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The Effect of Mixing Rind of Watermelon (*Citrullus Lanatus*) and Kweni Mango (*Mangifera Odorata Griff.*) on the Quality of Slice Jam

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Abstract: This study aimed to evaluate the effect of mixing watermelon rind (*Citrullus lanatus*) and kweni mango (*Mangifera odorata* Griff.) on the color and sensory quality of slice jam while promoting the utilization of fruit-processing by-products. The experiment employed a Completely Randomized Design (CRD) with four treatment ratios of watermelon rind to kweni mango pulp: P1 (20:80), P2 (30:70), P3 (40:60), and P4 (50:50), each replicated three times. Color parameters (L*, a*, b*) were measured using the Color Grab application, and sensory evaluation of color, aroma, taste, and texture was conducted by 25 untrained panelists using a seven-point hedonic scale. Results showed that increasing the proportion of watermelon rind significantly enhanced lightness (L*) and yellowness (b*) while decreasing redness (a*). The sensory test indicated that the P4 formulation achieved the highest overall preference score (5.12), corresponding to a bright golden-yellow color, balanced aroma, and chewy texture. The discussion highlights that the improvement in color and texture is associated with the higher natural pectin content of watermelon rind, which contributes to gel formation and product stability. Moreover, combining kweni mango and watermelon rind demonstrates a viable approach for valorizing agricultural waste into value-added food products. In conclusion, the 50:50 mixture produced the most acceptable slice jam, confirming that watermelon rind can serve as a sustainable, functional ingredient to enhance product quality and support circular-economy practices in tropical fruit processing.

Keywords: Color characteristics; Kweni mango; Sensory quality; Slice jam; Sustainable food innovation; Watermelon rind

Introduction

In recent years, consumers have increasingly preferred food products that are not only of high quality but also practical and convenient to use. Slice jam is a modified version of traditional spreadable jam, which was originally semi-solid (slightly runny), transformed into compact, plastic-like, and non-sticky sheets (Herman, 2009, as cited in Lencana et al., 2019). Slice jam is produced by pureeing fruit flesh, molding it into thin layers, and drying it in an oven at specific temperature and time conditions, resulting in thin, sheet-like jam products (Harahap et al., 2015). The key ingredients responsible for gel formation in slice jam include sugar, citric acid, pectin, and stabilizers. When these components are mixed and heated, they form a compact gel structure. The ideal pectin content for jam-making is in the range of 0.75% to 1.5% (Lencana et al., 2019), and the sugar content should not exceed 65%. Theoretically, the gel formation mechanism in jams occurs through the polymerization and cross-linking of pectin molecules in the presence of acid and sugar, producing a viscoelastic network that entraps water and stabilizes texture (Winarno, 2008). This principle underpins the functional role of natural pectin in determining product consistency, cohesiveness, and moisture retention in gel-based foods (May, 1990; Thakur et al., 1997).

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Kweni mango (*Mangifera odorata Griff.*) is a fruit rich in vitamin C (13–80 mg) and dietary fiber (crude fiber content of 2.33 g) (Ministry of Health of the Republic of Indonesia, as cited in Fauzan et al., 2019). However, it has a relatively low pectin content, approximately 0.35% (Pracaya, 2011, as cited in Putri et al., 2022). Kweni mango is characterized by a sweet-sour flavor, yellow fibrous flesh, and a distinct aroma, and it is a fruit with economic value that could be enhanced through processing. On the other hand, watermelon albedo (the white inner rind) remains underutilized and is often discarded as waste. Nevertheless, it contains pectin, with a pectin content of approximately 0.88% (Puspitasari, 2014), making it a potential complementary ingredient to improve the pectin levels in kweni mango-based jam. Pectin's functionality in high-sugar, low-pH systems derives from hydrophobic and hydrogen-bonding interactions modulated by degree of esterification, molecular weight, and co-solutes (Sarangi, et al., 2023; Kastner et al., 2011). Recent green extraction approaches have demonstrated that mild organic acids can yield high-quality pectin from fruit by-products with favorable gel-forming properties (Chen et al., 2022), supporting the potential of natural rind-derived pectin as a sustainable gelling agent.

According to pectin theory, pectin is a structural polysaccharide that forms gels in the presence of sugar and acid. Its degree of esterification and molecular weight strongly influence gel strength and stability. Therefore, increasing the natural pectin concentration through the combination of high-pectin and low-pectin fruits enhances the mechanical properties, water-holding capacity, and overall texture of the final product (Müller-Maatsch et al., 2016). In this context, the addition of watermelon rind rich in pectin serves not only as a gelling agent but also as a natural stabilizer that improves viscosity and product uniformity without synthetic additives.

The development of innovative jam products using fruit by-products has gained increasing attention in food science, particularly in the context of sustainability and functional food design. Previous studies have demonstrated the potential of various fruit parts (often considered waste) as valuable sources of pectin and nutrients (Li et al., 2022). For instance, Harahap et al. (2015) explored the combination of soursop and papaya for fruit leather production, highlighting the role of fruit fiber in enhancing texture and acceptability. Similarly, Megawati et al. (2017) utilized watermelon albedo and tamarillo, which improved the gel structure due to the pectin content in both components. Valorizing fruit by-products such as watermelon rind and mango peel aligns with current circular-bioeconomy strategies to recover dietary fibers and phytochemicals for new food applications (Nirmal et al., 2023; Frosi et al., 2023). Watermelon rind is a proven, high-yield source of food-grade pectin, and extraction under mild organic acids gives reproducible yields and functional gel properties suitable for fruit gels (Mamiru & Gonfa, 2023). Greener extraction routes for mango-peel pectin such as lemon-juice acidification, also demonstrate strong gel performance while aligning with low-impact processing (Banerjee et al., 2016).

Beyond product formulation, this research also responds to global sustainability challenges. According to the Food and Agriculture Organization (FAO, 2021), more than one-third of all food produced globally is lost or wasted, and fruit by-products such as peels and rinds contribute significantly to this waste stream (Mirabella et al., 2014). Utilizing agricultural residues like watermelon rind aligns with the circular economy and food waste valorization concept, promoting the transformation of waste into high-value food ingredients. This approach also supports the Sustainable Development Goal (SDG) 12 on responsible consumption and production. The incorporation of fruit by-products into functional food products thus reflects an environmentally responsible innovation in food technology.

Watermelon rind, specifically the white albedo layer, has been shown to contain up to 0.88% pectin (Puspitasari, 2014), making it a viable gelling agent in low-pectin fruits such as kweni mango. Mango varieties in general, including kweni mango, are known for their distinct aroma and high vitamin C content, but their naturally low pectin level (around 0.35%) limits their use in stand-alone jam production (Pracaya, 2011; Putri et al., 2022). The blending of mango pulp with high-pectin ingredients is a common strategy in the formulation of jams, jellies, and fruit leathers to improve texture and consistency (Mathiazhagan et al., 2022; Tariq et al., 2023).

Additionally, the application of sensory evaluation in food innovation has been widely documented. Studies by Bareen et al. (2025) and Lencana et al. (2019) emphasize the importance of hedonic testing in determining consumer preferences, particularly in products targeting novel textures such as slice jams. The present study builds on these insights by combining instrumental color analygrsis with sensory evaluation to develop a functional, visually appealing, and palatable jam from underutilized local ingredients.

In light of the above, this study aims to investigate the effect of mixing watermelon albedo pulp and kweni mango pulp on the color and level of consumer preference in slice jam. This research was conducted for several key reasons: (1) to provide a scientific contribution in understanding the role of natural pectin in gel-based product formation; (2) to reduce food waste through the utilization of fruit by-products; and (3) to support local-based food innovation using abundant

tropical fruits in Indonesia. The findings are expected to contribute to food diversification, sustainable product development, and the advancement of food technology research focusing on value-added agricultural materials.

Method

Research Design

This study uses an experimental quantitative approach with a Completely Randomized Design (CRD), consisting of four treatments and three replications. This research was conducted at the Agricultural Technology Laboratory of the Faculty of Agriculture, Sam Ratulangi University, Manado. The materials were sourced from Karombasan Market, Manado. The treatments involve variations in the ratio of watermelon albedo pulp and kweni mango pulp, as follows: P1 consisted of 20% watermelon albedo pulp and 80% kweni mango pulp; P2 consisted of 30% watermelon albedo pulp and 70% kweni mango pulp; P3 consisted of 40% watermelon albedo pulp and 60% kweni mango pulp; and P4 consisted of an equal mix of 50% watermelon albedo pulp and 50% kweni mango pulp.

Research Target/Subject

The research samples consisted of slice jam products made from varying proportions of watermelon albedo pulp and kweni mango pulp. The organoleptic tests were conducted using 25 untrained panelists.

Research Procedure

The procedure involved several preparation stages, beginning with the watermelon albedo pulp. Following the method outlined by Puspitasari (2014), selected red watermelons were peeled, and the rinds were thoroughly washed under running water. The green outer skin was carefully removed to extract the white albedo. This albedo was then chopped into small pieces and blanched at 70°C for approximately 5 minutes. After blanching, it was blended with water at a 2:1 ratio to produce a smooth watermelon albedo pulp.

Next, the preparation of the kweni mango pulp followed the modified method of Sachlan et al. (2020). Ripe kweni mangoes were washed and peeled, and the fruit flesh was chopped into smaller sections. The chopped flesh was blended with water in a 1:1 ratio until a uniform pulp was obtained.

For the final preparation of the slice jam, a modified method from Megawati et al. (2017) was employed. The watermelon albedo pulp and kweni mango pulp were weighed according to their respective treatment ratios and thoroughly mixed. To this mixture, 40% granulated sugar and 1% agar powder were added, and the ingredients were cooked at a temperature of 70–80°C for 10 minutes with constant stirring. Afterward, 0.25% citric acid was added, and the mixture was cooked again under the same conditions for an additional 5–6 minutes while stirring continuously.

The hot mixture was then poured onto molds lined with aluminum foil to a uniform thickness of 0.3 cm and allowed to cool at room temperature. Once cooled, the jam was oven-dried at 65°C for 6 hours. After drying, the slice jam was cut into standardized pieces measuring 8.5 x 8.5 cm for further analysis.

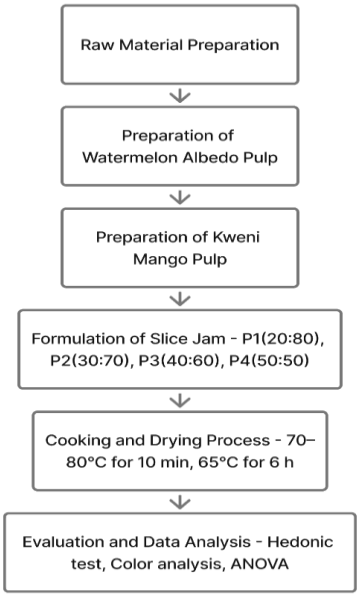

Figure 1. Research flow chart for the formulation and evaluation of slice jam from watermelon rind and kweni mango.

Instruments, and Data Collection Techniques

Materials used included red watermelon with dry stems and yellow spots on the rind, and ripe kweni mangoes identified by their fragrant aroma, golden yellow pulp, and soft texture. Other ingredients included Swallow Globe Brand agar powder, granulated sugar, water, and citric acid. Tools included an oven, blender, knife, cutting board, plastic containers, saucepan, spoon, spatula, digital scale, aluminum molds, frying pan, aluminum foil, gas stove, and plastic packaging. Data for this study were obtained through organoleptic testing and color analysis of the slice jam samples.

The organoleptic test was adapted from the method of Bareen et al. (2025), with several modifications. This test utilized a hedonic scale ranging from 1 (strongly dislike) to 7 (strongly like) to evaluate sensory attributes such as taste, texture, aroma, and color. Hedonic scale was used for consumer liking, following best-practice guidance in sensory science (Lim, 2011; Civille & Carr, 2015) . A total of 25 untrained panelists participated in the assessment. The samples were served at room

temperature on white plastic plates, with each sample cut to uniform dimensions of 8.5 x 8.5 x 0.3 cm (Lawless & Heymann, 2010).

The color analysis was conducted following the method described by Rahim et al. (2022). The evaluation used the "Color Grab" application on Android smartphones to capture color data. Samples were photographed in a controlled mini studio box with consistent lighting conditions and a white background. The color parameters measured included L* (lightness), a* (red-green spectrum), and b* (yellow-blue spectrum), allowing for objective comparison of the visual characteristics of each jam formulation.

Data analysis technique

The collected data were analyzed statistically using Analysis of Variance (ANOVA). Significant differences among treatments were further tested using appropriate post hoc tests to determine the effect of the watermelon albedo and kweni mango pulp ratios on the color and sensory acceptability of the slice jam.

Nutritional and Functional Potential

The combination of watermelon rind and kweni mango not only enhances the physicochemical characteristics of slice jam but also offers nutritional value that supports functional food development. Kweni mango is rich in vitamin C (13–80 mg per 100 g) and antioxidants, which play vital roles in immune support and collagen synthesis. Its dietary fiber content (2.33 g/100 g) also contributes to digestive health (Fauzan et al., 2019).

Meanwhile, watermelon rind despite often being discarded contains notable amounts of dietary fiber, natural sugars, amino acids, and most importantly, pectin. Puspitasari (2014) reported that the pectin content of watermelon albedo can reach 0.88%, a concentration sufficient to facilitate gel formation when combined with acidic and sugary media. Utilizing such by-products in food processing not only reduces food waste but also promotes sustainable and affordable alternatives to commercial thickeners or stabilizers (Said et al., 2023).

The integration of these two ingredients in a slice jam formulation demonstrates a promising approach to value-added product development from local agricultural resources. The resulting product provides both sensory appeal and potential functional benefits for health-conscious consumers.

Result and Discussion

Color

The panelists' evaluation of the color attribute of sheet jelly made from mixed watermelon albedo puree and kweni mango puree is presented in Table 1.

Table 1. Mean Liking Scores of Panelists for the Color of Sheet Jelly from Watermelon Albedo and Kweni Mango

Treatment	Mean Score	Criterion
P1	4.8	Slightly Like
P2	4.9	Slightly Like
P3	5.0	Slightly Like
P4	5.6	Like

Analysis of variance showed that the mixing treatments of watermelon albedo and kweni mango purees did not have a significant effect on the color attribute of the sheet jelly (F calculated < F table; α = 0.05). Therefore, no further multiple comparison test (Least Significant Difference) was conducted. This is due to the relatively similar orange-yellow color of the sheet jelly across treatments, mainly attributed to the dominant carotenoid pigments in kweni mango (Putri et al., 2017). Treatment P4, which consisted of 50% watermelon albedo and 50% kweni mango, obtained the highest mean score (5.6, categorized as "like") and was described by panelists as having a brighter golden-yellow color. These findings are in line with Megawati et al. (2017), who reported that combining watermelon albedo with tamarillo produced a more uniform and appealing yellow-red color in fruit leather, attributed to carotenoid and pectin interactions during heating. Similarly, Harahap et al. (2015) found that higher fruit pulp concentrations in soursop–papaya mixtures improved color stability and brightness. Furthermore, Zulaikhah and Fitria (2020) noted that positive b* (yellowness) and L* (lightness) values are key indicators of attractive color intensity in fruit-based gels. The present study reinforces these observations by demonstrating that the combination of kweni mango and watermelon rind enhances the jam's visual brightness and consumer appeal.

Aroma

The panelists' assessment of the aroma attribute is summarized in Table 2.

Table 2. Mean Liking Scores of Panelists for the Aroma of Sheet Jelly from Watermelon Albedo and Kweni Mango

Treatment	Mean Score	Criterion
P1	4.8	Slightly Like
P2	4.5	Neutral
P3	4.5	Neutral
P4	5.9	Slightly Like

Analysis of variance indicated that the treatment had no significant effect on aroma (F calculated < F table; α = 0.05), suggesting that the aroma profile of the sheet jelly was consistent across all formulations. The panelists noted that treatment P4 had a balanced aroma, not too

strong, yet still perceivable as kweni mango scent. This finding aligns with the chemical composition of kweni mango, which contains 45% oxygenated monoterpenes and 33% esters, with α-terpineol as the main component (Wong and Ong, 1993, cited in Iriani et al., 2019). Comparable observations were reported for mango: Liu et al. (2020) review hundreds of mango volatiles (terpenes, esters, aldehydes) and emphasize that cultivar and processing conditions primarily shape aroma, consistent with our finding that kweni mango dominated the profile. Detailed GC–MS work by Oldoni et al. (2022) further shows maturity-dependent shifts in mango volatiles that govern sensory perception. Similar ripening-driven changes in volatile composition have also been observed in other tropical fruits such as wampee (Mo et al., 2025), supporting the interpretation that the base fruit largely determines jam aroma. The reddish-orange hue observed in the mixed jam can be attributed to carotenoids from mango and betalains (if present from additives or co-ingredients); both pigment classes are heat- and pH-sensitive (Khoo et al., 2011; Azeredo, 2008)

Taste

The panelists' score for taste are shown in Table 3.

Table 3. Mean Liking Scores of Panelists for the Taste of Sheet Jelly from Watermelon Albedo and Kweni Mango

Treatment	Mean Score	Criterion
P1	5.3	Slightly Like
P2	5.1	Slightly Like
P3	4.8	Slightly Like
P4	5.1	Slightly Like

Analysis of variance revealed no significant differences in taste among the treatments (F calculated < F table; α = 0.05). The mean liking scores ranged from 4.8 to 5.3, indicating a slight preference overall. Treatment P1 (20% watermelon albedo and 80% kweni mango) scored the highest mean (5.3), described by panelists as having a sweeter and slightly acidic taste. The acidic and sweet flavors originate from the kweni mango and the added citric acid and sugar. This sweetness correlates with the carbohydrate content of kweni mango (12.4%), where starch is converted into reducing sugars during fruit maturation (Winarno, 2008, cited in Putri et al., 2017). These findings are consistent with Lencana et al. (2019), who emphasized that sugar concentration and acid addition directly affect the perceived sweetness and flavor balance in seaweed-based slice jams. Similarly, Pan et al. (2021) observed that the inclusion of low-pectin fruits such as mango in composite jams produces a desirable sweet–acidic profile favored by consumers. Therefore, the taste preference found in this study supports prior research showing that natural fruit sugar and acidity ratios are key determinants of acceptability in pectin-based products. Key mango aroma notes (terpenes such as terpinolene, β-myrcene; aldehydes such as hexanal) are consistent with known volatile profiles across cultivars (Pino et al., 2005; Munafo et al., 2014; Xie et al., 2023)

Texture

The panelists' evaluations of texture are reported in Table 4.

Table 4. Mean Liking Scores of Panelists for the Texture of Sheet Jelly from Watermelon Albedo and Kweni Mango

Treatment	Mean Score	Criterion
P1	4.3	Neutral
P2	4.3	Neutral
P3	4.7	Slightly Like
P4	4.9	Slightly Like

Analysis of variance showed no significant differences in texture across treatments (F calculated < F table; α = 0.05). This is attributed to similar moisture content in each formulation, which strongly influences texture. The mean liking scores varied from neutral to slightly like, with treatment P4 receiving the highest score (4.9). Panelists described P3 and P4 as having a chewy texture, whereas P1 and P2 were slightly less chewy. Increased moisture content tends to enhance the chewiness of the sheet jelly. This outcome corresponds with the findings of Megawati et al. (2017), who stated that increasing pectin content through watermelon albedo improves elasticity and reduces brittleness in slice jams. Rahim et al. (2022) further demonstrated that texture correlates with the water-holding capacity and polymer interaction of pectin chains during gel formation. Additionally, Müller-Maatsch et al. (2016) explained that natural pectin extracted from fruit waste enhances viscoelasticity and structural stability in fruit gels. The results of this study are consistent with these theories, confirming that the balance of watermelon rind and kweni mango can yield optimal chewiness and uniform texture. The increase in firmness and spreadability at higher pectin levels agrees with optimization studies on fruit jams, where pectin concentration positively correlates with hardness/adhesiveness up to an optimum (Nourmohammadi et al., 2021). Controlled increases in pectin level significantly raise apparent viscosity, firmness and cohesiveness of mixed-fruit jams while maintaining consumer acceptance within an optimal range (Estaji et al., 2020), aligning with the higher preference obtained for our P4 formulation. Our gel

strength trends with sugar and acid are compatible with LM/HM pectin gelation behavior under varying Ca^{2+} and pH/cooling-rate conditions.

Overall Acceptance

The overall acceptance scores for the sheet jelly products are presented in Table 5.

Table 5. Mean Overall Acceptance Scores of Panelists for Sheet Jelly from Watermelon Albedo and Kweni Mango

Treatment	Mean Score	Criterion
P1	5.0	Slightly Like
P2	4.9	Slightly Like
P3	5.0	Slightly Like
P4	5.12	Slightly Like

Treatment P4 (50% watermelon albedo and 50% kweni mango) scored the highest overall acceptance (5.12), falling between neutral and like. This treatment combined a brighter golden-yellow color, balanced aroma with a noticeable mango scent, sweeter and slightly acidic taste, and a chewy texture, making it the most preferred formulation among panelists. This finding aligns with Li et al. (2022), who reported that blending fruits with complementary color and texture characteristics enhances consumer acceptance. Tariq et al. (2023) also observed that using fruit by-products rich in fiber and pectin improved sensory quality while contributing to functional value. Therefore, the high acceptance of P4 can be attributed to its balanced sensory attributes and its sustainable use of agricultural residues, which add both environmental and nutritional advantages.

Color Measurement (Color Grab Application)

Instrumental color measurements of the sheet jelly are summarized in Table 6. The analysis of variance results showed that the mean values for L* (lightness) ranged from 56.4 to 66.4, which are close to 100, indicating a relatively high brightness level. The higher the L* value, the brighter the resulting slice jam. The b* values (yellowness or yellow-blue axis) ranged from +55.2 to +61.8, indicating that the slice jam tends to have a yellowish color. According to Zulaikhah and Fitria (2020), a negative (−) b* value indicates a tendency towards bluish hues, whereas a positive (+) value corresponds to a yellowish coloration. The a* values (redness or red-green axis) ranged from +5.6 to +14.1, showing that the jam tends to exhibit a reddish color. Comparable processing studies show that jam color and carotenoid/flavonoid retention depend strongly on the heating regime and storage time; in grapefruit jam, β-carotene and key flavonoids decline with both heat processing and extended storage (Igual et al., 2013), consistent with our observed lightness/yellowness shifts.

Table 6. Mean Color Values (L, a, b*) of Sheet Jelly from Watermelon Albedo and Kweni Mango

Treatment	Mean			Notes	
	L* (Lightness)	a* (Redness)	b* (Yellowness)	Color Name	Color
P1	55.7	+14.1[b]	+55.2	Honey yellow	
P2	59.8	+13.3[b]	+56.4	Honey yellow	
P3	62.3	+7.9[a]	+58.6	Golden yellow	
P4	66.4	+5.6[a]	+61.8	Golden yellow	

Note: (*) Different superscript letters indicate significant differences between treatments ($p < 0.05$).

These results correspond with Rahim et al. (2022), who found that color parameters (L*, a*, b*) in fruit-based gels are strongly influenced by pigment–pectin interactions and drying temperature. The increase in lightness and yellowness in higher rind proportions (P3–P4) may also relate to the Maillard reaction between sugars and amino acids during heating, a phenomenon previously observed by Li et al. (2022) in rose jam production. Thus, the present findings confirm that the combination of kweni mango and watermelon rind yields a stable, bright, and naturally pigmented product with strong visual appeal.

Limitations and Recommendations for Future Research

Although the present study provides useful insights into the formulation and sensory acceptability of slice jam made from watermelon rind and kweni mango, it has certain limitations. First, the research relied solely on untrained panelists, which may not reflect broader consumer preferences across different demographics. Second, the nutritional content was inferred from secondary sources rather than confirmed through laboratory-based proximate or micronutrient analysis. Lastly, the product's shelf-life and microbial safety were not evaluated, which are crucial for potential commercialization.

Future research should focus on several key areas to strengthen and expand upon the current findings. First, conducting proximate and micronutrient analyses would help verify the actual nutritional contribution of the watermelon albedo and kweni mango pulp. Additionally, shelf-life studies—including microbiological testing and moisture activity analysis—are essential to determine the product's safety and stability over time. Further sensory evaluation using trained panelists and a larger, more diverse consumer base would provide a more comprehensive understanding of the product's acceptability. Moreover, a cost-benefit analysis should be carried out to assess the economic feasibility of scaling up production. Collectively, such research efforts would enhance the scientific robustness of this study and contribute to the development of a sustainable food innovation utilizing fruit by-products. Taken together, greener pectin extraction from mango by-products (Banerjee et al., 2016) and proven rind-pectin functionality (Mamiru & Gonfa, 2023) support our approach of integrating by-product-derived gelling agents to deliver acceptable sensory quality with improved resource circularity.

Conclusion

The study demonstrated that mixing watermelon rind (*Citrullus lanatus*) and kweni mango (*Mangifera odorata* Griff.) significantly influences the color and sensory properties of slice jam. Increasing the proportion of watermelon rind improved lightness (L*) and yellowness (b*), producing an appealing golden-yellow appearance, while maintaining acceptable redness (a*) values. Among all formulations, the 50:50 combination (P4) achieved the highest overall preference score (5.12), indicating balanced sweetness, aroma, texture, and color. These results confirm that watermelon rind, a by-product often discarded as waste, can be effectively used as a natural pectin source to improve texture and visual quality without synthetic additives. The findings also reinforce the importance of valorizing agricultural residues to promote sustainable food innovation. Future research focusing on proximate analysis, shelf-life, and microbial stability would strengthen the scientific basis for scaling this formulation to industrial production. Overall, integrating rind-derived pectin and kweni mango pulp provides both functional and environmental benefits, supporting circular-economy approaches in tropical food processing.

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Author Contributions
Conceptualization, L.E.L. and A.C.P.; Methodology, L.E.L.; Investigation, T.M.L. and T.K.; Writing – Original Draft Preparation, L.E.L.; Writing – Review & Editing, A.C.P.; Supervision, T.K.

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Conflicts of Interest
The authors declare no conflict of interest.

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