

Influence of Allulose on the Physicochemical and Sensory Attributes of Papaya Jam

Muhammad Azri Ammanullah¹, Siti Fatimah Zaharah Mohamad Fuzi^{1*}

¹ Department of Technology and Natural Resources, Faculty of Applied Sciences and Technology, UTHM Kampus Cawangan Pagoh, Hab Pendidikan Tinggi Pagoh, KM 1, Jalan a, 84600, Pagoh, Muar, Johor, MALAYSIA.

*Corresponding Author: fatimahz@uthm.edu.my

DOI: <https://doi.org/10.30880/ekst.2025.05.02.041>

Article Info

Received: 30 December 2024

Accepted: 3 February 2025

Available online: 19 December 2025

Keywords

Papaya Jam, Allulose, Natural Sweetener, Papain, Physicochemical, Sensory Evaluation

Abstract

Excessive consumption of refined sugar widely used for its sweetening and preserving properties, poses significant health risks, leading to a global shift toward healthier alternatives like natural sweeteners. Transforming papaya into jam effectively reduces postharvest losses by extending the shelf life of papaya highly perishable fruit. This study objective is to replace normal sugar with allulose and conduct physicochemical and sensory analyses. Ripe papayas were selected, washed, peeled, and treated to inhibit papain activity using methods such as steaming, steaming with vinegar, steaming with vitamin C, and steaming with Sunquick. Allulose was added to the papaya pulp, and citric acid was used to adjust the pH before storing the jam in jars. The chosen method was applied to the jam production process again with different concentrations of allulose (150 g, 190 g, 225 g, 300 g). Among the tested methods, steaming was the most effective method to eliminate unwanted odours produce by papain while preserving natural flavours and nutritional value of papaya. Detailed analyses evaluated total dissolved solids (Brix), pH, moisture content, viscosity, and sensory attributes like colour, odour, texture, taste, and overall acceptance. The 190 g sample achieved the highest overall acceptance score of 6.520, attributed to its balanced sweetness (Brix value of 67.10) and optimal viscosity (12,587.00). In contrast, the 300 g sample, with a Brix value of 74.80 and high viscosity (26,426.70), was less preferred due to excessive sweetness and thickness. Sensory evaluation showed the 190 g sample scored highest for overall acceptance (6.520), colour (7.540), texture (7.020) and taste (6.620). These findings highlight the importance of optimizing allulose levels to balance physicochemical properties and sensory appeal, creating a sustainable, nutritious, and consumer-friendly product.

1. Introduction

Papaya (*Carica papaya*) is a tropical fruit known for its exceptional nutritional value, featuring high levels of fibre, water, antioxidants and vitamins such as vitamins A, C, E, and K, which support digestion, boost immunity, and reduce oxidative stress [1]. Additionally, bioactive compounds like zeaxanthin and lutein contribute to lowering the risk of chronic diseases such as heart disease and cancer. [2] Converting papaya into jam is a traditional preservation method that extends its shelf life while retaining its nutritional benefits, addressing post-harvest losses, and ensuring its availability year-round [3].

This is an open access article under the CC BY-NC-SA 4.0 license.



In response to the growing awareness of health risks associated with excessive added sugar consumption such as obesity, type 2 diabetes and dental decay, there has been a global push toward reducing sugar in food products, driven by public health policies and evolving consumer preferences [24]. A study in Public Health Nutrition found a 36% rise in natural sweetener use in beverages and a 22% decline in added sugar sales in high-income countries, highlighting growing demand for healthier, low-calorie alternatives [24]. This makes it a healthier option for individuals managing sugar intake or adhering to dietary restrictions [6]. Study found that jams made with allulose exhibited improved spread ability and reduced stickiness compared to traditional sucrose-based jams [26]. Moreover, these jams retained moisture more effectively during storage, which is critical for preserving quality over time [26]. Despite studies on natural sweeteners in other food products, limited research exists on their impact on the physicochemical and sensory qualities of papaya jam. This study aims to bridge that gap, focusing on developing healthier, consumer-friendly papaya jam formulations that align with modern dietary trends.

2. Methodology

2.1 Methodology overview

This study details the methodology for preparing and analysing papaya jam sweetened with allulose. The process began by selecting ripe papayas, which were washed, peeled, and then steamed for 10 minutes at 100°C before being pulped [8][9]. During the pulping stage, three samples were treated with vinegar, vitamin C, and Sunquick respectively, while one sample was left untreated as a control. Allulose was added to the pulp, and the mixture was boiled, with additional citric acid [8][11]. The jam was then filled into sterilized jars for storage [8]. Organoleptic testing was carried out on all four samples to assess taste and aroma, while physicochemical analysis focused on measuring Brix and pH levels. From four methods that were tested, one was selected for further analysis. The chosen method was applied to the jam production process again, followed by additional physicochemical and sensory evaluations with different concentrations of allulose. The physicochemical analysis measured Brix, pH, moisture content, and viscosity, while sensory evaluations assessed consumer acceptance based on colour, odour, texture, taste, and overall acceptance of the allulose-sweetened papaya jam.

2.2 Formulation of papain treatment method

Table 1 Formulation for papain treatment

Ingredient	Method			
	F1	F2	F3	F4
Papaya pulp	600 g	600 g	600 g	600 g
Allulose	150 g	150 g	150 g	150 g
Citric acid	3 ml	3 ml	3 ml	3 ml
Vinegar	-	10 ml	-	-
Vitamin C	-	-	10 ml	-
Sunquick	-	-	-	10 ml

*F1 (Steaming); F2 (Steaming + vinegar); F3 (Steaming + vitamin C); F4 (Steaming + sunquick)

2.3 Formulation of papaya jam of selected method

Table 2 Formulation of papaya jam for selected method

Ingredient	Sample			
	1	2	3	4
Papaya pulp	600 g	600 g	600 g	600 g
Allulose	150 g	190 g	225 g	300 g
Citric acid	3 ml	3 ml	3 ml	3 ml

The selection of 150 g, 190 g, 225 g, and 300 g of allulose was based on findings from preliminary trials that evaluated sweetness intensity and its impact on papaya flavour. At 150 g, the sweetness level was low, preserving the natural papaya aroma. At 190 g, the sweetness increased slightly without masking the papaya flavour. At 225 g, the sweetness was higher, with a slight masking of the papaya flavour, while 300 g provided the highest

sweetness level, significantly masking the papaya notes. These four levels were chosen to assess consumer preferences for different sweetness intensities in papaya jam.

2.4 Physicochemical analysis

2.4.1 TSS: Brix

The Brix measurement of the jam was conducted using a refractometer. The jam sample was homogenized, and the refractometer was calibrated according to the manufacturer's instructions [12]. A drop of the homogenized sample was placed on the refractometer prism, equilibrated, and the Brix value was recorded. The prism was cleaned and dried between measurements to ensure accuracy [12].

2.4.2 pH

The acidity of the jam was determined using a pH meter calibrated according to the manufacturer's instructions [13]. The jam sample was homogenized, and a calibrated pH electrode was immersed in the sample. After stabilization, the pH reading was recorded. Multiple measurements were taken across different sample areas to ensure accuracy.

2.4.3 Viscosity

Viscosity of papaya jam sweetened with allulose were determined by using the viscometer (Brookfield Digital Viscometer) with the viscometer first calibrated according to the manufacturer's instructions. The viscosity of 500 ml of papaya jam was measured by using this method. Spindle 07 was used to take measurement at 100 rpm. The process was conducted at a consistent temperature to prevent variations in viscosity due to temperature changes [14]. Finally, the viscosity data obtained were analysed to assess the texture of the jam.

2.4.4 Moisture content

The moisture content in jam was determined using a moisture analyser. The device was calibrated according to the manufacturer's guidelines to ensure accuracy. A 2-5 g representative sample was placed on the sample pan, and the analysis was conducted by heating the sample to 160°C to evaporate water while monitoring weight loss. The process concluded upon reaching a stable weight, indicating complete evaporation. The moisture content was calculated as a percentage based on the initial and final weights, following the equation (1) [15]

$$\text{Moisture content} = \frac{\text{Initial weight} - \text{final weight}}{\text{Initial weigh}} \times 100 \quad (1)$$

2.5 Sensory Evaluation

2.5.1 Organoleptic test

A sensory evaluation of papaya jam sweetened with allulose was conducted using the organoleptic test. The jams prepared using the four methods are used in this test. A panel of 10 untrained panellists, recruited from Universiti Tun Hussein Onn Malaysia (UTHM), Food Technology students, was selected to represent the target consumer demographic. Each panellist evaluated four samples based on key sensory attributes, which included odour and taste. The panellists were instructed to drink water to neutralize their palates between tastings.

2.5.2 Hedonic test

A sensory evaluation of papaya jam sweetened with allulose was conducted using a 9-point hedonic test to assess sensory attributes such as appearance, texture, flavour, colour, odour, and overall acceptability [16]. The evaluation involved 50 untrained panellists from UTHM, representing the target consumer demographic. To minimize bias, the samples were anonymized with random codes [16]. The evaluation was carried out in a controlled environment with adequate lighting and ventilation [16]. Panellists were instructed to cleanse their palate with water between samples, and a small reward was provided for their participation. Data on sensory scores and comments were collected for further analysis [16].

2.5.3 Statistical analysis

Every parameter was subjected to a triplicate analysis, and the outcomes of these analyses were reported as mean \pm standard deviation (SD). Statistical analysis carried out using the Minitab software, utilizing one-way analysis of

variance (ANOVA). A post-hoc test was conducted using a significance level of $p < 0.05$ to determine statistical thresholds, with p-values at or below this level regarded as statistically.

3. Result & Discussion

3.1 Screening of papain inhibitors

To inhibit papain activity in the production of papaya jam, four methods were evaluated: steaming, steaming with vinegar, steaming with vitamin C, and steaming with Sunquick. Vitamin C and Sunquick methods were selected due to their high vitamin C content, which is known to inhibit papain activity through a similar mechanism [17].

Table 3 Effects of various papain inhibitor methods on the physicochemical and organoleptic properties of papaya jam

Method	Physicochemical		Organoleptic	
	Brix	pH	Smell	Taste
F1	67.10 ± 0.0577 ^c	5.40 ± 0.252 ^a	No off flavour	palatable
F2	68.40 ± 0.1000 ^b	4.60 ± 0.0577 ^c	Off flavour	Unpalatable
F3	68.80 ± 0.208 ^b	5.30 ± 0.0577 ^{ab}	Off flavour	palatable
F4	73.50 ± 0.1528 ^a	5.00 ± 0.1528 ^b	Off flavour	palatable

*F1 (Steaming); F2 (Steaming + vinegar); F3 (Steaming + vitamin C); F4 (Steaming + sunquick) ** Data show in mean ± standard deviation ***In each column, means with the same letters had no significant difference with each other ($p < 0.05$)

Steaming (F1) was identified as the most effective method for inhibiting the unpleasant odor caused by papain in papaya jam while preserving its natural taste and nutritional value. This method achieved a Brix value of 67.1 and a pH of 5.4. Heat treatment, such as steaming, effectively denatures and inactivates the papain enzyme, which releases sulphur-containing compounds responsible for undesirable odors. Steaming with vinegar (F2) resulted in a higher Brix of 68.4 but introduced an undesirable acidic profile and pungent taste due to the acetic acid in vinegar, commonly used for its enzyme-denaturing properties in food preservation. Steaming with vitamin C (F3) achieved a Brix of 68.8 and a pH of 5.3 but did not fully inhibit papain, leaving a residual unpleasant odor. However, the antioxidant properties of vitamin C may help reduce odors by neutralizing reactive sulphur compounds, enhancing sensory quality. Steaming with Sunquick (F4) produced the highest Brix of 73.5 and a pH of 5.0, masking the papaya scent with an orange-like aroma and sweeter taste. However, the sucrose content in Sunquick conflicted with the objective of creating a low-calorie jam. Overall, F1 was concluded to be the optimal method for papain inhibition in papaya jam production based on sensory evaluation, Brix, and pH results.

3.2 Physicochemical properties of papaya jam

Table 4 Physicochemical properties of papaya jam sweetened with allulose

Sample	Physicochemical Analysis			
	Brix	pH	Viscosity (cP)	Moisture (%)
1	59.13 ± 0.0577 ^a	5.31 ± 0.0040 ^a	9150.30 ± 56.2 ^a	25.54 ± 0.0461 ^a
2	67.10 ± 0.5570 ^b	5.38 ± 0.0162 ^a	12587.00 ± 251.0 ^b	26.94 ± 0.0122 ^b
3	69.93 ± 0.0577 ^c	5.43 ± 0.0197 ^b	18603.30 ± 40.4 ^c	23.18 ± 0.0244 ^c
4	74.80 ± 0.2650 ^d	5.41 ± 0.0023 ^c	26426.70 ± 61.1 ^d	26.82 ± 0.0182 ^d

*Sample 1 (150 g); Sample 2 (190 g); Sample 3 (225 g); Sample 4 (300 g) **Data show in mean ± standard deviation ***In each column, means with the same letters had no significant difference with each other ($p < 0.05$)

3.2.1 TSS: Brix

Total Soluble Solids measured as Brix value, is a vital parameter in papaya jam production, reflecting the concentration of sugars, acids, and other soluble substances that influence the product's sweetness. TSS levels were assessed in jam samples with varying allulose amounts (150 g, 190 g, 225 g, and 300 g). Results showed a direct increase in Brix values with higher allulose content, ranging from 59.1 to 74.8. The 150 g sample failed to meet the legal minimum of 65 Brix set by the Food Act 1983, while the other samples (190 g, 225 g, 300 g) complied [18]. Statistical analysis confirmed significant differences ($p < 0.05$) among all samples. When compared to prior research, which reported typical jam Brix values between 67.0 and 71.0, the 190 g and 225 g samples

aligned with this range [19]. Despite allulose being 70% as sweet as sucrose, its similar physicochemical properties enabled the jams to achieve Brix values exceeding the regulatory threshold of 65 [10][20].

3.2.2 pH

The pH values of papaya jam sweetened with allulose range from 5.305 to 5.434, with specific measurements of 5.305 for the 150 g sample, 5.376 for the 190 g sample, 5.434 for the 225 g sample, and 5.411 for the 300 g sample. Low standard deviations, particularly for the 150 g (0.004) and 300 g (0.003) samples, indicate high measurement consistency. Tukey's post hoc analysis ($p < 0.05$) showed significant differences, grouping the 150 g and 190 g samples as "a," the 225 g sample as "b," and the 300 g sample as "c." However, these pH values are notably higher than the typical jam range of 3.0–3.8, which is crucial for microbial stability, tangy flavour, and preservation [19][25]. The elevated pH could compromise shelf stability and flavour by reducing acidity, thus creating conditions favourable for microbial growth, fermentation, mold, and spoilage, ultimately shortening shelf life [19][25]. Additionally, pH affects the gelation process of pectin, with an optimal range around 3.2 for proper gel formation [19][25]. A higher pH can weaken the gel structure, resulting in a runny or improperly set jam [19][25].

3.2.3 Viscosity

The viscosity of papaya jam sweetened with varying levels of allulose was measured and analysed through mean viscosity, standard deviation, and Tukey's grouping ($p < 0.05$). The 150 g sample had the lowest viscosity 9150.3 cP, while the 300 g sample had the highest 26426.7 cP. Low standard deviations indicated precise measurements, and Tukey's grouping ($p < 0.05$) revealed significant differences between all the samples. Viscosity is a critical factor influencing jam texture, spread ability, and consumer appeal, and is influenced by variables such as fruit type, sugar concentration, pectin levels, and pH. Typical jam viscosities range from 1,000 to 10,000 cP, which are ideal for spreadable products [21]. However, jams with higher pectin content or specific fruit types, such as jamun jam, can have viscosities exceeding 50,000 cP [21]. The viscosities of papaya jam samples in this study range from moderate below 20,000 cP for the 150 g, 190 g, and 225 g samples, to high viscosity above 25,000 cP for the 300 g sample, highlighting the impact of allulose concentration on viscosity.

3.2.4 Moisture content

The mean moisture content of the papaya jam samples ranged from 23.1770% to 26.9411%, with the highest moisture content in the 190g sample 26.9411%, potentially enhancing texture and spread ability. The 225g sample showed the lowest moisture content 23.1770%, which may improve shelf stability by reducing water activity and minimizing microbial growth risks. The 150g and 300g samples had intermediate moisture values of 25.5361% and 26.8156%, respectively. Compared to previous research, the moisture contents align with typical ranges of 23% to 49% [22]. Low standard deviations 0.0122% to 0.0461 indicate consistent, reliable measurements, while Tukey's test ($p < 0.05$) reveals significant differences in moisture content among all the samples, emphasizing the impact of allulose on moisture retention.

3.3 Sensorial properties of papaya jam

Table 5 Physicochemical properties of papaya jam sweetened with allulose

Sample	Sensorial Properties				
	Colour	Odour	Texture	Taste	Overall Acceptance
1	7.400 ± 1.512a	6.200 ± 1.726a	6.860 ± 1.443a	6.060 ± 2.152a	6.420 ± 1.819a
2	7.540 ± 1.515a	6.440 ± 1.606a	7.020 ± 1.363a	6.620 ± 1.627a	6.820 ± 1.453ab
3	7.060 ± 1.743a	6.180 ± 1.699a	6.680 ± 1.463a	6.180 ± 1.687a	6.520 ± 1.515ab
4	7.140 ± 1.726a	6.500 ± 2.003a	4.520 ± 2.270b	5.840 ± 2.113a	5.800 ± 1.927b

*Sample 1 (150 g); Sample 2 (190 g); Sample 3 (225 g); Sample 4 (300 g) **Data show in mean ± standard deviation ***In each column, means with the same letters had no significant difference with each other ($p < 0.05$)



Fig. 1 Illustration of papaya jam sweetened with allulose

3.3.1 Colour

The 190 g sample achieved the highest mean colour score of 7.540, followed closely by the 150 g sample with a score of 7.400. Both samples were grouped under "a" in Tukey's analysis, indicating no significant difference in colour perception. The 225 g sample, with a mean score of 7.060, and the 300 g sample, which scored 7.140, also fell within the same grouping, showing no significant differences ($p < 0.05$) in colour among all samples. Compared to previous research, where colour scores ranged from 8.0 to 8.3, the current samples had lower sensory acceptance, although still in the like moderate category [23].

3.3.2 Odour

The sensory evaluation of odour in papaya jam samples revealed varying mean scores across different sample weights. The 225 g sample had the lowest mean score 6.180, while the 300 g sample recorded the highest 6.500. Despite these numerical differences, all samples were grouped within the same Tukey category "a", indicating no significant differences ($p < 0.05$) in odour perception. These results highlight the consistency of odour quality across the samples. Compared to previous research which reported higher hedonic scores 7.2 to 7.7, the current study suggests potential for enhancing the sensory appeal of papaya jam formulations through recipe adjustments or process modifications [24].

3.3.3 Texture

The highest texture score 7.020 was observed for the 190 g sample, indicating favourable acceptance, while the 150 g sample followed closely with a score of 6.860, both within the same Tukey grouping "a". The 225 g sample, with a mean score of 6.680, also fell within grouping "a", showing no significant difference ($p \leq 0.05$) from the 150 g and 190 g samples. In contrast, the 300 g sample recorded the lowest texture score 4.520, which was statistically distinct, indicated by its unique Tukey grouping "b" ($p < 0.05$). These scores align with previous studies, where hedonic texture scores ranged from 6.6 to 8.2 except 300 g sample [23][24]. The texture and viscosity data revealed that higher viscosity, particularly in the 300 g sample, led to lower sensory acceptance. Jams with lower viscosity, such as the 150 g, 190 g, and 225 g samples, were preferred by panellists.

3.3.4 Taste

The 150 g sample had the lowest mean taste score 6.060, but no significant differences ($p < 0.05$) were observed across the samples, as indicated by Tukey's grouping "a". The 190 g score the highest which is 6.620 followed by 225 g score 6.180, showing consistency and also falling within the same grouping ($p < 0.05$). The 300 g sample had a slightly lower score of 5.840 but remained within the same group, suggesting no notable variation in taste perception. Compared to previous studies where hedonic scores ranged from 7.2 to 7.9, the taste scores in this study were slightly lower [23][24]. However, the scores for the 150 g, 190 g, and 225 g samples are still within an acceptable range, with potential for improvement in future investigations.

3.3.5 Overall acceptance

The sensory evaluation of papaya jam samples revealed that the 190 g sample achieved the highest overall acceptance score 6.820, followed closely by the 225 g sample 6.520, with no significant difference ($p < 0.05$) between them. The 190 g sample was preferred for its balanced sensory properties, including colour, texture, and taste, while the 225 g sample was particularly favoured for taste. The 150 g sample 6.420 was placed in a distinct Tukey grouping "a" and showed similar overall acceptance despite slight differences in sensory attributes. The 300 g sample had the lowest score 5.800 and was categorized in a separate Tukey grouping "b" ($p < 0.05$). Compared to previous studies reporting higher hedonic scores for papaya-based jams 7.2–8.2, the samples in this

study had lower sensory acceptance, although they still fell within the "slightly acceptable" category [23][24]. Differences in formulation, sweetener type such as allulose, and panel preferences may explain this variation

4. Conclusion

In conclusion, the study on papaya jam sweetened with allulose provided valuable insights into both physicochemical and sensory properties across various formulations. Steaming was identified as the most effective method for inhibiting papain activity, successfully eliminating undesirable odours while preserving the fruit's natural flavour and nutritional value. The physicochemical analysis revealed a correlation between moisture content, viscosity, and allulose concentration, with lower viscosity linked to higher sensory acceptability. Sensory evaluations showed that the 190 g sample was the most preferred, achieving the highest scores in colour, taste, and overall acceptance while maintaining a balanced texture. In contrast, the 300 g sample, with higher viscosity, received the lowest acceptance scores, highlighting the negative impact of excessive viscosity. The global market is witnessing a surge in demand for healthier food alternatives, with consumers increasingly seeking products that align with their dietary preferences and health goals. If the product enters the market, it can capture consumer attention due to the advantages it offers, such as allulose not raising blood glucose or insulin levels, making it suitable for individuals managing diabetes or those seeking to maintain stable blood sugar levels. However, the price of the jam is expected to be relatively high due to the cost of raw materials, as allulose is an expensive natural sweetener. Future studies could explore additional papain inhibitors beyond steaming to further reduce undesirable odours, conduct a comprehensive nutritional analysis of papaya jam sweetened with allulose focusing on key components such as sugar content, caloric value, and vitamin C levels and undertake broader sensory evaluations with a diverse panel to provide deeper insights into consumer preferences.

Acknowledgement

The authors would like to thank the Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia, for its support.

Conflict of Interest

There is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Muhammad Azri Ammanullah, Siti Fatimah Zaharah Mohamad Fuzi; **data collection:** Muhammad Azri Ammanullah; **analysis and interpretation of results:** Muhammad Azri Ammanullah; **draft manuscript preparation:** Muhammad Azri Ammanullah, Siti Fatimah Zaharah Mohamad Fuzi. All authors reviewed the results and approved the final version of the manuscript.

References

- [1] Pandey, S., Cabot, P. J., Shaw, P. N., & Hewavitharana, A. K. (2016). *Anti-inflammatory and immunomodulatory properties of Carica papaya*. *Journal of Immunotoxicology*, 13(4), 590–602. <https://doi.org/10.3109/1547691X.2016.1149528>
- [2] Mahomud, Md. Sultan & Pervin, K & Gupta, N & Ali, Mohammad & Amin, M. (2022). *Processing And Preservation Of Papaya Jam*.
- [3] Naw, Naeem & Md Noh, Mohd & Norhayati, M.K. & Zaiton, A. & Norliza, A.H. & Syuriahti, W. & Jamilan, mohd azerulazree & Rashed, Aswir & Selamat, Rusidah. (2017). *The Nutritional Composition of Fruit Jams in the Malaysian market*. *Journal of the Saudi Society of Agricultural Sciences*. 6. 10.1016/j.jssas.2015.03.002.
- [4] Shiza Arshad, Tahniat Rehman, Summaya Saif, Muhammad Shahid Riaz Rajoka, Muhammad Modassar Ali Nawaz Ranjha, Abdo Hassoun, Janna Crobotova, Monica Trif, Aqsa Younas, Rana Muhammad Aadil. (2022). *Replacement of refined sugar by natural sweeteners: focus on potential health benefits*. doi.org/10.1016/j.heliyon.2022.e10711.
- [5] Belović, Miona; Torbica, Aleksandra; Pajić-Lijaković, Ivana; Mastilović, Jasna (2017). *Development of low calorie jams with increased content of natural dietary fibre made from tomato pomace*. *Food Chemistry*, (), S0308814617310270 . [doi:10.1016/j.foodchem.2017.06.045](https://doi.org/10.1016/j.foodchem.2017.06.045)
- [6] Kumar, Chandini Shantha, Ali, Amanat, Manickavasagan, Annamalai. (2020). *Health Benefits of Substituting Added Sugars with Fruits in Developing Value-Added Food Products: A Review*. *International Journal of Nutrition, Pharmacology, Neurological Diseases* 10(3) DOI: 10.4103/ijnpnd.ijnpnd_34_20
- [7] Awulachew, Melaku. (2021). *A Current Perspective to Jam Production*. *Current Nutrition & Food Science*. 10.33140/ANFS.06.01.01.

- [8] Awulachew, Melaku. (2021). *Fruit Jam Production*. International Journal of Food Science, Nutrition and Dietetics. 532-537. 10.19070/2326-3350-2100092.
- [9] Winnick, T., Davis, A. R., & Greenberg, D. M. (1940). *Physicochemical properties of the proteolytic enzyme from the latex of the milkweed, asclepias speciosa torr.* The Journal of general physiology, 23(3), 301–308. <https://doi.org/10.1085/jgp.23.3.301>
- [10] Yoshimura, M. (2019). *Fruit jam comprising allulose and methods for manufacturing the same (KR101975666B1)*. Korean Intellectual Property Office. <https://patents.google.com/patent/KR101975666B1/en>
- [11] Sampson, G. O., Afoakwa, E. O., Ogunseye, O. C., & Amanquah, D. T. (2022). *Response Surface Methodology for Studying the Effects of Sugar Concentration and Acid Balancing on the Physico-Chemical Properties of Watermelon (Citrullus Vulgaris) Jam*. Journal of Food Science, 10(1), 2.
- [12] Jaywant, S.A.; Singh, H.; Arif, K.M. (2022). *Sensors and Instruments for Brix Measurement: A Review*. Sensors, 22(6), 2290. <https://doi.org/10.3390/s22062290>
- [13] Cheng, K.L.; Zhu, D.-M. (2005). *On Calibration of pH Meters*. Sensors, 5, 209-219. <https://doi.org/10.3390/s5040209>
- [14] A&D Company. (2009). *Moisture Analyzers MF-50 / ML-50 Q&A / Users' Handbook*. https://www.aandd.jp/products/weighing/balance/moisture/mxmfhandbook/phmxmf_users.pdf
- [15] Kavaya, R. I., Omwamba, M. N., Chikamai, B. N., & Mahungu, S. M. (2019). *Sensory Evaluation of Syneresis Reduced Jam and Marmalade Containing Gum Arabic from Acacia senegal var. kerensis*. Dairy, Food Science and Technology Department, Egerton University, Nakuru, Kenya. Network for Natural Gums and Resins in Africa (NGARA), Nairobi, Kenya. DOI: 10.4236/fns.2019.1011096
- [16] Bradshaw MP, Barril C, Clark AC, Prenzler PD, Scollary GR. (2011). *Ascorbic acid: a review of its chemistry and reactivity in relation to a wine environment*. Crit Rev Food Sci Nutr. 2011 Jul;51(6):479-98. doi: 10.1080/10408391003690559. PMID: 21929328.
- [17] Malaysia. (2023). *Food Act 1983 (Act 281) & Regulations (as at 5th February 2023)*. International Law Book Services.
- [18] Palka Nafri, Anil Kumar Singh, Ashutosh Sharma and Indu Sharma. (2021). *Effect of storage condition on physiochemical and sensory properties of papaya jam*. J Pharmacogn Phytochem. DOI: 10.22271/phyto.2021.v10.i2q.13990
- [19] Jürkenbeck, K., Haarhoff, T., Spiller, A., & Schulze, M. (2022). *Does Allulose Appeal to Consumers? Results from a Discrete Choice Experiment in Germany*. Nutrients, 14(16), 3350. <https://doi.org/10.3390/nu14163350>
- [20] M. Shahnawaz and S. A. Shiekh. (2011). *Analysis of viscosity of jamun fruit juice, squash and jam at different compositions to ensure the suitability of processing applications*. International Journal of Plant Physiology and Biochemistry
- [21] Emelike, Nkechi & O.M, Akusu. (2019). *Quality Attributes of Jams and Marmalades Produced from Some Selected Tropical Fruits*. 10.4172/2157-7110.1000790.
- [22] Anuradha Doke, Asha Arya, Jaishree G. Bhalerao, Rupali S. Shinde. (2017). *Development of value added papaya and pineapple jams*. Food Science Research Journal
- [23] K. Das, K. Mia, J. N. Nice, R. Zaman, S. M. S. Alam, M. K. Debnath. (2023). *Development and Quality Evaluation of Papaya Jam with Blended Carrot*. CIGR Journal
- [24] Russell, C., Baker, P., Grimes, C., Lindberg, R., & Lawrence, M. A. (2023). *Global trends in added sugars and non-nutritive sweetener use in the packaged food supply: drivers and implications for public health*. Public Health Nutrition, 26(5), 952–964. doi:10.1017/S1368980022001598
- [25] Luke LaBorde. (2024). *Food for Profit: Commercial Production of Jams, Jellies, and Fruit Butters*. Pennstate Extension. <https://extension.psu.edu/food-for-profit-commercial-production-of-jams-jellies-and-fruit-butters?utm>
- [26] Jong Min Choi, Su-Jeong KIM, Seung Won Park, Youn-Kyung BAK, Jung Gyu Park, Sung Bae Byun, Dong Seok SHIM, In Lee, Dong Chul JUNG. (2021). *Fruit jam comprising allulose and method for manufacturing same*. (U.S. Patent No. 20210401011A1). U.S. Patent and Trademark Office.