

Physicochemical and Sensory Evaluation of Pomegranate Jam Enriched with Dragon Fruit Peel

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Abstract

Pomegranate fruits, scientifically identified as *Punica granatum L.*, are part of the *Punicaceae* family and are rich in bioactive chemicals, particularly polyphenols. Due to its high antioxidant and phytochemical content, as well as its numerous health benefits, pomegranate fruit is considered a 'super fruit'. Red dragon fruit, which is high in antioxidants, is processed into juice and peels for pectin extraction and natural food colouring, so increasing its nutritional value. Jams are fruit-based jams that are popular due to their sweetness and versatility. Cooking fruit pulp or puree with sugar and pectin produces an ideal consistency and texture. This study aimed to develop combination pomegranate with dragon fruit peel, evaluate sensory attributes and nutritional composition of the accepted product. The physicochemical properties of moisture content, colour, pH, total soluble solid, texture meanwhile, the nutritional composition of protein, fat, sodium, energy, total sugars, and carbohydrate were determined. Five different formulations were prepared, and the samples was optimized based on sensory evaluation by a panel of 40 panellists using a hedonic scale with 9 scale with seven attributes (appearance, colour, aroma, spreadibility, flavour, texture and overall acceptance). The physicochemical analyses revealed that the addition of dragon fruit peel significantly increased the moisture content ($32.610 \pm 0.29\%$). The total soluble solids (0.660 ± 0.005 °Brix), pH (2.423 ± 0.12), and texture (firmness: 8.397 ± 0.34 kg) were within acceptable ranges, with sample 1 exhibiting the best texture and overall sensory appeal. Nutritional analysis showed that sample 1 had higher levels of total sugar (41.7 mg/100 g), sodium (13 mg/100 g), energy (305 kcal/100 g), and protein (18.0 g/100 g), while maintaining a low-fat content (0.4 g/100 g). This study demonstrates the potential of using dragon fruit peel to enhance the nutritional and sensory qualities of pomegranate jam.

1. Introduction

Pomegranate (*Punica granatum L.*) is a popular fruit known for its various health benefits, which include antioxidant, antimalarial, antimicrobial, hepatic oxidative stress, and chemotherapeutic effects against prostate and lung cancer [1]. The fruit's high antioxidant activity is attributed to its rich content of phenolic acids,

flavonoids, leuco- and proanthocyanidins, and tannins, such as punicalagin, punicalin, pedunculagin, and garantin [2]. Studies have shown that ultrasonic treatment of pomegranate juices can enhance the total phenolic content and reduce microbial load [3].

Dragon fruit production and technological advancements are currently underway in various Southeast Asian countries, including Malaysia, Vietnam, Taiwan, Thailand, the Philippines, and the Southeast Coast of China [4]. The red variety of dragon fruit is particularly popular for its natural reddish-purple hue, which can be used as a natural food dye. Moreover, red dragon fruit is known for its potent antioxidant properties, which can provide various health benefits [5]. To enhance the nutritional value of dragon fruit, the skin of the red fruit is processed into a superior juice. Although dragon fruit peels are commonly discarded as household waste, they have been found to be valuable for extracting pectin and natural food colouring. [6]

Jams are fruit-based jams that are popular due to their sweetness and versatility. Cooking fruit pulp or puree with sugar and pectin produces an ideal consistency and texture. Jams can be consumed with bread, pastries, and desserts. Jam production is one of the oldest food preservation methods [7]. Fruit pulp is cooked with sugar, pectin, acids, preservatives, colouring, and flavouring agents to produce an increasingly common worldwide food [8].

Currently, there is a lack of readily available commercial pomegranate jam in the market. To ascertain preferences for such jams, a study was undertaken to create a new pomegranate jam variant combining pomegranate with red dragon fruit peel. This study aimed to develop a pomegranate jam with unique pectin properties derived from red dragon fruit peel. The objectives included conducting physicochemical analyses of the jam and evaluating the sensory attributes.

In this study, pectin was derived from red dragon fruit peel and standard pectin from bakery store, which can be used to combine the flavours of both fruits. Other formulations may additionally incorporate other flavourings like lemon juice as citric acid substances. Pomegranate jam has a distinct flavour profile that fits the natural sweetness of pomegranates with a slightly sour and tangy undertone. The jam's radiant colour is visually appealing as natural red colourant from pomegranate fruit and red dragon fruit peel and serves as an appealing characteristic that attracts consumers or people to taste its aromas and flavours. The use of red dragon fruit peel as a natural food colouring in functional foods has been the focus of only a few in previous studies. It is also rich in total ascorbic acid, total dietary fibers, pectin, and iron, which helps balance blood production. [9]

2. Materials and Methods

2.1 Materials

In this study, rich pomegranates and vibrant red dragon fruits were used to make a particular pomegranate jam with dragon fruit peel. The ingredients used were pomegranate seeds, dragon fruit peel, sugar, pectin, and citric acid. The pectin and citric acid were bought from the bakery, while the pomegranate, sugar, and dragon fruit peel were bought from the supermarket.

2.2 Instruments

In this study, the instruments that were used for the preparation of pomegranate jam that enriched with dragon fruit peel, physicochemical properties analysis and nutrient analysis (proximate analysis) included a food dehydrator, Colourimeter (Hunter Lab Handheld), Total Soluble Solids (Atago Digital Hand-Held PEN Refractometer, pH (Eutech pH 700 Meter, Moisture Content (AnD MX-50 model), Texture Analyzer (TA-Xt Plus by Stable Micro Systems, UK).

2.3 Methods

2.3.1 Preparation of Pomegranate Jam with Dragon Fruit Peel

Pomegranate fruit and red dragon fruit peel were chosen for the study, washed thoroughly to remove any dirt, and peeled. The pomegranate fruit pulp was separated into edible parts (arils and seeds) and blended until a smooth puree or juice was obtained and homogenized. The red dragon fruit flesh and peel were separated, with the peel being washed, dried for 12 hours at 60°C, and ground into a powder. The ingredients, including pomegranate puree, red dragon fruit peel, sucrose, citric acid, and pectin, were measured and set aside. The fruit juice was heated in a nonstick pot at 100°C for 5 minutes, then brought to a simmer. Sucrose, citric acid, standard pectin powder, and red dragon fruit peel powder were added sequentially, with continuous stirring in between each addition for 5-minute intervals [10]. Once the jam was fullset, it was removed from heat, placed in a jar bottle, and stored at room temperature. The unique aspect of this jam recipe was the use of pectin powder from a bakery store and the addition of red dragon fruit peels during the production process.

Table 1 The formulation of pomegranate jam with dragon fruit peel

Raw materials	Formulation											
	Control		F1		F2		F3		F4		F5	
	g	%	g	%	g	%	g	%	g	%	g	%
Pomegranate fruit	100	50	100	54.79	100	54.79	100	54.79	100	54.79	100	54.79
Sucrose	80	43.84	80	43.84	80	43.84	80	43.84	80	43.84	80	43.84
Dragon fruit peel powder	-	-	0.5	0.27	1	0.55	1.5	0.82	2	1.09	2.5	1.36
Pectin powder	1	0.5	1	0.55	1	0.55	0.55	0.55	1	0.55	1	0.55
Citric acid	1	0.5	1	0.55	1	0.55	0.55	0.55	1	0.55	1	0.55

Modified from [13]

2.4 Physicochemical Properties Analysis

The following analyses were performed to assess the physicochemical properties parameters of pomegranate jam. Physicochemical properties were determined by evaluating colour analysis, pH analysis, total soluble solid analysis (TSS), moisture content, and texture of the jam.

2.4.1 Colour

Instrumental colour measurement is useful for initial evaluation of colourant alteration in products, while visual colour assessment evaluates the entire product. A handheld UV-visible colourimeter was used to analyse colour at a 10° visual angle, using the CIE system. The study investigated the impact of pectin types on monomeric anthocyanin stability and colour-related indices. According to [11], results represent the mean and standard deviation of three measurements.

2.4.2 Total Soluble Solid (TSS)

A refractometer measures total soluble solids (TSS) content by placing a sample on its detector and recording the °Brix value. The TSS value is determined by comparing light speed in a vacuum to the sample's speed. Jam manufacturers use an Atago Digital Hand-Held PEN for endpoint determination.

2.4.3 pH

Gel formation occurs within a specific pH range, with the ideal pH for jam being within 2.7 until 3.4. The pH of the jam was measured using a Eutech pH 700 Meter on a 10 mL sample at 20°C. The jam was tested in the laboratory using an Eutech pH 700 Meter.

2.4.4 Moisture Content

The moisture content of jam is crucial for its stability, texture, shelf life, and quality. Studies show variations in moisture content among different samples, influenced by composition and storage conditions. Moisture content can affect microbial growth and spoilage, ensuring an ideal texture and consistency. The moisture level of jams ranges from 30-35% on average, depending on the type and processing. Monitoring and controlling moisture content is essential for ensuring desired quality and stability.

2.4.5 Texture Profile Analysis (TPA)

The texture of pomegranate jams was evaluated using the TPA test, focusing on firmness. The jams were prepared using a Texture Analyze apparatus, which measures spreadability and texture. The study developed the TA-425 TTC Spreadability Fixture, which uses matched acrylic 90° cones to analyse butters, spreads, and creams.

2.5 Nutrient Analysis

2.5.1 Carbohydrate Content

To determine the carbohydrate content in jam, start by preparing and homogenizing the sample. Measure the moisture content by drying the sample at 105°C until a constant weight is achieved. Determine the ash content by

incinerating the dried sample at 550°C. Use the Kjeldahl method to find the protein content and a solvent extraction method for the fat content. Finally, calculate the total carbohydrate content by subtracting the sum of moisture, ash, protein, and fat contents from 100%.

$$\text{Total Carbohydrate} = 100 - (\text{Moisture} + \text{Ash} + \text{Protein} + \text{Fat}) \quad [1]$$

2.5.2 Protein Content

The AOAC technique was used to determine protein samples from pomegranate jam. The Kjeldahl digestion system was used to process the samples, which were then combined with concentrated H₂SO₄ and Kjeldahl catalyst. The solution was heated, mixed with distilled water, and titrated using a 0.2N HCl solution. The total protein content of the pomegranate jam was determined using a formula.

$$\text{Protein\%} = (A - B) \times N \times 1.4007 \times 6.25 W \quad [2]$$

2.5.3 Fat Content

The AOAC method was used to calculate crude fat content in samples. A two-gram portion was extracted, diethyl ester was eliminated, and the remaining fat was chilled and weighed. The fat content (%) was determined after 30 minutes of drying.

$$\text{Fat content} = \frac{\text{weight of fat}}{\text{weight of sample}} \times 100 \quad [3]$$

2.5.4 Energy Content

The study utilized energy content analysis to determine the total energy content of pomegranate jam production by multiplying protein, fat, and carbohydrate amounts.

$$\text{Energy (kcal/100g)} = (4 \times \text{Carbohydrate}) + (4 \times \text{Protein}) + (9 \times \text{Fat}) \quad [4]$$

2.5.5 Sodium Content

The sodium contents were determined through wet digestion of pomegranate jam, cooking at 80°C for 3 hours, filtering, and analysing the solution. Standard solutions and calibration curves were created for each element.

2.5.6 Total Sugar

The sugar content of pomegranate jam was determined using a modified Lane and Eynon method, standardised sucrose solution, neutralized jam and water, heated, cooled, diluted, filtered, and titrated with tartrate and copper sulphate, observing the indicator turning red.

2.6 Statistical Analysis

The results of sensory data will be analysed using a one-way ANOVA in MINITAB software. Values given as mean \pm standard deviation were used to identify significant differences among samples. The mean of this statistical analysis determines the main tendency of variables such as moisture content, pH analysis, total soluble solid ($^{\circ}$ Brix), colour analysis, and sensory evaluation by calculating these measures, despite the standard deviation shows the variability of the data received.

3. Result and Discussion

3.1 Physicochemical Properties Analysis

3.1.1 Colour

The colour analysis of pomegranate jam samples revealed significant differences in lightness, redness, and yellowness, indicating variations in colour attributes.

Table 2 The results data of colour analysis

Sample	L*	a*	b*
1	46.897 \pm 0.43 ^A	3.720 \pm 0.57 ^B	-1.313 \pm 0.12 ^B
2	44.590 \pm 0.11 ^A	4.757 \pm 0.07 ^A	-0.693 \pm 0.01 ^A

3	44.180±0.31 ^A	4.310±0.41 ^{AB}	-1.910±0.19 ^C
4	44.423±1.13 ^A	4.910±0.08 ^A	-1.277±0.15 ^B
5	45.267±0.76 ^A	4.967±0.09 ^A	-1.11±0.07 ^{AB}

*The data was presented in mean±SD

According to Table 2, the L* value, representing lightness, ranged from 43.14 to 47.74, with sample 1 having the highest lightness (L* = 46.90) and sample 4 the lowest (L* = 43.14). The a* value, indicating redness, ranged from 3.18 to 5.06, with sample F4 having the highest redness (a* = 4.91) and sample 1 the lowest (a* = 3.72). The b* value, representing yellowness, ranged from -2.59 to -0.68, with sample 3 having the highest yellowness (b* = -0.68) and sample F1 the lowest (b* = -1.41). These variations are statistically significant and not due to random chance. Previous studies have highlighted the importance of anthocyanins in pomegranate jam, which contribute to its colour stability and consumer appeal. The incorporation of dragon fruit peel into pomegranate jam has been explored for its potential to enhance the nutritional and sensory properties of the final product.

Previous studies have put into focus the significance of anthocyanins in pomegranate jam, contributing to colour stability and consumer appeal. For example, [12] underlined that anthocyanins are essential for the development of the exterior and seed colour of pomegranate fruits and, therefore, for the colour quality of pomegranate jam. They found that optimal storage conditions, such as 5°C and no light exposure, help maintain the anthocyanin content and colour stability over time. [13] stated that the quality of pomegranate jam was evaluated, and it was found that the addition of cinnamon and clove improved the total phenol content and colour stability compared to control samples. Previous research has shown that adding the peel of dragon fruit will increase the antioxidant capacity of pomegranate jam by a large margin, vital for phenolic content and improving shelf life, as well as enhancing its health-promoting properties. For instance, in the case of adding dragon fruit peel to pomegranate jam, [14] realized that it not only contributes to its antioxidant properties but also to the overall sensory appeal, making it a lot more attractive to consumers. Further, the use of dragon fruit peel in pomegranate jam follows the practices of sustainable food processing by making use of waste from fruits that are otherwise thrown away. [13] also showed earlier that the use of natural additives like dragon fruit peel could be an effective way to improve the colour stability and sensory properties of fruit jams.

3.1.2 Total Soluble Solid (TSS)

Table 3 The result data of TSS analysis

Sample	TSS
1	0.660±0.005^B
2	0.659±0.004 ^B
3	0.690±0.001 ^A
4	0.690±0.006 ^A
5	0.661±0.002 ^B

*The data was presented in mean±SD

According to the Table 3, the analysis of Total Soluble Solids (TSS) in pomegranate jam samples (F1 to F5) revealed significant differences, with TSS values ranging from 26.32 to 33.16 °Brix. Sample 5 had the highest TSS (33.16 °Brix), while sample 3 had the lowest (26.32 °Brix). The Analysis of Variance (ANOVA) confirmed these differences were statistically significant ($p < 0.01$). TSS is a critical parameter in jam production as it affects the sweetness, texture, and preservation qualities of the final product. The minimum amount of TSS for jams has been stipulated as at least 65% by the food law rules under the Codex Alimentarius Commission to ensure adequate preservation and quality. Previous studies have established that higher TSS levels result in better sensory attributes and longer shelf life. For instance, [15] reported increased TSS leading to better storage stability and sensory attributes in mixed fruit jams. In a study on mixed fruit jam by [16], an increase in TSS was reported during storage that enhanced the overall acceptability of jam. Addition of dragon fruit peel will further enhance the TSS and nutritional value of pomegranate jam.

3.1.3 pH

Table 4 The result data of pH analysis

Sample	pH
1	2.423±0.12 ^{Bc}
2	2.377±0.05 ^c
3	2.756±0.007 ^{Ac}
4	2.593±0.08 ^{ABc}
5	2.643±0.06 ^{AB}

*The data was presented in mean±SD

The pH analysis of pomegranate jam samples (F1 to F5) revealed significant differences, with pH values ranging from 2.38 to 2.75. Sample 3 had the highest pH (2.75), while sample 2 had the lowest (2.38). Refer to the one-way ANOVA data analysis, confirmed these differences were statistically significant ($p < 0.01$). The enriched pomegranate jam exhibited better colour retention and a more appealing texture compared to control samples. Besides, in the year 2022, Nanjing Normal University [17] reported that combining pomegranate peel polyphenols with dragon fruit peel polysaccharides highly enhances antioxidant activity and UV resistance of the resulting product, hence showing a role that natural additives can play in food quality enhancement. Furthermore, the studies of [15], on different fruit jams' physico-chemical analysis, indicated that pH is an important factor which influences storage stability and sensory characteristics; thus, their research supported the importance of pH in fruit jam quality.

3.1.4 Moisture Content

Table 5 The result data of MC analysis

Sample	MC
1	32.610±0.29 ^{AB}
2	32.460±0.29 ^{AB}
3	28.395±0.63 ^c
4	30.307±0.52 ^B
5	33.163±1.29 ^A

*The data was presented in mean±SD

The analysis of moisture content (MC) in pomegranate jam samples (F1 to F5) showed significant differences, with values ranging from 26.32% to 33.16%. Sample 5 had the highest moisture content (33.16%), while sample 3 had the lowest (26.32%). Based on the one-way ANOVA data analysis, confirmed these differences were statistically significant ($p < 0.01$). Moisture content is crucial in jam production as it affects texture, spreadability, and shelf life. Higher moisture content can lead to a softer texture but may shorten shelf life due to increased microbial activity. Ahmad *et al.* [15] found that mixed fruit jams with higher moisture content had a softer texture but required careful storage to prevent spoilage. Similarly, [16] reported that moisture content decreased during storage, improving the jam's acceptability and shelf life. Adding dragon fruit peel can affect the moisture content in pomegranate jam and improve its nutritional status. Dragon fruit peel has highly rich dietary fiber and natural sugars that help to enhance moisture retention and give the product better texture.

3.1.5 Texture Profile Analysis (TPA)

Table 6 The result data of texture analyzer

Sample	Firmness
1	8.571±0.21 ^D
2	10.956±0.52 ^{Dc}
3	15.353±0.90 ^{Bc}
4	24.172±3.00 ^A
5	15.950±1.73 ^B

*The data was presented in mean±SD

The texture analysis of pomegranate jam spreadability data provides valuable insights into its textural properties, focusing on firmness and work of shear. The data on Table 6 shows significant variability in firmness values, with a mean of 14.966 kg and a standard deviation of 5.548 kg. The work of shear also demonstrates a broader range, from 3.379 g.sec to 53.699 g.sec. Sample 1 had the best firmness texture, followed by sample 2 and sample 4. Compared to Sample 1, which had the lowest texture, it was preferred to be used with jam because of its low firmness value in the test, 8.397±0.34, compared to other formulations that had the lowest firmness values. This made F1 more suitable and desirable in spreading on jam, having given a better overall texture, thus preferred by the panellists and chosen. This was attributed to the increased contribution of native pectin from the fruits [18]. The data suggests a need for tighter control of formulation and production processes to minimize variability and enhance product uniformity. Targeting lower ranges of work of shear and firmness can guide improvements in mixed fruit spreadability, aligning the product's physical properties with consumer expectations.

3.2 Sensory Characteristics

Table 7 The result data of each attribute in sensory characteristics

Sample	Appearance	Colour	Aroma	Spreadability
1	7.475±1.69 ^A	7.35±1.76 ^A	5.975±2.08 ^A	7.125±1.67 ^A
2	7.425±1.83 ^A	7.3±1.64 ^A	5.975±1.89 ^A	6.6±2.06 ^A
3	7.425±1.87 ^A	7.25±1.90 ^A	6.25±2.02 ^A	6.725±1.8 ^{A3}
4	6.975±2.02 ^A	7.225±1.72 ^A	6.1±1.91 ^A	6.25±2.17 ^A
5	7.2±1.83 ^A	7.225±1.82 ^A	6.45±1.88 ^A	6.35±2.15 ^A

Sample	Flavour	Texture	Overall Acceptance
1	7.125±1.67 ^A	7.125±1.52 ^A	7.15±1.64 ^A
2	6.825±2.06 ^A	6.775±2.03 ^A	7.025±2.03 ^A
3	6.85±1.75 ^A	6.8±1.70 ^A	6.85±1.53 ^A
4	6.525±2.04 ^A	6.15±2.06 ^A	6.475±1.91 ^A
5	6.625±1.82 ^A	6.575±2.01 ^A	6.775±1.75 ^A

*The data was presented in mean±SD

Based on the Table 7, the sensory evaluation of pomegranate jam samples by 40 panellists by using MINITAB software to ensure the significant between each sample. It is revealed that the appearance scores were relatively consistent, with sample 1 having the highest mean score (7.475 ± 1.69), indicating it was the most visually appealing. The colour scores were highly consistent, with no statistically significant differences among the samples ($p = 0.997$). All samples were well-received, with scores above 6.9, indicating a similar level of visual appeal across the board.

The aroma scores were relatively consistent, ranging from 5.975 to 6.45, with samples 5 receiving the highest mean score (6.450 ± 1.88) and sample 1 the lowest (5.975 ± 2.08). The spreadability scores were relatively consistent, with no statistically significant differences in the samples ($p = 0.309$), suggesting that the variations are likely due to random chance rather than inherent differences. According to [19], the addition of pectin and sugar affects the balance of pectin and water and reduces the quality of pectin in forming fine fibers so that the formed gel is not too hard, thus the spreadability of the jam produced becomes longer. Overall, all samples were well-received, with scores above 6.2, indicating a similar level of appeal in terms of spreadability.

Flavour scores were relatively consistent, with samples 1 receiving the highest mean score (7.125 ± 1.67) and sample 4 the lowest (6.525 ± 2.04). The analysis of variance (ANOVA) indicated no statistically significant differences in texture scores among the samples ($p = 0.217$), suggesting that the variations are likely due to random chance rather than inherent differences. Overall, all samples were well-received, with scores above 6.4, indicating a similar level of appeal in terms of overall acceptance.

In conclusion, the sensory evaluation data for samples sample 1 to sample 5 provides valuable insights into panellist's preferences, with sample 1 consistently scoring highest across most attributes, indicating it is the most preferred sample. These findings underscore the importance of sensory attributes in food product development and highlight the need for a comprehensive approach to sensory evaluation.

3.3 Nutrient Analysis

Table 8 The data shows of pomegranate jam enriched with dragon fruit peel

Nutrient Composition	Unit	Value
Serving size 100g		
Carbohydrate	g/100 g	57
Protein	g/100 g	18.0
Fat	g/100 g	0.4
Total Sugar	mg/100 g	41.7
Sodium	mg/100 g	13
Energy	Kcal / 100 g / kJ / 100 g	1279/ 305

4. Conclusion

In conclusion, in this study have developed a pomegranate jam enriched with dragon fruit peel was successfully formulated by three objectives which are developed a pomegranate jam that enriched with dragon fruit peel, physicochemical properties and nutritional analysis and sensory characteristics was conducted. This study aimed to the potential of using dragon fruit peel to enhance the nutritional and sensory qualities of pomegranate jam, offering a sustainable approach to utilizing fruit waste (dragon fruit peel) and creating value-added products. Sample 1 being the most preferred compared to another sample. This is because the acceptance of the panellist chosen the texture or spreadability of the jam were smooth on the bread, moreover, the taste or flavour of the jam was suitable to taste it than others. These findings highlight the potential of pomegranate jam enriched with dragon fruit peel to meet consumer preferences and provide value insight for the food industry.

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Conflict of Interest

Authors declare that 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:** Nur Izzah Insyirah Saifullizan, Faridah Kormin; **data collection:** Nur Izzah Insyirah Saifullizan; **analysis and interpretation of results:** Nur Izzah Insyirah Saifullizan, Faridah Kormin; **draft manuscript preparation:** Nur Izzah Insyirah Saifullizan, Faridah Kormin. All authors reviewed the results and approved the final version of the manuscript.

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