PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol 12(1): 1-8
https://doi.org/10.14719/pst.4417

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RESEARCH ARTICLE

Starfruit (*Averrhoa carambola* L.) jam enriched with different types of sugar: A comparative study

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OPEN ACCESS

ARTICLE HISTORY
Received: 21 July 2024
Accepted: 04 December 2024
Available online
Version 1.0 : 06 February 2025
Version 2.0 : 13 February 2025

Check for updates

Additional information
Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
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Apolonio KBM. Starfruit (*Averrhoa carambola* L.) jam enriched with different types of sugar: A comparative study. Plant Science Today. 2025; 12(1): 1-8. https://doi.org/10.14719/pst.4417

Abstract

This study used an experimental research design. The study was conducted to develop food products using starfruit as the main ingredient and to determine the nutritional composition of starfruit jam. Fifty respondents evaluated the starfruit jam through organoleptic criteria such as appearance, aroma, flavor, consistency, taste, aftertaste, and overall acceptability; a 9-point hedonic scale was used to determine the level of acceptability. This study included three treatments using varying types of sugar, such as white (treatment 1), brown (treatment 2), and muscovado (treatment 3), with the same measurements of ingredients generally acceptable as a result. Treatment 2 has the highest overall acceptability, followed by Treatment 3, and the least is Treatment 1, which are all described as very much by the respondents. Additionally, treatment 2 is the most preferred product regarding taste and aftertaste, while the different age groups have diverse acceptability levels when the food product was evaluated. Starfruit jam was analyzed, and its various nutritional content was determined to ensure that it is healthy and nutritious when consumed. Furthermore, the economic value of starfruit jam provides high investment returns due to the province's availability and affordability of supply. Finally, a potential source of income and product commercialization was forecasted for this newly developed foodstuff.

Keywords

Averroha carambola L.; comparative, enriched; lemon rind; nutrient content; organoleptic; starfruit

Introduction

Fruits provide a significant share of the vitamins, minerals, and fiber in our daily diet, making them a key component of a balanced diet and a good source of vitamins and minerals (1). These fruits are not only consumed fresh but are significantly produced into jams, preserves, and marmalades, considering their nutritional content and health benefits for consumers (2-5).

One of the most common but underutilized fruits in the Philippines is *Averrhoa carambola* L. or balimbing. The starfruit (*A. carambola* L.) is a popular tropical and non-tropical fruit (6). *A. carambola* L., or star fruit, is a species of Oxalidaceae perennial tree. Although it is assumed to be indigenous to Malaysia, it is a tropical American plant transported to Asia by Spanish galleons and commonly cultivated in tropical and warm subtropical climes. The starfruit is highly commercially

valuable, widely distributed, and farmed throughout southern China, Southeast Asia, India, and northern South America (7-9). Starfruit (*A. carambola* L.) is considered an underutilized fruit due to its perishale and high-moisture content, possessing significant and unique nutritional properties and adaptability to local growing conditions (10, 11). Hence, it must extend its shelf life through proper storage to be utilized for food production and human consumption (12, 13). This fruit is typically consumed fresh and uncooked, but it can also be sliced and added to dishes and salads. Additionally, it can be processed and turned into jam, jelly, a preserve, or even just a straightforward juice bearing its vital vitamins and minerals that the body needs, such as calcium, iron, thiamin, riboflavin, niacin, and ascorbic acid; it has a variety of nutritional and therapeutic advantages (14); it is also high in vitamins, minerals, and antioxidants, which help with body maintenance and growth (15).

It was revealed that starfruit has a sweet and sour taste, is shaped like a five-point star, differentiated by its yellow or green hue, and is employed as a potential source of functional foods (16, 17). *A. carambola* L. is completely palatable and can make a range of goods; it also tastes savory, crunchy, juicy, slightly sour, acidic, and sweet. Carambola or the star fruit (*A. carambola* L.) is an underutilized fruit with nutritional and medicinal values (18); therefore, the development of new processed products would be extremely beneficial in maximizing the utilization of carambola fruits that are a good source of natural antioxidants and minerals. Through the use of low-quality and underutilized fruits that cannot be marketed, a research was performed to create value-added food products, thereby increasing the good flavors of the products to minimize waste while raising farmers' profits and crop value (19-22).

During the fruit-bearing season, fruits are abundant; chopped or crushed fruits can be blended with sugar to make jam and then stored for future use. It is widely used in producing fruit salads and fruit platters, as a garnish in cocktails and beverages, or squeezed into juice and given as a functional beverage. Jam production is a common method for preserving fruits, extending their shelf life while retaining their nutritional and sensory qualities. The choice of sugar in jam formulation plays a crucial role in determining the final product's texture, taste, and overall quality (23, 24). The high moisture content and perishability of starfruit (25, 26) can be used in jams, jellies, fruit purees, ice creams, preserves, sweets, and vinegar (27). This common and underutilized fruit in the Philippines is known as an amazing crop and is mostly used by Filipinos as food and for culinary purposes. Hence, the starfruit was utilized as the primary raw ingredient in making the starfruit jam, a valued product from this uncommon or underutilized fruit in the province of Quirino. Due to the abundance of starfruit at the Quirino State University (QSU)-Diffun Campus, especially during the season, different product versions were created to add food products and lessen wastage, and a starfruit jam was produced.

Jam is a stable product comprised of fruits and sugar (28, 29); hence, sugars serve as sweeteners and preserve the shelf life of products (30). Understanding how different sugars impact the sensory and nutritional qualities of starfruit jam is essential for optimizing product development and meeting consumer preferences. This comparative study aims to provide insights into the formulation of high-quality starfruit jam enriched with sugars, contributing to the diversification of the jam industry and promoting the consumption of nutritious tropical fruits like starfruit. When making jam, the type of sugar used can significantly affect the product's flavor, texture, and overall outcome, which impacts the jam-making process. Brown granulated sugar is light-yellow due to the presence of small amounts of molasses (31). Brown sugar is well-known for its sweetness and delightful caramel-like aroma (32).

Furthermore, it is important to consider factors such as the choice of sugar types, cooking techniques, and packaging methods to ensure the successful creation of a marketable and appealing product. Additionally, after determining the most preferred and acceptable starfruit jam, which is treatment 2 using brown sugar, the starfruit jam was also analyzed based on its nutrient content to ensure that the food product provides nutritional value and health benefits to all types of consumers. A comprehensive proximate analysis of the nutritional composition of the preferred starfruit jam was conducted at the Chemistry Laboratory, College of Health Sciences in QSU-Diffun Campus, Andres Bonifacio, Diffun, Quirino. This study provides insights into the potential of using alternative sweeteners in jam production, which could cater to consumers' increasing demand for healthier and more diverse food products. This starfruit jam has a sweet taste that consumers can love due to the new tastes that it brings to their cravings and palate. Finally, this food item was created to provide additional products for consumers and tourists visiting the Quirino province.

Materials and Methods

The starfruit was harvested at the QSU-Diffun Campus compound and used as the main ingredient for the food product. After cleaning and washing, the starfruit was chopped and pureed using the blender. The processing techniques in the preparation of starfruit is shown in Fig. 1. The product preparation or formulation was done at the food laboratory facility as a venue for preparing and producing the starfruit jam.

In the study, starfruit jam was prepared, and different types of sugar were used following the three (3) treatments: white sugar (T1), brown sugar (T2), and muscovado sugar (T3). Fig. 2 shows the procedures for making starfruit jam. This procedure started with preparing the needed utensils, materials, and equipment that were thoroughly cleaned and sanitized; the starfruit was cleaned, deseeded, and pureed. After the ingredients were measured using the weighing scale. The following procedures were made as follows: (a) The ingredients were

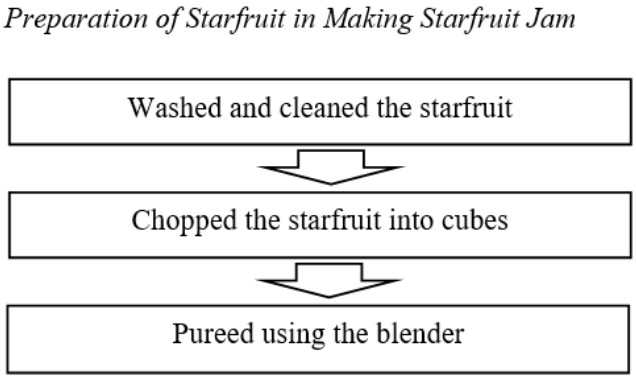

Fig. 1. Processing techniques of the starfruit.

Fig. 2. Procedures in making starfruit jam.

prepared; (b) The ingredients were mixed in a mixing bowl; (c) The ingredients were transferred to a saucepan, then place on the burner stove over medium heat; (d) The mixture of starfruit was stirred to avoid lumps and sticking into the pan until achieving the desired consistency; (e) The mixture was then cooled and transferred in a sterilized bottle; and (f) finally it was labeled and kept in a cool, dry, and safe place (33).

Research design

The study employed experimental research design in the development and analysis of starfruit jam, which was also used in evaluating and developing a food product (33). Moreover, this study conducted treatments of the food products to assess their quality and sensory evaluation. The acceptability level of starfruit jam enriched with different types of sugar among respondents was determined based on appearance, aroma, flavor, consistency, taste, aftertaste, and overall acceptability.

Data Analysis

The study employed both descriptive and inferential statistics to attain the main objective. Descriptive statistics like percent and frequency were used to describe the distribution and profile of the selected respondents of the study based on sex and age. Mean, and standard deviation were used to describe the evaluated treatments in terms of the criteria set and the overall acceptability of the prepared treatments.

The data gathered was subjected to statistical analysis using SPSS Statistics computer software version 21. Inferential statistics like repeated measures Analysis of Variance (ANOVA) were used to compare and contrast between and among three treatments based on the acceptability criterion. This statistical approach was employed to assess variations within and between the treatments, providing a robust analysis of the impact on acceptability.

To interpret the level of acceptability of the respondents along the different parameters, the mean scores of the nine-point hedonic scale were verbally interpreted using the range of scores shown in Table 1.

Percentage (Return on Investment or ROI) was used to determine and describe the economic profitability of starfruit jam. The ROI formula is:

ROI= Net Profit/Expenses (100%) (Eqn.1)

Table 1. Hedonic scale

Scale	Descriptive Interpretation
1.00-1.49	Dislike Extremely
1.50-2.49	Dislike Very Much
2.50-3.49	Dislike Moderately
3.50-4.49	Dislike Slightly
4.50-5.49	Neither Like nor Dislike
5.50-6.49	Like Slightly
6.50-7.49	Like Moderately
7.50-8.49	Like Very Much
8.50-9.00	Like Extremely

Product tasting procedures

The research study involved fifty respondents, faculty and students of QSU-Diffun Campus, who served as evaluators of the sensory taste of the food product. The tasting assesses the appearance, aroma, flavor, consistency, taste, aftertaste, and overall acceptability. The respondents were briefed and evaluated before the product tasting of the starfruit jam to ensure that they could properly evaluate the sensory characteristics of the food product. The researcher distributed the survey questionnaires and starfruit jam to the respondents for product tasting. The sensory evaluation was conducted

closely with the respondents to optimize sensory testing efficiently. A nine-point hedonic scale was used to determine the Hedonic characteristics of the food product (34-40).

Results and Discussion

This section presents the data gathered, which are systematically displayed in table form. The data were analyzed and interpreted through appropriate statistical procedures. The results and discussion of the study are presented in the following order: profile of the respondents, consumers' acceptability, proximate analysis, and the economic value of starfruit jam.

Profile of the respondents

The profiles of the 50 respondents, including their information in terms of sex and age, were presented in table 2. Most respondents are female, with 37 or 74%, while the majority are aged 16-20, with 27 or 54%. Based on the results, most respondents are females, and the highest are from 16-20. The attitudes and perceptions of consumers regarding innovations in food product development are relevant in determining their acceptability to consumers (41).

Table 2. Profile of respondents as to sex

Sex	Frequency	Percent
male	13	26.0
female	37	74.0
Total	**50**	**100.0**
Age	**Frequency**	**Percent**
16-20	27	54.0
21-25	13	26.0
26-30	5	10.0
31-35	3	6.0
36-40	1	2.0
41-50	1	2.0
Total	**50**	**100.0**

Consumers' acceptability and organoleptic characteristics of the prepared treatments

Organoleptic evaluation is a method that uses taste and smell, two human senses, to assess the qualities of food, water, medications, and consumer goods (42). Given that consumers judge the quality of a product using their senses, it is crucial to assess the quality of products, hence offering valuable information for creating starfruit-based food products that suit consumer preferences (43).

Starfruit jam 1: This treatment is prepared by using white sugar. Table 3 reveals that treatment 1 exhibited an overall acceptability of 8.27, described as very much. It garnered the highest mean rating of 8.50, defined as "Like extremely" in terms of appearance, while aroma, flavor, consistency, taste, and aftertaste are described as like very much. This implies that the starfruit jam is acceptable to the consumers in all criteria.

Table 3. Level of acceptability of treatment 1 in terms of the organoleptic criterion and its overall acceptability

Criterion	N	Mean	SD*	Qualitative Description
Appearance	50	8.5000	0.81441	**Like Extremely**
Aroma	50	8.2400	1.04119	Like Very Much
Flavor	50	8.3200	1.01900	Like Very Much
Consistency	50	8.2200	1.09339	Like Very Much
Taste	50	8.4400	0.90711	Like Very Much
Aftertaste	50	7.9200	1.17526	Like Very Much
Overall Acceptability	**50**	**8.2733**	**0.64485**	**Like Very Much**

1.00-1.49 Dislike Extremely; 1.50-2.49 Dislike Very Much; 2.50-3.49 Dislike Moderately;
3.50-4.49 Dislike Slightly; 4.50-5.49 Neither Like nor Dislike; 5.50-6.49 Like Slightly;
6.50-7.49 Like Moderately; 7.50-8.49 Like Very Much; 8.50-9.00 Like Extremely

Starfruit jam 2: This treatment is prepared by using brown sugar.Table 4 explains the mean ratings attained by treatment 2 of starfruit jam. Concerning the taste, it garnered the highest mean rating of 8.60, which is described as "Like extremely". Moreover, appearance, aroma, flavor, consistency, aftertaste, and overall acceptability were all described as "Like very much". This implies that the starfruit jam is acceptable to the consumers.

Table 4. Level of acceptability of treatment 2 in terms of organoleptic criterion and overall acceptability

Criterion	N	Mean	SD*	Qualitative Description
Appearance	50	8.4600	0.83812	Like Very Much
Aroma	50	8.2800	0.94847	Like Very Much
Flavor	50	8.4400	0.95105	Like Very Much
Consistency	50	8.0000	0.00000	Like Very Much
Taste	50	8.6000	0.75593	**Like Extremely**
Aftertaste	50	8.4200	0.97080	Like Very Much
Overall Acceptability	**50**	**8.3667**	**0.39412**	**Like Very Much**

1.00-1.49 Dislike Extremely; 1.50-2.49 Dislike Very Much; 2.50-3.49 Dislike Moderately;
3.50-4.49 Dislike Slightly; 4.50-5.49 Neither Like nor Dislike; 5.50-6.49 Like Slightly;
6.50-7.49 Like Moderately; 7.50-8.49 Like Very Much; 8.50-9.00 Like Extremely

Starfruit jam 3: This treatment is prepared by using muscovado sugar. Table 5 shows the mean ratings attained by treatment 3 of starfruit jam. Aroma obtained the highest mean score of 8.44, while aftertaste, appearance, flavor, consistency, taste, and overall acceptability were described as "Like very much". This implies that the starfruit jam is acceptable to the consumers.

Comparison of the overall acceptability and organoleptic properties of the three treatments of prepared jam

The three prepared treatments were compared statistically via repeated measures ANOVA.

Table 5. Level of aceptability of treatment 3 in terms of organoleptic criterion and overall acceptability

Criterion	N	Mean	SD*	Qualitative Description
Appearance	50	8.3000	1.34392	Like Very Much
Aroma	50	8.4400	1.07210	Like Very Much
Flavor	50	8.2600	1.22574	Like Very Much
Consistency	50	8.2600	1.20898	Like Very Much
Taste	50	8.2200	1.23371	Like Very Much
Aftertaste	50	8.3200	1.31615	Like Very Much
Overall Acceptability	**50**	**8.3000**	**0.84984**	**Like Very Much**

1.00-1.49 Dislike Extremely; 1.50-2.49 Dislike Very Much; 2.50-3.49 Dislike Moderately;
3.50-4.49 Dislike Slightly; 4.50-5.49 Neither Like nor Dislike; 5.50-6.49 Like Slightly;
6.50-7.49 Like Moderately; 7.50-8.49 Like Very Much; 8.50-9.00 Like Extremely

Result of repeated measures ANOVA: Table 6 highlights the result of a comparison between and among the three treatments. Results reveal a significant difference in some criteria for organoleptic properties. Looking closely at the table, T2 and T3 are significantly different in terms of Taste (p value = 0.021), while T1 and T2 are significantly different in terms of the criterion aftertaste (p value=0.025). No significant difference was exhibited on the other criterion between and among the three treatments. Table 6 shows the descriptive statistics, specifically the mean scores for the extent of evaluation for each treatment.

Table 6. Result of repeated measures ANOVA

Criterion	T1-T2-T3		
	T1/T2	T1/T3	T2/T3
Appearance	0.811	0.274	0.501
Aroma	0.780	0.358	0.382
Flavor	0.508	0.766	0.426
Consistency	0.161	0.862	0.135
Taste	0.382	0.345	**0.021***
Aftertaste	**0.025***	0.117	0.534
Overall Acceptability	0.325	0.857	0.489

*p < 0.05, n = 50

Summary result for mean scores of each treatment: Table 7 identifies the treatment that demonstrates a significantly higher mean score for criteria displaying notable differences. The summarized results for mean scores are presented in this table. A significant distinction was observed between T1 and T2 concerning aftertaste, whereas T2 and T3 displayed a noteworthy difference specifically in terms of taste, as presented in Table 6. The mean scores in Table 7 show that in terms of aftertaste T2 (mean=8.42) is significantly higher than T1 (mean=7.92). This implies that in terms of aftertaste, T2 is most preferred by the respondents. In terms of taste, T2 and T3 are significantly different. The descriptive statistics summary in Table 6 shows that T2 (mean=8.6) is significantly higher than T3 (8.22). This implies that T2 is the most preferred in terms of Taste.

Table 7. Summary results for mean scores of each treatment

Criterion	Mean (T1)	Mean (T2)	Mean (T3)
Appearance	8.5000	8.4600	8.3000
Aroma	8.2400	8.2800	8.4400
Flavor	8.3200	8.4400	8.2600
Consistency	8.2200	8.0000	8.2600
Taste	8.4400	8.6000	8.2200
Aftertaste	7.9200	8.4200	8.3200
Overall Acceptability	**8.2733**	**8.3667**	**8.3000**

Comparison of the overall acceptability and organoleptic properties of the three treatments of prepared jam in terms of profile

Comparative statistical result for two selected variables on the criterion for organoleptic properties and overall acceptability: Table 8 shows no significant difference in overall acceptability and organoleptic properties when grouped by sex. Furthermore, the results reveal a significant difference in age groups, particularly the choice of aroma (p value=0.003), flavor (p value=0.001), taste (p value=0.017), aftertaste (p value=0.003), and overall acceptability (p value=0.002).

Table 8. Comparative statistical results for two selected variables on the criterion for organoleptic properties and overall acceptability

Criterion	PROFILE	
	SEX	AGE
Appearance	**0.845**	**0.550**
Aroma	0.733	**0.003***
Flavor	0.500	**0.001***
Consistency	0.803	0.287
Taste	0.339	**0.017***
Aftertaste	0.581	**0.003***
Overall Acceptability	0.723	**0.002***

*p < 0.05, n = 50

This implies that the respondents, when grouped by sex have the same level of acceptability of starfruit jam with different varieties of sugar using the three treatments. On the contrary, the respondents had a significant difference when the product was evaluated in terms of age. Conducting age-specific sensory evaluations and market research helps fine-tune products to meet the diverse expectations of consumers at different life stages. Comparing the acceptability of products based on respondent profiles enhances market understanding, supports targeted marketing efforts, and contributes to strategic decision-making in product development and promotion. It is a valuable tool for creating products that align with diverse consumer preferences and optimizing business outcomes.

Proximate analysis of the nutritional composition of the preferred starfruit jam

Proximate analysis result on the preferred treatment: Table 9 explains the nutrient content and proximate analysis of starfruit jam using different types of sugar. This table illustrates that the food product has a moisture content of 28.19%. Moreover, the starfruit jam has .84g

total protein, 0.02g lipid, 0.64g ash, 1.2g fiber, 69.11g carbohydrate and 590Kcal metabolized energy, and ascorbic acid equivalent was analyzed in every 100g of the product sample. The findings presented in Table 9, detailing the nutrient content and proximate analysis of starfruit jam with various sugar types, carry significant implications. Notably, the moisture content of 28.19% suggests a balanced level, contributing to the product's texture and overall quality. The nutritional composition per 100g of the starfruit jam indicates a substantial carbohydrate content (69.11g), providing a considerable energy source (590 kcal). The presence of 0.84g total protein signifies a modest protein content, contributing to the product's nutritional profile. The minimal lipid content (.02g) aligns with the expectations for fruit-based jams, emphasizing a low-fat profile. The presence of .64g ash and 1.2g fiber underscores the product's mineral and dietary fiber content, contributing to potential health benefits such as digestive health.

Table 9. Proximate analysis results on the preferred treatment

Nutritional Test	Method Employed	Result
Moisture Content	Moisture Analyzer	28.19%
Total Protein	Biuret Method	0.84 g in every 100 g of the sample
Total Lipid	Folch	0.02 g in every 100 g of the sample
Total Ash	Raghuramalu	0.64 g in every 100 g of sample
Total Fiber	Raghuramalu	1.2 g in every 100 g of the sample
Total Carbohydrate	Raghuramalu	69.11 g in every 100 g of the sample
Metabolized Energy (ME)	Randive	590 Kcal/100g of the sample
Ascorbic Acid Equivalent	Ragazzi	80.85 mg Ascorbic Acid Equivalent per gram

Furthermore, the inclusion of ascorbic acid equivalent in the analysis emphasizes the product's potential as a source of vitamin C, which is a positive attribute from a nutritional standpoint. These nutritional insights suggest that the starfruit jam, particularly when prepared with the specified types of sugar, offers a well-rounded balance of macronutrients and additional health-promoting components. This information is valuable for consumers seeking products with specific nutritional characteristics and for product developers aiming to effectively communicate the starfruit jam's nutritional benefits. Starfruit is considered a fruit high in nutrients and a potential source for a balanced diet when placed as an ingredient in food products (44).

Economic value of starfruit jam with different types of sugar

Table 10 shows the economic assessment revolves around the production of starfruit jam using different types of sugar. Each treatment incurs varying total costs, with the muscovado sugar (T3) where the cost is the highest at Php115.50.00, followed by Php112.25 for white sugar (T1), and the lowest total cost of Php109.25 for the brown sugar (T2).

Table 10. Result of the economic value of starfruit jam with different types of sugar

	Treatment 1 (White Sugar)	Treatment 2 (Brown Sugar)	Treatment 3 (Muscovado Sugar)
Per Preparation (Total Cost)	112.25	109.25	115.50
Yield	3	3	3
Price Per Bottle	50.00	48.00	52.00
Gross Profit	150.00	144.00	156.00
Net Profit	37.75	34.35	40.50
Return on Investment (ROI)	**33.63%**	**31.33%**	**35.06%**

The yield, or the quantity of starfruit jam per preparation, is the same across the treatments produced three (3) items of products at a net weight of 150g per bottle. The price per bottle varies depending on the sugar used in the product. Consequently, this leads to gross profits of Php156 for T3 as the highest price per bottle of jam, followed by Php150.00 for T1, and the lowest profit is Php 144.00 for T2. After deducting the respective total costs, the net profit for each treatment is calculated. The T3 yields the highest net profit, while T2 has the least. In this context, the T3 boasts an ROI of 35.06%, the T1 has a 33.63%, and T2 garnered a 31.33% ROI. These percentages signify the returns gained relative to the initial investment.

The economic evaluation of starfruit jam using different types of sugar production demonstrates that T3 using muscovado sugar treatment yields the highest economic value. It incurs the highest total cost and produces the highest price per bottle of jam, gross profit, and return on investment among the three treatments. Conversely, the T2 using brown sugar incurs the lowest total cost and yields the lowest economic value. The T1 using white sugar falls in between, showing favorable results across various economic metrics.

The people's initiative to process starfruit into food products significantly extends the fruit's shelf life and increases its economic value (45) to improve community welfare through this additional source of income from food products (46). Additionally, it was found that the production and selling of unutilized fruits yielded a profitable return on investment (47). Moreover, star fruit's economic value can be raised through processing into derivative goods or products (48, 49).

Conclusion

The study revealed that starfruit jam using brown sugar provides valuable insights into consumer preferences, nutritional composition, and economic viability. Age was identified as a significant factor influencing preferences in various sensory attributes. The proximate analysis demonstrated that the preferred starfruit jam offers a balanced nutritional profile, with notable levels of carbohydrates, proteins, and dietary fiber.

Making a starfruit jam is a delightful way to enjoy the unique flavour of this tropical fruit. The starfruit jam

using brown sugar is preferred for sensory appeal and economic considerations. Therefore, it is recommended for further development and marketing. Additionally, considering the influence of age on preferences, targeted marketing strategies could be tailored to different age groups. The study contributes to the broader understanding of product development, consumer preferences, and economic considerations in the context of fruit-based products. Future research could explore variations in formulations, packaging, or marketing strategies to enhance the product's appeal and market reach.

Acknowledgements

The author wishes to express her gratitude to Quirino State University for all the support, financial assistance and for allowing the researcher to accomplish this research endeavour and share the results and benefits of this product with the people in the province of Quirino. Above all, to our Almighty God, for the gift of life and wisdom.

Compliance with Ethical Standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author used QuillBot's free AI detection to paraphrase, refine text, express ideas, and/or improve the language and readability of this study. After using this tool/service, the author reviewed and edited the content as needed and took full responsibility for the content of the publication.

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