolved solids (Brix), and viscosity. Total sugar was analyzed using the phenol-sulfuric acid method, while viscosity was determined with a viscometer. Total dissolved solids were measured with a refractometer. Microbiological quality was assessed through total plate count (TPC), expressed as colony-forming units per milliliter (CFU/mL).

Sensory evaluation was carried out in two stages. A descriptive test was used to assess color, aroma, taste, and guava flavor intensity. A hedonic test was then performed with a nine-point scale to determine consumer acceptability for each of the same attributes. Panelists were drawn from a trained group familiar with sensory evaluation protocols. All evaluations were conducted under standardized sensory testing conditions to minimize bias.

Data were subjected to analysis of variance (ANOVA) to determine the significance of main effects and interactions. When significant differences were detected, treatment means were compared using Duncan’s Multiple Range Test (DMRT) at the 5% significance level. Statistical analyses ensured that the effects of fruit-to-water ratio and sugar concentration were appropriately distinguished and interpreted.

3. RESULTS

Physicochemical Characteristics

The ratio of fruit pulp to water and the concentration of sugar significantly influenced the physicochemical properties of crystal guava syrup, namely total sugar content, total dissolved solids (TDS), and viscosity. However, no significant interaction between the two factors was detected, indicating that each factor exerted independent effects. As shown in Fig. 1, increasing the proportion of fruit pulp and the concentration of sugar consistently raised the levels of total sugar, TDS, and viscosity.

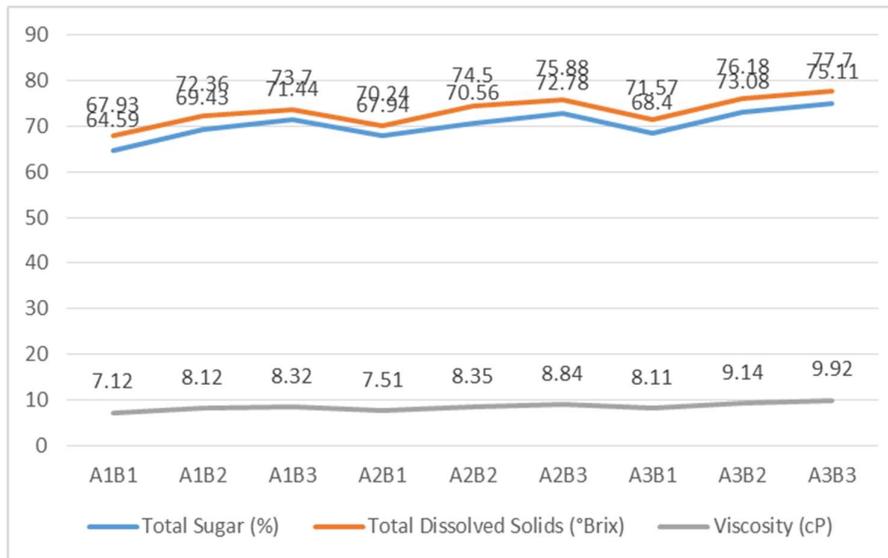


Fig. 1: Effect of Fruit-to-Water Ratio and Sugar Concentration on Physicochemical Properties of Crystal Guava Syrup

The treatment with the highest fruit ratio (50:50) combined with 70% sugar (A3B3) produced the highest values for all physicochemical parameters, namely 75.11% total sugar, 77.70 °Brix TDS, and 9.92 cP viscosity. By contrast, the lowest values were observed in the treatment with the lowest fruit content (30:70) and lowest sugar concentration (50%), which recorded only 64.59% total sugar, 67.93 °Brix, and 7.12 cP. These results confirm that both sugar and fruit content are critical in determining the sweetness, density, and texture of guava syrup.

Microbiological Quality

Microbiological analysis showed that all syrup formulations met the Indonesian National Standard (SNI 3544:2013), which requires total plate counts (TPC) below 1×10^2 CFU/mL. As shown in Fig. 2, TPC values ranged from 5.3×10^1 to 7.7×10^1 CFU/mL, with no significant differences across treatments. The highest TPC value was recorded in A3B3 (7.7×10^1 CFU/mL), while the lowest occurred in A1B1 (5.3×10^1 CFU/mL). Despite these variations, all values were well within acceptable limits, confirming that the syrup was microbiologically safe.

Sensory Quality

Descriptive sensory analysis (Table 3) showed that guava syrup color was generally yellowish-white, with intensity increasing alongside fruit content and sugar concentration. Aroma and flavor were dominated by guava characteristics, while sweetness and sourness were balanced in most treatments. The best descriptive scores for guava aroma, sweet-acidic taste, and overall guava flavor were consistently associated with treatments containing higher fruit ratios and sugar concentrations, particularly A3B3.

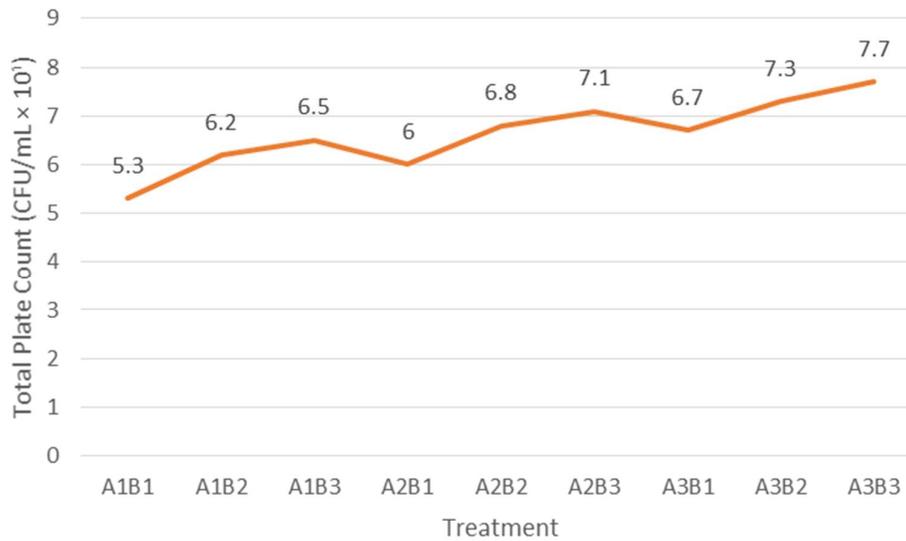


Fig. 2: Total Plate Count (TPC) of Crystal Guava Syrup

Table 3: Descriptive Sensory Quality of Crystal Guava Syrup

Attribute	Sensory Description (Overall Result)
Color	Yellowish-white, more intense at higher fruit ratios
Aroma	Strong guava aroma, increasing with higher pulp ratio
Taste	Sweet-acidic, balanced most at A3B3
Flavor	Strong guava flavor, most pronounced in A3B3

Hedonic Acceptability

Hedonic test results indicated that panelists found all formulations acceptable, with scores ranging from 6.07 to 6.89 on a nine-point scale, indicating moderate to high preference (Fig. 3). The most preferred formulation was A3B3 (50:50 ratio with 70% sugar), which achieved the highest overall liking score of 6.89. Panelists noted that this treatment provided the best balance of sweetness, acidity, guava aroma, and flavor intensity.

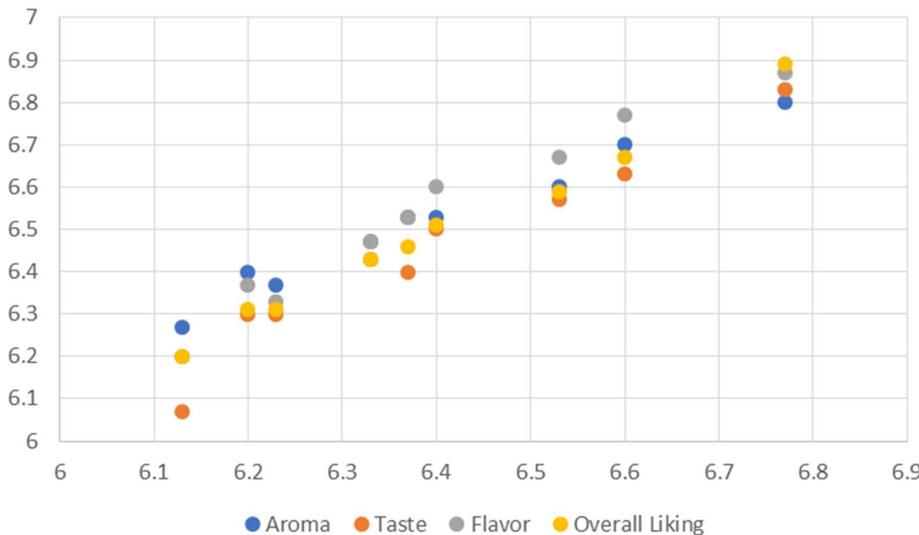


Fig. 3: Hedonic Scores of Crystal Guava Syrup (9-point scale)

Taken together, the results indicate that both fruit-to-water ratio and sugar concentration strongly affected the physicochemical and sensory quality of crystal guava syrup. The best treatment was A3B3 (50:50 fruit-to-water ratio with 70% sugar concentration), which produced the highest physicochemical values, remained within microbial safety limits, and achieved the highest consumer acceptability scores.

4. DISCUSSION

The development of crystal guava syrup requires careful attention to formulation parameters that affect both physicochemical and sensory qualities. The present study demonstrated that the ratio of fruit pulp to water and the concentration of added sugar exerted significant and independent effects on total sugar content, total dissolved solids, and viscosity (Fig. 1). In addition, these factors strongly influenced sensory characteristics and consumer acceptability (Tables 3 and 4), while microbiological analysis confirmed that all formulations met food safety standards (Fig. 2). Among the treatments tested, A3B3 (50:50 fruit-to-water ratio with 70% sugar concentration) produced the most favorable outcomes, yielding the highest physicochemical values, acceptable microbial load, and the greatest consumer preference.

The increase in total sugar and TDS with higher fruit ratios and sugar concentrations is consistent with the chemical composition of fruit-based beverages. Guava pulp naturally contains simple sugars such as glucose, fructose, and sucrose, in addition to organic acids and soluble solids. Increasing the proportion of pulp in the syrup mixture therefore elevates the concentration of naturally occurring sugars and soluble solids, while added sugar further amplifies these effects. Previous studies on fruit beverages such as mango and pineapple syrups have reported similar trends, where higher pulp and sugar contents correlated with increased °Brix values and total sugar percentages. The maximum TDS observed in the present study (77.70 Brix under A3B3) reflects the combined contribution of both natural and added sugars, placing the product well within the expected range for concentrated syrups.

Viscosity was also influenced by pulp ratio and sugar concentration (Fig. 1). Treatments with higher pulp levels exhibited greater viscosity, likely due to the presence of soluble pectin, fiber, and colloidal material in guava pulp. Sugar concentration additionally contributed to viscosity by increasing the density of the syrup. The highest viscosity value of 9.92 cP under A3B3 confirms that syrup texture is optimized at balanced fruit and sugar levels. This is important because viscosity affects consumer perception of mouthfeel and product quality. Too low a viscosity may suggest dilution, while excessively high viscosity can be undesirable for dilution during consumption. Earlier work in tropical fruit syrups noted that consumer preference is highest for products with moderate viscosity values that balance ease of pouring with richness of texture (Rahman et al., 2024).

Microbiological analysis revealed that all treatments complied with SNI 3544:2013 standards, with TPC values ranging from 5.3×10^1 to 7.7×10^1 CFU/mL (Fig. 2). These values are well below the maximum permissible limits, confirming that the syrup formulations were microbiologically safe. The slight increase in TPC with higher pulp and sugar concentrations may reflect the greater availability of substrates for microbial growth, although sugar also functions as a preservative by reducing water activity. Thermal processing during syrup preparation likely played a major role in suppressing microbial contamination. These results agree with observations in other fruit syrup studies, where appropriate pasteurization and high sugar concentrations maintained microbial safety throughout storage (Singh et al., 2022).

The sensory evaluation provided critical insights into consumer perceptions. Descriptive analysis (Table 3) indicated that higher pulp and sugar levels enhanced color intensity, guava aroma, and flavor richness. This is expected, as increasing pulp content enhances pigment and volatile compound concentrations, while sugar accentuates flavor perception. Panelists described A3B3 syrup as having the most balanced sweet-acidic taste and the strongest guava flavor, which aligns with the chemical composition results. Hedonic testing confirmed that A3B3 was the most preferred formulation, with an overall liking score of 6.89 (Fig. 3). The combination of a 50:50 fruit ratio and 70% sugar provided an optimal balance between natural guava flavor and sweetness, enhancing both quality and acceptability. These findings are consistent with reports that consumer acceptance of fruit beverages is highest when sweetness complements rather than overpowers natural fruit flavors (Rahman et al., 2024).

The role of sugar in shaping sensory acceptance is particularly important. Sugar not only enhances sweetness but also masks undesirable acidic or bitter notes, improves mouthfeel, and contributes to preservation. However, excessive sugar may limit consumer acceptance in health-conscious markets. This highlights the importance of carefully calibrating sugar levels to balance flavor and health considerations. The results of the present study suggest that a 70% sugar concentration is effective for crystal guava syrup, but future research may explore alternative sweeteners or blends to reduce sugar content without compromising sensory quality. Recent innovations in fruit beverage formulation have demonstrated the potential of natural sweeteners such as stevia and monk fruit extract to maintain sweetness while lowering calorie content (Singh et al., 2022).

The strong sensory performance of higher pulp ratios underscores the role of fruit content in delivering authentic flavor and nutritional benefits. Crystal guava is rich in vitamin C, carotenoids, and polyphenols, which contribute not only to flavor but also to functional health properties. Formulations with higher pulp content are therefore more likely to deliver superior nutritional profiles alongside improved sensory appeal. Similar findings have been reported in studies of mango and papaya syrups, where higher fruit-to-water ratios enhanced antioxidant activity and consumer preference. By contrast, formulations with lower pulp content risk being perceived as diluted and nutritionally inferior, even when sugar levels are adequate.

The integration of physicochemical, sensory, and microbiological analyses provides a comprehensive understanding of syrup quality. The present results demonstrate that A3B3 achieved the highest performance across all criteria: elevated sugar content, acceptable viscosity, compliance with microbial safety standards, and strong consumer preference. This confirms the value of factorial design experiments in identifying optimal formulation conditions. Similar optimization approaches have been successfully applied in the development of functional fruit-based products, ensuring that both technical quality and consumer acceptability are achieved (Rahman et al., 2024).

From a commercial perspective, these findings provide practical recommendations for food processors and entrepreneurs. The results suggest that crystal guava syrup can be successfully developed into a marketable product by adopting a 50:50 fruit-to-water ratio with 70% sugar concentration. Such a formulation maximizes consumer acceptance while ensuring compliance with quality and safety standards. This is particularly relevant for small- and medium-scale enterprises seeking to diversify fruit-based product lines and add value to guava cultivation. The high acceptability of the A3B3 formulation indicates potential for scaling up production and marketing within local and regional beverage markets.

At the same time, broader consumer trends toward reduced sugar intake and functional beverages suggest future directions for product innovation. Although the 70% sugar concentration was optimal in this study, consumer demand for lower-calorie alternatives is rising. Incorporating natural sweeteners, fortifying with functional ingredients, or developing reduced-sugar variants could broaden the appeal of crystal guava syrup in health-conscious markets. Recent advances in food technology highlight the potential for combining traditional fruit-based products with modern nutritional innovations, creating beverages that are both enjoyable and beneficial to health.

CONCLUSION

This study confirmed that the formulation of crystal guava syrup is strongly influenced by the fruit pulp-to-water ratio and sugar concentration. Increasing both factors improved total sugar content, total dissolved solids, viscosity, and sensory attributes, though their interaction was not significant. All formulations met microbiological safety standards, ensuring product suitability for consumption. The optimal treatment was identified as A3B3, which combined a 50:50 pulp-to-water ratio with 70% sugar concentration. This formulation produced the highest physicochemical values, complied with microbial limits, and achieved the strongest consumer preference in sensory evaluations.

From a commercial perspective, these results provide practical guidance for food processors and small enterprises seeking to develop high-quality guava syrup. The identified formulation ensures not only consumer acceptability but also compliance with food safety standards, making it suitable for large-scale production. Future research may explore reduced-sugar or functional variants to align with emerging consumer preferences for healthier beverages.

DECLARATIONS

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