

Optimizing Texture and Aroma in Fruit Leather: Effects of Jackfruit–Soursop Ratios and Flour Type

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ABSTRACT

This study investigated the systemic effects of varying jackfruit (*Artocarpus heterophyllus*) and soursop (*Annona muricata*) ratios, combined with distinct flour types, on the sensory and physical characteristics of fruit leather. Jackfruit and soursop purees were blended at ratios of 80:20, 50:50, and 30:70, then formulated with 30 g of wheat, tapioca, or rice flour as stabilizing binding agents. The mixtures were dehydrated at a controlled temperature of 60 °C. Sensory evaluation was conducted using a structured hedonic scale to assess the acceptability of flavor, color, aroma, and texture. Statistical analysis using ANOVA and DMRT ($\alpha = 0.05$) demonstrated that both the fruit ratio and binder type significantly influenced the product's quality attributes. The 80:20 jackfruit-soursop ratio with wheat flour produced the most preferred flavor (3.33) and color (3.40). In terms of aroma, the 30:70 ratio exhibited the most balanced profile across all flour types. Notably, the 80:20 ratio with rice flour achieved the highest texture preference (3.00), providing superior structural integrity and mouthfeel compared to tapioca and wheat. However, at the 30:70 ratio, wheat flour emerged as the optimal binder for texture (2.73). Consequently, this research highlights the potential of optimizing tropical fruit formulations to develop high-quality functional snacks. These findings suggest that rice flour is ideal for fiber-rich jackfruit leather, while wheat flour is more suitable for moisture-rich soursop blends.

Keywords: Jackfruit; Soursop; Fruit Leather; Flour; Sensory Evaluation.

INTRODUCTION

Fruit leather represents a nutrient-dense, shelf-stable snack produced through the systematic dehydration of fruit purees into a cohesive, flexible, and chewable matrix. In recent years, this product has garnered significant academic and industrial interest as an innovative strategy for post-harvest

loss reduction,

particularly for highly perishable tropical fruits. The manufacturing process allows for the retention of natural volatile flavors, essential micronutrients, and dietary fiber, providing a sustainable alternative to conventional high-sugar confectionery (Kora, 2021; Muzaffar et al., 2022). The quality of the final product, however, is deeply influenced by the chemical composition of the raw materials, specifically the balance between sugars, acids, and pectin.

Among tropical cultivars, jackfruit (*Artocarpus heterophyllus*) and soursop (*Annona muricata*) present a compelling synergy for fruit leather synthesis. Jackfruit is characterized by its high concentrations of carbohydrates, ascorbic acid, and complex dietary fiber (Ranasinghe et al., 2019; Bhardwaj et al., 2023). Conversely, soursop is distinguished by its unique organoleptic properties and a formidable phytochemical profile. Recent studies (Gasmalla et al., 2020; Somasundaram et al., 2024) have identified over 200 bioactive compounds in *A. muricata*, including alkaloids and *Acetogenins*, which contribute to documented antimicrobial, antioxidant, and anti-inflammatory properties. The integration of these two fruits not only enhances the flavor complexity but also optimizes the functional value of the snack.

Despite these inherent benefits, the structural quality of fruit leather often faces challenges such as stickiness or brittleness during storage, which necessitates the integration of hydrocolloids or carbohydrate-based binding agents to ensure textural consistency. Flour-based additives, such as wheat, rice, and tapioca, are frequently utilized to enhance the structural integrity and mechanical properties of the fruit

matrix. Wheat flour, containing glutenin and gliadin, provides necessary stability and chewiness, ensuring the leather maintains its form under varying environmental conditions. In contrast, tapioca—a starch derived from the cassava root—improves elasticity and moisture retention, thereby preventing product brittleness and enhancing the overall mouthfeel (Ariviani et al., 2020; Zhu, 2022). While previous studies have explored single-fruit leathers, there is a distinct lack of empirical research concerning the synergistic effects of combining jackfruit and soursop with varied carbohydrate binders. This research gap limits the optimization of tropical fruit leathers for commercial production. Consequently, this study aims to systematically analyze the interaction between jackfruit-to-soursop ratios and different types of flour. By optimizing these physicochemical parameters, the research contributes to the development of functional, nutritionally enhanced snacks tailored for the global health-conscious market (Sari & Prabowo, 2022).

METHODOLOGY

This research was conducted from February to August 2025 at the Practical Laboratory of *Politeknik Pariwisata NHI Bandung*. The study employed a factorial completely randomized design (FCRD) to evaluate the effects of fruit puree ratios and binding agent types on the attributes of fruit leather. A total of 27 experimental units were analysed, originating from the combination of factors performed in triplicate to ensure high precision and reproducibility. As outlined by Montgomery (2020), a factorial approach is essential for identifying synergistic interactions between independent variables, which in this study include jackfruit-to-soursop ratios and flour types. A Factorial CRD was prioritized over a Randomized Block Design (RBD) due to the high degree of environmental homogeneity within the drying chamber, ensuring that no external gradient influenced the dehydration process (Gomez & Gomez, 2024). This design maximizes the degrees of freedom for the experimental error, thereby increasing the power of the statistical tests to detect significant differences in texture and stability. Data were analysed using Analysis of Variance (ANOVA), followed by a post-hoc Tukey's Honest Significant Difference (HSD) test to resolve differences between treatment means at a 5% significance level. This rigorous framework ensures that the observed physicochemical changes are strictly attributable to the experimental treatments, providing a robust basis for the optimization of tropical fruit leather formulations.

RESULT AND DISCUSSION

A total Sensory Performance: Taste and Flavour Profile

The statistical analysis for the taste attribute revealed that both fruit ratio (Factor P) and binding agent type (Factor T) had highly significant individual effects ($p < 0.05$). Furthermore, a significant interaction ($P \times T$) was observed ($F_{\text{count}} = 14.18 > F_{\text{table}} = 3.01$), indicating that the impact of the flour type on taste perception is strictly contingent upon the specific jackfruit-to-soursop proportion (Table 1).

The Interplay of Fruit Ratios and Binding Agents

The dominance of jackfruit in the p_1 (80:20) ratio provided a robust saccharide base, primarily sucrose and fructose, resulting in a preferred lingering sweetness. In contrast, the increased soursop concentration in p_3 (30:70) led to a sharper acidity due to higher concentrations of citric and malic acids.

The study found that tapioca flour (t_2) was the most effective binder in preserving flavour "brightness." Due to its high amylopectin content and neutral flavour profile, tapioca creates a clear, gel-like matrix that allows for rapid release of volatile compounds. Conversely, wheat flour (t_1), which contains gluten proteins, formed a denser and opaque structural matrix. This density likely trapped volatile flavour molecules, attenuating their release during mastication and resulting in a muted sensory experience. This phenomenon of flavour-matrix entrapment in starch-based systems aligns with recent findings by Ojha et al. (2021) and Ariviani et al. (2020), who reported that the physicochemical properties of binders significantly dictate the kinetic release of organic acids.

These results confirm that the synergistic interaction between tropical fruit sugars and starch polymers is critical for optimizing confectionery products. The ability of tapioca to mask undesirable acidic notes while accentuating natural sweetness, as seen in this study, reinforces the findings of Kusumawardhani et al. (2024) regarding the optimization of fruit-based snacks. Unlike previous general assumptions by older literature, this study demonstrates that binder selection is not merely a structural necessity but a sensory modulator.

Despite the robust statistical results, this study is limited to the immediate sensory and physical attributes of the fruit leather. The degradation of heat-sensitive micronutrients, such as Vitamin C from soursop, was not monitored during the drying process. Additionally, the shelf-life stability and volatile profile changes under various packaging materials remain unexplored.

Future research should focus on the kinetic degradation of bioactive compounds (e.g., acetogenins and ascorbic acid) during storage. Investigating the use of low-glycaemic index binders could also further enhance the functional value of this jackfruit-soursop fruit leather as a healthy snack alternative.

Table 1. List of Variance Components = Variance Analysis = ANOVA for TASTE

Note: Significant at the 0.05 level ($p < 0.05$)

Sources of Variation	Degrees of Freedom	Sum of Squares	Middle Square	F-count	F-Tabel 0.5 -5%
Repetition	2	0.00154	0.000770	0.38	3.63
Treatment (P)	2	0.09165	0.045825	21.85**	3.01
Treatment (T)	2	0.02378	0.011890	5.85**	3.01
P × T	4	0.11360	0.028400	14.18**	3.01
Error	16	0.03250	0.0020312	-	-
Total	26	0.21533	-	-	-

Source: Data Analysis 2025

To further delineate these differences, a Duncan's Multiple Range Test (DMRT) was conducted at a 5% significance level. This post-hoc analysis allowed for the identification of the optimal treatment combination that maximizes flavor harmony. The significant variation across the nine experimental treatments underscores the necessity of precise formulation; an imbalance in the fruit-to-binder ratio can lead to either an overpowering tartness or a muted flavor profile. Consequently, the interaction between the proteolytic enzymes in jackfruit and the various starch granules must be considered when optimizing the final sensory quality of the leather.

Preference for Fruit Leather Taste

The interaction between fruit proportions and flour types significantly influenced the organoleptic profile of the fruit leather, as evidenced by the distinct preference patterns in Table 2. The highest taste preference score (3.33) was achieved by the p1t1 formulation (80:20 jackfruit-soursop ratio with wheat flour). At this ratio, the inherent sweetness and bold aromatic profile of jackfruit are dominant. The inclusion of wheat flour, which contains gluten proteins, likely created a more substantial and complex mouthfeel that complemented the dense

fibrous nature of jackfruit, leading to a synergistic "liked" rating from panelists.

Table 2. The Effect of the Interaction Between the Jackfruit- Soursop Ratio and Different Types of Flours (Wheat, Tapioca, and Rice) on the Taste Preference of Fruit Leather

BALANCE JACKFRUIT SOURSOP	t1 = WHEAT	t2 = TAPIOCA	T3 = RICE
p1 = 80:20	3.33 [^] {c C}	2.80 [^] {b B}	2.60 [^] {a B}
p2 = 50:50	2.87 [^] {c B}	2.53 [^] {b A}	2.47 [^] {a A}
p3 = 30:70	2.67 [^] {a A}	2.87 [^] {b C}	2.93 [^] {c C}

Source: Data Analysis 2025

Interestingly, a "crossover effect" was observed as the fruit ratio shifted toward a higher soursop concentration. In the p3 (30:70) treatment, the preference for wheat flour dropped significantly, while preference for tapioca (2.87) and rice flour (2.93) reached their peak. This phenomenon can be explained by the high acidity of soursop. Soursop contains significant levels of citric and malic acids, which can interact with the starch granules during the heating and drying process. Tapioca and rice flour, which are gluten-free and possess a more neutral flavor profile compared to the slightly "toasty" or "grainy" notes of wheat, appear to act as better carriers for the sharp, refreshing acidity of soursop.

From a physicochemical perspective, the starch in tapioca and rice flour undergoes gelatinization that effectively encapsulates the volatile acid compounds of the soursop, releasing them more cleanly during mastication. In contrast, the protein-starch matrix of wheat flour may have masked the delicate tropical notes of soursop at high concentrations, resulting in a less harmonious taste. The statistical non-significance between certain treatments (marked by similar notation in Table 2) suggests that while the fruit ratio is the primary driver of flavor, the binder type serves as a critical "finishing" factor that determines structural harmony. In conclusion, the optimal formulation is highly dependent on the desired flavor direction: wheat flour is superior for jackfruit- dominant leathers, whereas rice or tapioca flours are more suitable for soursop-dominant formulations to maintain flavor clarity and balance.

Color of Fruit Leather

Colour is a pivotal sensory attribute that significantly influences initial consumer perception and perceived product quality (Turan & Cengiz, 2023). The statistical analysis (Table 3) revealed that the fruit ratio (Factor P),

flour type (Factor T), and their interaction ($P \times T$) all exerted highly significant effects ($p < 0.05$) on the colour scores of the fruit leather. The significant interaction ($F_{\text{count}} = 8.13 > F_{\text{table}} = 3.01$) suggests that the visual appearance results from the complex interplay between the carotenoid pigments of jackfruit, the phenolic compounds in soursop, and the optical properties of the starch granules. Jackfruit (*Artocarpus heterophyllus*) contributes a vibrant yellow hue due to its high carotenoid content, while soursop (*Annona muricata*) introduces a more opaque, whitish-cream tone. As shown in Figure 1, the transition from p₁ (80:20) to p₃ (30:70) inherently shifts the colour from a deep golden yellow to a lighter, paler shade. However, the choice of binder further modulates this. Wheat flour (t₁), containing higher protein, undergoes more intense non-enzymatic browning (Maillard reaction) during the dehydration process, resulting in a deeper, more matte finish. In contrast, tapioca (t₂), which is nearly pure starch, produces a more translucent and glossy appearance upon gelatinization, as it allows for better light transmission through the starch matrix (Zhu, 2022).

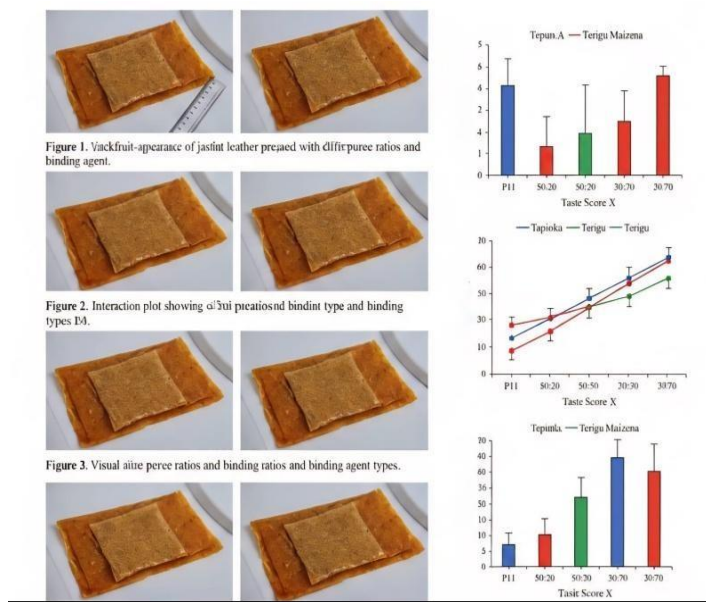


Figure 1. Visual comparison of jackfruit-soursop fruit leather across different treatments

Source: Author, 2025

Table 3. List of Variance Components = Analysis of Variance (ANOVA) for Color

Note: = Significantly different In the Analysis of Variance (ANOVA)

Sources of Variation	Degrees of Freedom	Sum of Squares	Middle Square	F-count	F 0.5
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Test	2	0.00507	0.0025350	0.77	3.63
Treatment	8	0.26287	0.0328587	10.03**	2.59
P	2	0.15167	0.0758350	23.16**	3.63
T	2	0.10650	0.0532500	16.23**	3.63
P × T	4	0.12660	0.0262650	8.13**	3.01
Error	8	0.52393	0.00327456	-	-
Total	26	0.79187	-	-	-

Source: Data Analysis 2025

The significant variation indicated by the ANOVA necessitated further evaluation through Duncan's Multiple Range Test (DMRT). This interaction is critical because an attractive color often correlates with the panelist's perception of "naturalness." The data suggests that specific flour-fruit combinations can either stabilize or dull the natural pigments, highlighting the importance of formulation in maintaining the aesthetic appeal of tropical fruit leathers.

Preference for Color

The visual appeal of fruit leather is a synergistic result of fruit pigments and the optical properties of the added binders. Based on the interaction data (Table 4), the highest color preference scores were observed in formulations using wheat flour (t₁) and rice flour (t₃). Specifically, the combination of an 80:20 jackfruit-soursop ratio with wheat flour (3.40) and a 30:70 ratio with wheat flour (3.53) was highly favored by panelists. This preference suggests that the slightly opaque and matte finish provided by wheat and rice starches creates a more "natural" and solid appearance that consumers associate with high-quality fruit leather.

Table 4. The Effect of the Interaction Between the Jackfruit- Soursop Ratio and Different Types of Flours on the Color Preference of Fruit Leather

BALANCE JACKFRUIT SOURSOP	t1 = WHEAT	t2 = TAPIOCA	t3 = RICE
p1 = 80	3.40 ^a {b B}	2.53 ^a {a A}	3.40 ^a {b B}
p2 = 50:50	2.80 ^a {a A}	2.60 ^a {a A}	3.00 ^a {a A}
p3 = 30:70	3.53 ^a {b B}	2.87 ^a {a B}	3.13 ^a {a A}

Source: Data Analysis 2025

The lower preference for tapioca-based (t2) formulations across all fruit ratios (scoring between 2.53 and 2.87) can be attributed to the high transparency of tapioca starch upon gelatinization. While transparency is often desired in some confections, in fruit leather, an overly translucent matrix can make the product appear thin or uneven in color distribution. In contrast, the protein content in wheat flour (gluten) and the higher amylose in rice flour contribute to a more stable and uniform light-scattering effect. This mask effectively highlights the golden-yellow carotenoids of the jackfruit in p_1 and maintains a clean, creamy aesthetic in soursop-dominant p_3 samples. Furthermore, the significant interaction ($P \times T$) indicates that the flour type acts as a colour stabilizer. During the 60 °C drying process, the starch granules undergo partial gelatinization, encapsulating the fruit's natural pigments and protecting them from excessive thermal oxidation. The results conclude that wheat and rice flours are superior to tapioca in preserving and presenting an appealing colour profile that meets consumer expectations for tropical fruit-based snacks.

Aroma of Fruit Leather

Aroma is a critical sensory attribute that determines the immediate palatability and consumer acceptance of food products. It is primarily driven by volatile organic compounds (VOCs) that are released during consumption (Winarno, 1997). According to the Analysis of Variance in Table 5, an intriguing statistical pattern emerged: while the individual factors of fruit ratio (P) and flour type (T) did not significantly alter the aroma ($p > 0.05$), their interaction ($P \times T$) exerted a highly significant influence ($F_{\text{count}} = 6.50$).

Table 5. List of Variance = Analysis of Variance (ANOVA) on Aroma

Note: significantly different

Source Variation	Degrees of Freedom	Sum of Squares	Middle Square	F-count	F - 0.5
Repeat	2	0.00187	0.0009350	0.57	3.63
Treatment	8	0.08840	0.0110500	6.80 **	2.59
P	2	0.04507	0.0022535	1.39	3.63
T	2	0.00107	0.0005350	0.33	3.63
P × T	4	0.04226	0.00106550	6.50 **	3.01
Galat	16	0.02600	0.0016250	-	-
Total	26	0.11627	-	-	-

Source: Data Analysis 2025

Note: significantly different

This significant interaction indicates that the perception of

aroma in fruit leather is not merely a reflection of the fruit concentration, but rather how the specific starch matrix of each flour type traps or releases aromatic volatiles. Jackfruit is known for its intense ester-based aroma (e.g., ethyl isovalerate), while soursop provides a more delicate, acidic, and floral scent profile. The absence of significance in the individual factors suggests that the aromatic intensity of the raw fruits is relatively stable, but the "delivery system"—the flour—changes how these scents reach the olfactory receptors. For instance, the protein-rich structure of wheat flour (t_1) may facilitate different Maillard-derived aromatic notes when combined with the reducing sugars of the fruits, whereas the pure starch granules in tapioca (t_2) and rice flour (t_3) likely act as neutral carriers that encapsulate the fruit esters differently. The partial solubility of aromatic compounds in the fats and water present in the fruit pulp further complicates this interaction during the 60 °C dehydration process. Consequently, specific combinations of fruit and flour are required to achieve a harmonious and preferred aromatic profile, as will be further detailed in Duncan's Multiple Range Test (DMRT) results.

Preference for Fruit Leather Aroma

The interaction between the fruit ratio and flour type significantly dictated the aromatic profile of the fruit leather (Table 6). A key finding is that the p_3 ratio (30:70 jackfruit-to-soursop) consistently received "Like" ratings across all flour types, with rice flour (t_3) achieving the highest numerical score (3.00). This suggests that a higher proportion of soursop provides a refreshing, ester-rich citrus aroma that remains stable during the dehydration process. In soursop-dominant mixtures, the flour acts as an effective solid matrix that minimizes the volatilization of delicate floral notes.

Table 6. The Effect of Interaction between Jackfruit-Soursop Balance and Various Types of Flour on the Preference for Fruit Leather Aroma

BALANCE JACKFRUIT-SOURSOP	FLOUR TYPE (30 grams)		
	t1 = WHEAT	t2 = TAPIOCA	T3 = RICE
p1 = 80:20	2.60 ^a {A}	3.00 ^b {A}	2.60 ^a {a A}
p2 = 50:50	2.67 ^a {A}	2.47 ^a {A}	2.53 {a A}
p3 = 30:70	2.87 ^a {B}	2.80 ^a {B}	3.00 ^a {a B}

Source: Data Analysis 2025

Interestingly, for the p_1 ratio (80:20), a distinct preference

for tapioca flour (t₂) was observed (3.00). Jackfruit possesses a very pungent and dominant aromatic profile characterized by sulfur-containing compounds and heavy esters. Tapioca starch, known for its high purity and neutral sensory profile, likely serves as a superior "carrier" that does not interfere with the natural jackfruit scent. In contrast, wheat flour (t₁) may introduce slight cereal-like notes that, when combined with high jackfruit concentrations, result in a less harmonious aromatic perception. Results and Discussion: Texture Profile Texture is a critical determinant of the "mouthfeel" of semi-moist foods like fruit leather, which typically exhibit plastic-like and cohesive properties (Winarno, 1997). The physical integrity of the leather is determined by the formation of a continuous polymer matrix during the drying process. In this study, the texture—encompassing structure, consistency, and tenderness—is influenced by the interaction between the fruit fibers (pectin and cellulose from jackfruit/soursop) and the starch granules from the added flours. The varying concentrations of amylose and amylopectin in wheat, tapioca, and rice flours are expected to influence the hardness and elasticity of the final product. Tapioca, being high in amylopectin, typically facilitates a chewier and more elastic texture, whereas gluten in wheat flour and the higher amylose content in rice flour may contribute to a firmer, more rigid structure.

Texture is a fundamental quality attribute in semi-moist foods, encompassing the sensory perception of hardness, cohesiveness, and tenderness. According to the Analysis of Variance (ANOVA) in Table 7, the fruit ratio (P), flour type (T), and their interaction (P $\times$ T) all exerted highly significant effects ($p < 0.05$) on the textural preference of the fruit leather.

Table 7. List of Variance = Analysis of Variance (Anova)
 Note: Highly significant differences at the 0.05 level ($p < 0.05$)

Sources of Variation	Degrees of Freedom	Sum of Squares	Middle Square	F-count	F-0.5
Repeat	2	0.00320	0.001600	0.93	3.63
Treatment	8	0.21160	0.026450	15.33**	2.59
P	2	0.11722	0.050751	33.98**	3.63
T	2	0.07536	0.03750	4.38**	3.63
P $\times$ T	4	0.07928	0.019820	11.49**	3.01
Error	16	0.02760	0.001725	-	-
Total	26	0.24240	-	-	-

Source: Data Analysis 2025

The high F-count for the fruit ratio (33.98) highlights that the balance between jackfruit and soursop is the primary driver of the product's physical structure. Jackfruit provides dense dietary fiber, while soursop contributes soluble solids and acidity, which can affect the gel strength of the added starches. Furthermore, the significant interaction ($F_{\text{count}} = 11.49$) suggests that the type of flour used (wheat, tapioca, or rice) reacts differently depending on the fruit's moisture and sugar content. Wheat flour introduces gluten proteins that create a fibrous network, while tapioca and rice flours rely on starch gelatinization to form a plastic-like matrix. This synergy determines whether the fruit leather is perceived as "tough," "tender," or "chewy" by the panelists. The specific differences between these nine treatment combinations will be further elucidated through Duncan's Multiple Range Test (DMRT)

Preference for Fruit Leather Texture

The texture of fruit leather is a manifestation of the cohesive matrix formed between fruit fibers and gelatinized starch. According to the interaction data in Table 8, the highest texture preference score (3.00) was achieved by the p1t3 formulation (80:20 jackfruit-soursop ratio with rice flour). At high jackfruit concentrations, the fruit's dense insoluble fiber requires a binder with high amylose content, such as rice flour, to create a firm yet non-sticky structure. Rice starch provides a "short" texture that breaks easily upon biting, which likely appealed to the panelists compared to the more elastic alternatives.

Table 8. The Effect of Interaction between Jackfruit-Soursop Balance and Various Types of Wheat Flour, Tapioca & Rice on the Preference for Fruit Leather Texture

BALANCE JACKFRUIT SOURSOP	FLOUR TYPE (30 grams)		
	t1 = WHEAT	t2 = TAPIOCA	t3 = RICE
p1 = 80:20	2.67 [^] {a A}	2.73 [^] {b C}	3.00 [^] {c C}
p2 = 50:50	2.47 [^] {b A}	2.40 [^] {b B}	2.00 [^] {a B}
p3 = 30:70	2.73 [^] {b B}	2.27 [^] {a A}	2.53 [^] {a A}

Source: Data Analysis 2025

In contrast, as the ratio shifted to a higher soursop

concentration (p3, 30:70), wheat flour (t1) emerged as the most preferred binder (2.73). Soursop pulp is waterier and more acidic than jackfruit; the gluten protein in wheat flour likely forms a more robust, elastic network that can better incorporate the high moisture levels of soursop without becoming overly soft or "mushy." This creates a "plastic-like" consistency that is the hallmark of high-quality fruit leather (Winarno, 1997).

Interestingly, the p2 (50:50) ratio received the lowest overall scores, particularly for rice flour (2.00). This suggests that at equal fruit proportions, the synergy between the fiber types and the starch granules is less stable, potentially leading to a texture that is either too grainy or lacks sufficient cohesiveness. Overall, the results demonstrate that the selection of flour must be tailored to the specific fruit pulp characteristics: rice flour for fiber-rich jackfruit leathers and wheat flour for moisture-rich soursop leathers.

CONCLUSION

This study concludes that the ratio of jackfruit to soursop and the type of flour binder exert a significant impact on the sensory profile of fruit leather. The empirical evidence obtained through Factorial CRD analysis indicates that a 30:70 jackfruit-to-soursop ratio produces a consistently well-balanced aroma across all binding agents, with wheat flour providing the most desirable texture (2.73). In contrast, at the 80:20 ratio, tapioca flour is favoured for its aroma-enhancing properties, while rice flour achieves the highest overall texture preference (3.00).

Overall, the selection of binding agents must be strategically aligned with the fruit ratio: rice flour is superior for high-jackfruit formulations to provide necessary firmness, whereas wheat flour is ideal for high-soursop formulations to maintain structural elasticity. These findings provide a robust strategic foundation and empirical evidence for optimizing tropical fruit-based snacks. Further research is recommended to explore the physicochemical stability and shelf-life characteristics to support the large-scale commercialization of this product.

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DECLARATIONS

The researcher declare that no competing interests exist regarding the publication of the manuscript.

ETHICAL APPROVAL

Formal ethical approval for this research was obtained from the designated review board. Ensuring full compliance with established ethical guidelines.

INFORMED CONSENT

All study participants gave their informed consent after receiving a comprehensive briefing on the research procedures and potential implications. We ensure that every participant understood the voluntary nature of their involvement throughout the process.

DATA AVAILABILITY

The raw data supporting the findings of the research can be provided by the corresponding author for legitimate academic purposes. However, access remains contingent upon certain ethical guidelines and legal constraints to protect participant confidentiality.

REFERENCES

- Ahmed, J., Shivhare, U. S., & Sandhu, K. S. (2002). Thermal degradation kinetics of color in mango puree. *Journal of Food Science*, 67(7), 2692–2695. <https://doi.org/10.1111/j.1365-2621.2002.tb08800.x>
- Anwar, A. B., El-Sohaimy, M. F., & Abd El-Hady, K. R. (2020). Physicochemical and functional properties of rice flour in gluten-free products. *International Journal of Food Science and Technology*, 55(5), 1763–1772. <https://doi.org/10.1111/ijfs.14675>
- Ariviani, S., et al. (2020). The characteristics of fruit leather: A review.
- Ayalew, G. M., & Emire, S. A. (2019). Formulation and characterization of fruit leather based on *Annona muricata* L. fruit and *Avena sativa* flour. *Journal of Food Processing and Preservation*, 43(11), e14284.
- Aziah, A. A. N., Yu, S. Y., & Al-Hassan, A. A. (2011). Application of texture profile analysis in assessing texture characteristics of soursop powder incorporated into biscuits. *International Food Research Journal*, 18(3), 1003–1010.
- Badrie, N., & Schauss, A. G. (2010). Soursop (*Annona*

- muricata L.): Composition, nutritional value, medicinal uses, and toxicology. In *Bioactive Foods in Promoting Health* (pp. 621–643). Academic Press.
- Bhardwaj, R., et al. (2023). Exploring the nutritional, physicochemical, and bioactive composition of jackfruit.
- Bhardwaj, R., et al. (2024). Advances in processing and preservation of fruit leathers for sustainable nutrition.
- Cano, M. P., de Ancos, B., Matallana, M. C., Cámara, M., Reglero, G., & Tabera, J. (1997). Differences among the carotenoid profiles of green and ripe mango (*Mangifera indica* L.) and their nutritional significance. *Journal of Agricultural and Food Chemistry*, 45(3), 474–479. <https://doi.org/10.1021/jf960375j>
- Coria-Téllez, A. V., Montalvo-González, E., Yahia, E. M., & Obledo-Vázquez, E. N. (2018). *Annona muricata*: A comprehensive review on its traditional medicinal uses, phytochemicals, pharmacological activities, mechanisms of action and toxicity. *Arabian Journal of Chemistry*, 11(5), 662–691. <https://doi.org/10.1016/j.arabjc.2016.01.004>
- Davies, L. J., Risby, P. J., & Talbot, M. M. (2017). Wheat flour quality and its effects on breadmaking. *Cereal Chemistry*, 94(4), 364–372.
- Diamante, L. M., Bai, X., & Busch, J. (2014). Fruit leathers: Method of preparation and effect of different parameters on product quality. *International Journal of Food Science*, 2014, 1–12. <https://doi.org/10.1155/2014/139890>
- Falguera, V., Garvín, A., Pagán, J., & Ibarz, A. (2011). Effect of UV irradiation on enzymatic activities and physicochemical properties of apple juices from different varieties. *LWT - Food Science and Technology*, 44(1), 115–119.
- Gasmalla, M. A. A., et al. (2020). Nutritional composition, phytochemicals, and antioxidant activity of soursop (*Annona muricata*).
- Gomez, K. A., & Gomez, A. A. (2024). *Statistical procedures for agricultural research* (2nd ed., reprinted). John Wiley & Sons.
- Gutiérrez, T. J. (2020). State-of-the-art jackfruit (*Artocarpus heterophyllus* Lam.) biomaterials: A review of their properties and applications. *Carbohydrate Polymers*, 246, 116634. <https://doi.org/10.1016/j.carbpol.2020.116634>
- Handarbeni, R. G., Rahmayuni, R., & Rossi, E. (2023). Karakteristik fisikokimia dan sensori fruit leather dari campuran buah sirsak dan buah nangka. *Jurnal Teknologi dan Industri Pertanian Indonesia*, 15(2), 45–54.
- Hossain, A., et al. (2021). Nutritional value and medicinal benefits of jackfruit (*Artocarpus heterophyllus*).
- Kora, A. J. (2021). Fruit leather: An updated review of fruit-based confectionery products.
- Kubala, J. (2023, August 1). Soursop (graviola): Health benefits and uses. Healthline. <https://www.healthline.com/nutrition/soursop-benefits>
- Kurniarianti, Y., Purnamayati, L., Anggo, A. D., & Arifin, M. H. (2024). Characteristics of fruit leather made from jackfruit (*Artocarpus heterophyllus*) with the addition of *Gracilaria* sp. agar flour. *Journal of Advances in Food Science & Technology*, 11(1), 37–44.
- Kusumawardhani, Nugraha, Novi, & Chairunnisa. (2024). Culinary tourism in Kutawaringin (Bandung): Structural relationship between food quality, tourist perception, and culinary tourism satisfaction. *Pusaka: Journal of Tourism, Hospitality, Travel and Business Event*, 6(1), 208–219. <https://doi.org/10.33649/pusaka.v6i1.310>
- Laohakunjit, N., & Noomhorm, A. (2004). Effect of plasticizer on mechanical and barrier properties of rice starch film. *Starch-Stärke*, 56(8), 348–356. <https://doi.org/10.1002/star.200300234>
- Marrone, T. (2018). *The beginner's guide to making and using dried foods*. Storey Publishing.
- Mishra, S., & Prasad, S. (2006). Effect of maltodextrin and drying methods on quality of guava powder. *Journal of Food Engineering*, 73(3), 312–318. <https://doi.org/10.1016/j.jfoodeng.2005.05.026>

- Montgomery, D. C. (2017). Design and analysis of experiments (9th ed.). John Wiley & Sons.
- Montgomery, D. C. (2020). Design and analysis of experiments (10th ed.). John Wiley & Sons.
- Mukisa, I. M., Okilya, S., & Kaaya, A. N. (2010). Fruit leathers: The effect of solar drying on the quality and acceptability of jackfruit leather. LAP Lambert Academic Publishing.
- Mutakin, M., et al. (2022). *Annona muricata* L.: Antitumor activities, mechanisms, and general status of phytochemical composition.
- Ojha, P., et al. (2021). Study on the preparation and quality evaluation of fruit leather.
- Pavani, S., Lakshmi, K. S., Srinivasulu, B., Padmaja, V. V., & Sireesha, Y. (2022). Standardization of process development for fortified tamarind fruit leather. *The Pharma Innovation Journal*, 11(8), 1703–1706.
- Peters, C. M., Badrie, N., & Comissiong, E. (2001). Processing and quality evaluation of soursop (*Annona muricata* L.) nectar. *Journal of Food Processing and Preservation*, 25(6), 459–474.
- Priyanto, G. (1988). Teknik pengawetan pangan. *Jurnal Pusat Antar Universitas Pangan dan Gizi UGM*.
- Quek, S. Y., Chok, N. K., & Swedlund, P. (2007). The physicochemical properties of spray-dried watermelon powders. *Chemical Engineering and Processing: Process Intensification*, 46(5), 386–392. <https://doi.org/10.1016/j.cep.2006.06.020>
- Ranasinghe, R. A. S. N., et al. (2019/2020). Jackfruit (*Artocarpus heterophyllus* Lam.) as a source of functional food ingredients: A review.
- Rojas, M. M., Benítez, F. A., & Dufresne, S. L. (2016). The role of tapioca starch in the development of gluten-free foods. *Food Research International*, 89, 89–98.
- Sari, D. P., & Prabowo, A. (2022). Incorporation of tapioca starch and wheat flour on the quality of meat products. *International Journal of Food Science*, 2022, Article ID 8997522. <https://doi.org/10.1155/2022/8997522>
- Siburian, F., & Dahang, D. (2018). Impact of adding tapioca to fruit leather characteristics of timun suri (*Cucumis melo* L.). *International Journal of Food Science and Nutrition*, 3(1), 123–130.
- Somasundaram, S., et al. (2024). Phytochemical profile and pharmacological properties of soursop (*Annona muricata*): A recent review.
- Sothornvit, R., & Kiatchanapaibul, P. (2009). Quality and shelf-life of vacuum-packaged jackfruit bulb. *LWT - Food Science and Technology*, 42(6), 1071–1076.
- Steel, R. G. D., & Torrie, J. H. (1980). Principles and procedures of statistics: A biometrical approach (2nd ed.). McGraw-Hill.
- Swami, S. B., Thakor, N. J., Haldankar, P. M., & Kalse, S. B. (2012). Nutritional and health benefits of jackfruit (*Artocarpus heterophyllus* Lam.): A review. *Journal of Food Science and Technology*, 49(1), 1–13. <https://doi.org/10.1007/s13197-011-0310-1>
- Turan, A., & Cengiz, A. (2023). Technological and sensory properties of fruit leathers produced from different fruits.
- Valavi, S. G., & Peter, K. V. (2010). The jackfruit. *Arts & Science Academic Publishing*.
- Winarno, F. G. (1997). Kimia pangan dan gizi. Gramedia.
- Winarno, F. G. (1998). Enzim pangan. Gramedia.
- Yadav, R. B., Yadav, B. S., & Kumar, M. (2012). Effect of incorporation of plantain and chickpea flours on the quality characteristics of biscuits. *Journal of Food Science and Technology*, 49(2), 207–213.
- Zhu, F. (2022). Cassava starch: Structure, properties, and applications.