

Physicochemical and Sensory Evaluation of Seaweed Jam with Various Palm Sugar

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DOI: <https://doi.org/10.30880/ekst.2024.04.02.062>

Article Info

Received: 27 December 2023

Accepted: 12 January 2024

Available online: 12 December 2024

Keywords

Gula apong, gula kabong, gula melaka, glycemic index, optimization,

Abstract

According to Food Act 1983, jam shall be the product prepared by boiling one or more types of fruits, whether raw, processed, or semi-processed, with a permitted sweetening substance with or without added pectin. *Gracilaria changii*, a red seaweed species recently discovered in Muar, Johor, offers a rich blend of essential nutrients. Sweeteners use are gula apong, gula melaka, and gula kabong, exhibit a glycemic index below 55, signifying their ability to hinder and control the elevation of blood glucose levels. This study is to optimize the use of *G. changii* as jam based due to its agar content and to develop new jam from red seaweed that can improve public health. The optimum formulation was run 4, which consists of 50% gula apong and 50% gula kabong due to its sensory evaluation test that had the most acceptable with a test score of 7. The physicochemical properties of seaweed jam for 13 formulations were analyzed, where high moisture content was obtained for all samples, low total soluble solid for every sample, pH for seaweed jam was standardized into 3.9, and firmness of each jam differed due to the different palm sugar used. Lower glycemic index was obtained from optimized sample which is run 4 is 37. As for the nutritional composition for optimized sample, it has low fat content and high energy level. In summary, run 4 is optimized based on sensory acceptability and its glycemic index is low and nutritional analysis were analyzed.

1. Introduction

According to the Food Act 1983, jam is defined as a product made by boiling one or more types of fruits, whether raw, processed, or semi-processed with a permitted sweetening substance, with or without added pectin and fruit pulp is added to improve the structure of jam due to the amount of pectin in the fruit [1]. However, red seaweed holds promise for improving jam texture as it contains agar that can act as a thickening agent. Tropical red seaweed, *Gracilaria changii*, has excellent-quality agar, which has potential for commercial use [2]. Yet, the jam production using *G. changii* species is still not evaluated. This study is important to optimize the use of *G. changii* as jam based due to its agar content and to develop new jam from red seaweed that can improve public health. Aims of this research are to optimized seaweed jam formulation based on sensory acceptability from consumer.

Commonly, sugar is added into any type of jam to enhance the taste, texture, and aroma. Suitable substitute for sucrose in jam are gula apong, gula melaka and gula kabong. Dried *G. changii* have the strong seaweed aroma [6]. However, increasing palm sugar concentration improved the aroma of *Eucheuma cottonii* seaweed jam,

affecting both physicochemical properties and sensory analysis [7]. Due to the seaweed that has an extraordinarily strong ocean smell and salty taste, addition of various palm sugar can mask the smell and flavor of the seaweed jam. Research from Yee Tai *et. al* (2019) highlights that adding gula apong enhances the sensory attributes of carrot cakes [8]. Thus, development of jam seaweed could benefit food industries and public health because palm sugar is added into the jam to replace artificial sweeteners. Thus, the physicochemical properties of jam from seaweed will be analyzed.

The impact of added sugar consumption on health remains controversial, with links to dangerous diseases like diabetes and cardiovascular diseases (CVD). To meet consumer demand, seaweed jam has been developed, incorporating various types of palm sugar. Due to public that have become more concern towards their healthy lifestyle especially their diet, the development of this jam seaweed with addition of various sugar can give enormous impact towards food industries. Palm sugar, known for its low glycaemic index as claimed to be <55 by Australian Standard (2007) and can be serves as a healthier alternative. Nutrient composition and glycemic index of optimum formulation will be access based on acceptability from consumer.

2. Materials and Methods

2.1 Materials

The various of palm sugar used in this study were gula apong, gula melaka, and gula kabong that purchased from local suppliers. Dried seaweed, *Gracilaria changii*, was obtained from Muar. Chemical used for analysis were concentrated H₂SO₄, NH₃ solution, 0.2N HCl solution, 5 mL HNO₃ and 5 mL H₂O₂ and 1 N NaOH.

2.2 Seaweed Jam Preparation with Various Palm Sugar

The dried *G. changii* seaweed was cleaned using tape water to remove any remaining dirt [7] and was placed in a container and soaked in hot water (100 °C), along with the addition of lime and coarse salt. On the following day, the seaweed underwent another round of cleaning using hot water at 100 °C, to create the seaweed porridge, 90 grams of dried seaweed were combined with 1.05 liters of water. The seaweed itself, 1.05 L of water, and 60 g of palm sugar were prepared. These components were heated to approximately 95°C [7] and cooked for a duration of 90 minutes. After cooling down to room temperature, the sample received an additional touch of flavor with the addition of 1.2 grams of blueberry flavor and red artificial color. The jam's recipe from Kurniawati (2019) were used in preparing and making jam sample and a few modifications has been made.

2.3 Experimental Design on Optimization Process for the Preparation of Seaweed Jam with Various Palm Sugar.

As shown in Table 3.2, 13 formulations samples were designed using simplex lattice mixture design to obtain different percentage of various palm sugar. The percentage ranged between 33 and 100 percent (33 % ≤ X ≤ 100 %).

Table 1 Variable ingredients in the production of seaweed jam with various palm sugar

	Gula Apong (%)	Gula Melaka (%)	Gula Kabong (%)
1	100	0	0
2	66	17	17
3	0	100	0
4	50	0	50
5	0	0	100
*6	100	0	0
7	17	17	66
8	33	33	33
9	0	0	100
10	0	50	50
11	0	100	0
12	50	50	0

13	17	66	17
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2.4 Sample preparation for sensory evaluation

13 formulations of seaweed jam had been served on a white plate with a slice of bread from the same loaf. Each seaweed jam, has been served as much as 10g [12]. All 13 formulation of seaweed jam were divided into 2 sets. Sensory evaluation was conducted for 2 days where set 1 (formulation 1 -6) was conducted on the first day while set 2 (formulation 7 - 13) was conducted on the second day [12]. Panelist were also provided with a scorecard for sensory evaluation.

2.5 Selection of Panelist

In a sensory evaluation test, 50 panelists assessed seaweed jam across several sensory attributes, including color, taste, aroma, mouthfeel, aftertaste, and overall acceptability. They used the 9-point hedonic scale, where 9 represents "like extremely" and 1 indicates the opposite end of the scale [13].

2.6 Analysis on Physicochemical Properties

2.6.1 Moisture content

The moisture content of jam samples was assessed using the AOAC 925.10 method. First, a 1 g portion of the jam sample was weighed and dried in an oven at 120°C for 1 hour. After drying, the samples were cooled in a desiccator and the process was repeated until the sample weight remained constant. The moisture content was then calculated using the following formula [14].

$$\text{Moisture (\%)} = \frac{\text{Wet weight} - \text{Weight after drying}}{\text{Wei weight}} \times 100 \quad (1)$$

2.6.2 Total Soluble Solid

The Brix value of seaweed jam was determined using a refractometer at room temperature. Initially, a 40-gram portion of the jam was mixed with 150 mL of water. After allowing the sample to stand for 20 minutes, it was filtered and weighed. Finally, two drops of the sample solution were placed onto the refractometer prism, and the resulting Brix measurement was recorded [15].

2.6.3 Texture Profile Analyzer (TPA)

A cylindrical probe with a diameter of 36 mm was employed. The jam sample was carefully positioned on the stage, and the probe head was adjusted until it made contact with the sample's surface. By measuring the maximum force needed to compress the jam within a specified time frame, its textural properties were obtained, specifically its firmness. This test was conducted three times, and the average value was calculated [14].

2.6.4 pH value

A 5 g portion of jam was mixed with 50 mL of water. The pH of the resulting mixture was measured using a pH Meter Kit (EUTECH pH 700) [12].

2.7 Nutrient Analysis

2.7.1 Carbohydrate Content

The carbohydrate content of the seaweed jam was determined according to the method by AOAC 2020.07 and calculated using the equation below [12].

$$\text{Carbohydrate} = 100 - (\% \text{ Moisture} + \% \text{ Fat} + \% \text{ Protein} + \% \text{ crude fiber} + \% \text{ Ash}) \quad (2)$$

2.7.2 Protein Content

The protein content was determined using AOAC 2001.11. 0.8g sample was digested in the Kjeldahl digestion system under a fume chamber. The sample was weighed, transferred into a digestion flask, and mixed with 5g of Kjeldahl catalyst (90% K₂SO₄ and 10% CuSO₄) along with 200ml of concentrated H₂SO₄. Blank solutions were also prepared using the same Kjeldahl catalyst and concentrated H₂SO₄, but without the seaweed jam sample. These flasks were heated until the solution turned clear. After cooling down, 60ml of distilled water was added to the solution. The flask with added water was connected to a condenser, and the tip of the condenser was soaked in standard acid with 5 drops of a mixed indicator in the receiver. The solution was heated until all the NH₃ was distilled. The receiver was then removed and titrated with 0.2N HCl solution. The volume of HCl solution used was recorded, and the total protein content of the seaweed jam was calculated using the formula [12].

$$\text{Protein content} = \frac{A - B \times N \times 1.4007}{W} \times 100 \quad (3)$$

2.7.3 Fat Content

AOAC method of 922.06 were used to determined fat content. 2g of the prepared sample was weighed into Soxhlet thimbles. The thimbles were fixed into the extraction flask of a given weight. The remaining fat in the flask was dried in an oven at 60°C for 30 minutes. Subsequently, it was cooled for 15 minutes and then weighed [12].

$$\text{Fat content} = \frac{\text{weight of fat}}{\text{weight of sample}} \times 100 \quad (4)$$

2.7.4 Sodium Content

The sodium content was determined by AOAC method 937.09. 0.25 g of the seaweed jam sample was added to a solution prepared by mixing 5 mL HNO₃ and 5 mL H₂O₂. The mixture was heated at 80°C for 3 hours. Undissolved solids were filtered out and the filtrates were diluted to 20 mL. Sodium elements in the solution were analyzed. Standard solutions were prepared for sodium, and calibration curves were drawn [16].

2.7.5 Energy Content

The energy content analysis for seaweed jam was determined using AOAC method 973.18, involves calculating the energy by multiplying the amounts of protein, fat, and carbohydrate with their specific physiological energy values [16]. The formula used is as follows:

$$\text{Energy (kcal/100g)} = (4 \times \text{Carbohydrate}) + (4 \times \text{Protein}) + (9 \times \text{Fat}) \quad (5)$$

2.7.6 Total sugars

The total sugar content in the seaweed jam was quantified using the Lane and Eynon method, with slight modifications based on AOAC 968.28 (2000). 10 g of seaweed jam was mixed with distilled water (100 mL) and neutralized with 1 N NaOH. The sample was then boiled for 1 hour with stirring and made up to a final volume of 500 mL after cooling. The solution was filtered, and a 100 mL aliquot was transferred into a burette. In a flask, a 10 mL mixture of copper sulfate solution and alkaline tartrate solution was placed. The flask was heated on a hot plate for 2 minutes. While heating, 1 mL of 0.2% aqueous methylene blue solution was added. The volume required for complete titration (2-3 drops) of the sample solution to discoloration of the indicator was recorded [16].

2.8 Glycemic Index

12 panelists need to have 10 hours overnight fasting and blood glucose level is determined by capillary blood glucose analyzer. The baseline (fasting) concentration was determined by averaging the glucose concentrations

at the three finger-stick fasting blood samples collected on each test occasion at intervals of 5 minutes (-5, 0). 250 mL of water and a test meal were provided to the panelists. They had 12 to 15 minutes to finish all the food and water while eating comfortably. After begin eating, further finger-prick blood samples were taken 15, 30, 45, 60, 90, and 120 minutes later. One blood sample from the same drop of blood from each panelist will be taken to get each blood glucose value. The panelists' initials, identification number, date, body weight, test food, test beverage, start and stop times for eating, how long it took to eat, when and what they had for their previous meal, and any odd behaviors were entered into a blood glucose test record both before and during the test [16].

3. Results and Discussion

3.1 Sensory evaluation test

A sensory test on thirteen (13) samples of seaweed jam with various palm sugar was carried out for fifty (50) panelists. The sensory attributes evaluated included color, taste, aroma, aftertaste and overall acceptability. Each attribute was determined using 9-point hedonic scale. All 13-seaweed jam were accepted by panelists with the sensory scores of 5-9. The result of each seaweed jam sample was shown in Table 2.

Table 2 Sensory results of seaweed jam with various palm sugar

Run	Color	Taste	Aroma	Aftertaste	Overall acceptability
1	6.58±1.84	6.76±1.74	6.48±1.75	7.02±1.79	6.90±1.70
2	6.14±2.24	6.28±1.88	6.10±1.88	6.20±1.97	6.32±2.06
3	6.42±1.89	5.88±2.11	5.80±1.94	5.92±2.05	5.88±2.13
4	7.30±1.55	6.96±1.48	6.92±1.48	7.20±1.52	7.30±1.37
5	6.64±1.77	6.34±1.81	6.34±1.81	6.42±1.80	6.46±1.75
6	6.37±1.84	6.77±1.74	6.58±1.75	7.00±1.79	6.60±1.70
7	6.12±1.94	6.08±1.66	5.94±1.69	6.00±1.99	6.10±1.77
8	6.54±2.06	6.80±1.93	6.14±1.80	6.48±2.05	6.60±1.99
9	6.13±1.77	6.55±1.81	6.74±1.81	6.00±1.80	6.50±1.75
10	7.30±1.58	6.18±2.32	5.94±2.06	6.20±2.14	6.32±2.04
11	6.73±1.89	6.08±2.11	5.60±1.94	5.80±2.05	5.90±2.13
12	6.36±1.68	6.06±1.78	5.58±1.92	5.72±1.85	6.00±1.79
13	7.00±1.37	6.52±1.43	6.38±1.61	6.18±1.79	6.52±1.47

Run 4, (50% gula apong and 50% gula kabong) obtained highest acceptance of colour. The lowest colour value was observed in run 7 (17% gula apong, 17% gula melaka, and 66% gula kabong) with a value of 6.12±1.94. Differences in colour values may be attributed to the type of palm sugar used and previous research using gula melaka as a sweetener in cookies affected their colour [17]. Furthermore, cooking at higher temperatures for an extended length of time enhances the non-enzymatic browning that comes from Maillard reactions, giving the desired dark-coloured coconut sugar as an ingredient [17]. The process of making seaweed jam involves prolonged heating, which impacts the colour transformation. Longer heating periods led to an increase in brown colour intensity in gula kabong [18].

Gracilaria changii inherently has an unpleasant taste and an oceanic flavour. The study evaluated different sugar samples in terms of taste, aroma, and aftertaste. Sample 4 (50% gula apong and 50% gula kabong) received the highest taste, aroma, and aftertaste scores which were 6.96±1.48, 6.92±1.48 and 7.20±1.52 respectively, while run 3 (100% gula melaka) had the lowest taste score, 5.88±2.11. Interestingly, sample 12 (50% gula apong and 50% gula melaka) had the lowest aroma and aftertaste values which were 5.58±1.92 and 5.72±1.85.

Researchers found that combination of 50% gula apong added to kaya resulted in a synergistic effect on both sweetness and aroma [11]. The flavours of the syrup may be linked to the phytochemicals present in gula apong syrup. Interestingly, when gula kabong was produced, the high temperature encouraged the formation of chemicals that contributed to the sugary taste and caramel scent [18]. Furthermore, the percentage of gula kabong and gula apong being equal in run 4 led to the occurrence of the Maillard reaction in palm sugar, resulting in a strong aroma and taste. This highlights the intricate interplay between ingredients and production conditions in creating the delightful flavours of seaweed jam. Thus, based from the result, panellist preferred gula apong and gula kabong more than gula melaka because concentration of gula apong and kabong can mask the taste of seaweed and its combination can be accepted by panellist.

The aftertaste experienced from each sample of seaweed jam is primarily influenced by the seaweed itself. The drying process of *Gracilaria changii* under sunlight significantly impacts the aftertaste in food [20]. Specifically, it had been proven that samples dried under sunlight received the lowest aftertaste ratings [20]. In

our current study, the dried *G. changii* used in jam was also dried under sunlight, reinforcing the notion that this drying method affects the seaweed jam's aftertaste.

Interestingly, panellists preferred run 4 than run 12 due to the pre-treatment applied to the dried *G. changii* before making the jam were soaking the dried seaweed overnight with hot water with adding lime and salt. Notably, seaweed can act as an adsorbent in wastewater treatment, effectively replacing functional activated carbon and aiding in the removal of toxic heavy metals [21]. Thus, in our present study, it can be concluded that the environmental conditions significantly impact the aftertaste of the samples

Lastly, the overall acceptability among panellists were highest for sample 4, with a value of 7.30 ± 1.37 . This result can be attributed to the balanced concentration of gula apong and gula kabong, which contributed to an acceptable sensory quality for seaweed jam development. Specifically, sample 4 stood out in terms of colour, taste, aroma, and aftertaste. Interestingly, previous studies support the positive impact of gula apong in various food products. Researcher found that incorporating gula apong into ice cream significantly affected attributes such as colour, taste, aroma, aftertaste, and overall acceptability [22]. Similarly, adding gula apong to kaya had a significant influence on consumer acceptability [11].

3.2 Physicochemical Analysis

3.2.1 Moisture content, total soluble solid, pH

Table 3 below shows result of moisture content, total soluble solid and pH value for 13 formulation of seaweed jam with various palm sugar where sample 8 has highest value for moisture content, sample 12 has highest value for total soluble solid and value for all 13 sample were standardize.

Table 3 Moisture content, total soluble solid and pH of seaweed jam with various palm sugar

Run	Moisture Content (%)	Total Soluble Solid (Brix)	pH
1	57.40±0.05	39.97 ± 0.06	3.95±0.09
2	55.1±0.21	42.51±0.21	3.90±0.05
3	50.1±0.65	42.15±0.42	3.90±0.05
4	56.86±1.75	38.65±0.27	3.97±0.01
5	58.61±0.23	38.33±0.28	3.90±0.04
6	56.99±0.05	39.97±0.06	3.95±0.09
7	56.62±0.92	39.62±0.70	3.91±0.02
8	59.31±0.64	37.57±0.23	3.95±0.04
9	57.9±0.23	38.33±0.28	3.90±0.04
10	55.41±0.38	40.19±0.26	3.92±0.02
11	54.78±0.05	42.15±0.42	3.90±0.05
12	50.05±1.80	44.44±0.63	3.91±0.01
13	53.99±0.50	42.70±0.63	3.90±0.07

The value for moisture content, as indicated in Table 3, falls within the range of 50.05% to 59.31%. However, the standard moisture content of fruit jam was 31.23-33.36% [56]. Run 8 exhibited the highest moisture content, measuring $59.31\% \pm 0.64$, while run 12 had the lowest moisture content at $50.05\% \pm 1.80$. The discrepancy may arise because dried *G. changii* underwent an overnight soaking process during jam production, potentially impacting its moisture content. The step of soaking dried *G. changii* likely increased its moisture content. As marine organisms, seaweeds are inherently water-rich, containing 75–85% water when fresh [25]. Sweeteners also play a crucial role. Gummy jelly made from the palmyra palm (*Borassus flabellifer*) boasts a higher moisture content of 15.79% [26]. The different concentration of gula melaka in the samples contributed to higher moisture content because gula melaka derived from *Cocos nucifera*, has 1.18 to 2.39 g of moisture content and it has a tendency to absorb moisture from the ambient air and may agglutinate due to its hygroscopic nature [19].

In the context of seaweed jam, the TSS reading falls within the range of 38.33 to 44.44 °Brix. Standard total soluble solid value according to Codex Alimentarius (2009) was 60- 65 %. Notably, seaweed jam made from *Gracilaria edulis* exhibited a TSS value of 65 °Brix [28]. In our current research, the highest TSS observed in seaweed jam with various palm sugars was 44.44 ± 0.63 °Brix (run 12) and the Melaka smallest TSS value was recorded in run 8, measuring 37.57 ± 0.23 °Brix. Interestingly, our results deviate from previous research due to the interplay of three different types of palm sugar at varying concentrations, totalling 60 g in each sample. Research on mango puree found that the duration of the heating process during blending significantly impacts the total soluble solids (TSS) [29]. Additionally, in this study, it can be concluded that boiling seaweed jam for only 90 minutes affects the reducing value of TSS in the jam. Another factor affecting the total soluble solids (TSS) is the storage period [30]. TSS values of guava fruits rises as the storage period extends [30] and due to the short storage period of samples, the TSS value reduce because the analysis was conducted within 2 weeks after production of each sample.

Based from Table 3, pH of the samples falls within the range of 3.90 – 3.97. As comparison with standard pH value which were 3.3, this pH stability is achieved by adding 0.1g of citric acid, which acts as a buffer. Citric acid is commonly used in jam production due to its taste, antioxidant properties, solubility, and storage benefits [31]. However, variations in temperature and total soluble solids (TSS) can impact the pH of *Arenga Pinnata* [32]. The sugar-heating process increased the pH of *A. pinnata* until it reached a final pH of 6.2. The pH value of the seaweed jam is acidic, with the lowest recorded value being 3.90. This acidity is attributed to the presence of organic acids in *nypa fruticans* sap [11]. Interestingly, the pH of seaweed jam is comparable to that of honey-sweetened jam produced from a blend of carrot and cucumber, which falls within the range of 3.36 to 3.98 [33]. This acidic condition contributes to the jam's longer shelf life and is crucial for gel formation and flavour enhancement [53].

3.2.2 Texture profile analyzer

Table 4 below show a result of texture for all seaweed sample where the firmness is measured by using texture profile analyzer. Sample 10 tend to has best texture for firmness while the lowest firmness value was in sample 3.

Table 4 Results of texture analyzer of seaweed jam with various palm sugar

Run	Firmness
1	205.57 ± 4.37
2	230.63±22.25
3	325.85±28.53
4	267.45±23.37
5	198.09 ± 10.11
6	205.57± 4.37
7	125.10±16.55
8	241.11±8.89
9	198.09 ± 10.11
10	119.78±4.73
11	325.85±28.53
12	218.17±11.63
13	305.53±5.83

The firmness values for the seaweed jam fall within the range of 119.789 to 325.852. In our study, the lowest firmness value (run 10) indicates the best texture. In contrast, run 3 has the highest firmness value. The variations among samples may be attributed to the types and concentrations of palm sugar used. Sugar enhances gel strength and synergies in extraction [34]. Too little sugar results in weak or no gel formation, while an adequate amount improves stiffness. Run 3 consisting of 100% gula melaka (*Cocos nucifera*), may influence the jam's texture. Interestingly, chocolate sweetened with coconut sugar tends to be harder than that sweetened with sucrose [35]. Differences in particle density, size distribution, moisture content, and sugar composition contribute to this hardness [35]. Referring to Table 3, the higher moisture content in run 3, could influence the jam's firmness, as it leads to the formation of strong sugar networks. Thus, run 10 was easier to spread compared to run 3 due to the differences in the firmness value.

The lowest firmness value was observed in sample 10, which consisted of a 50% combination of gula melaka and gula kabong. Additionally, the seaweed jam produced with the addition of gula kabong resulted in a watery texture due to the absence of sugar binding water [7]. Substituting *Nypa fruticans* sap as a sweetener in carrot cakes resulted in a lower springiness value (0.21 ± 0.08) compared to the control carrot cake (0.31 ± 0.04) [30]. However, types of palm sugar influence the firmness of the texture along with its ability to spread on bread [34].

3.3 Nutrient Analysis

6 nutrient compositions for sample 4 in seaweed jam including carbohydrate, protein, total fat, sodium, total sugar and energy were analysed and the results are shown in Table 5 below. A sample that has been analysed was based on its higher value for sensory evaluation and sample 4 tends to have a low fat content and a high energy value.

Table 5 Nutrient analysis of sample 4 of seaweed jam with various palm sugar

Nutrient Composition	Unit	Value	Recommended Daily Intake
Carbohydrate	g/100 g	22.4	130 g
Protein	g/100 g	0.75	0.83 g /kg
Total Fat	g/100 g	2.3	51-75 g/day
Sodium	mg/100 g	107.7	1500 mg
Total sugar	g/100 g	7.8	86 g/day
Energy	kcal /100 g / kJ/100 g	114 / 479	2310 - 2740 kcal/day

G. changii contains 41.5 g carbohydrate [23]. Additionally, *G. changii* contains agar, which falls under the category of carbohydrates and is commonly used in food as a thickener and gelling agent. The Ministry of Health Malaysia recommends a daily carbohydrate intake of 130 g for adults. The carbohydrate content of seaweed jam with various palm sugars was 22.4 g per 100 g, making it an acceptable choice for daily consumption. Furthermore, individuals with cardiovascular disease who followed a high-glycemic diet faced an increased risk of mortality or significant cardiovascular events [36].

Dried *G. changii* has been identified as a potential protein source due to its high protein content (ranging from 10% to 47%). However, in the specific case of sample 4, the protein content was only 0.75 g per 100 g, falling below the recommended 10% of the Nutrient Reference Value (NRV). The alteration in taste and aroma observed in the jam may be attributed to the pre-treatment of dried seaweed, particularly soaking it overnight in hot water. Additionally, the solar drying method, especially at temperatures exceeding 50°C, led to a reduction in total protein content [37]. Despite the low protein content, it's important to note that the recommended protein intake for adults is approximately 0.83 g/kg [55].

Studies on gula apong and gula kabong revealed no significant increase in fat content when added to kaya and yogurt, respectively. Gula kabong, classified as a fat-free sugar, effectively reduced yogurt fat content [39]. Additionally, *G. changii*, with a low-fat content of 1-3%, aligns with the range for gula apong and gula kabong [23]. Sample 4, containing 2.3 g of fat per 100 g, can be claimed as a low-fat food according to Food Regulation 1985 [54].

The sodium content in seaweed jam sample 4 was 107.7 mg per 100 g. This high sodium value is primarily attributed to the sodium-rich composition of gula apong, which may be influenced by its growth habitat [40]. Additionally, gula kabong also contains significant sodium levels, potentially contributing to the prevention of health conditions like edema, anaemia, and hypertension [41]. Notably, *G. changii* has been demonstrated to have low sodium content [23]. Considering overall evidence, the Malaysian Ministry of Health recommends a daily sodium intake of 1500 mg to mitigate risks such as heart disease [55].

Gula kabong, primarily composed of sucrose with trace amounts of glucose and fructose, is considered a healthy sweetener due to its high sucrose content compared to synthetic sweeteners [18]. Run 4 exhibited a total sugar content of 7.8 g per 100 g, which aligns with previous research where the total sugar content was 23.00 g per 100 g [18]. The reduction in sucrose content in sample 4 may be attributed to the long heating period during seaweed jam production [18]. Although sample 4 does not qualify as a low-sugar food (as per Food Regulation 1985), the recommended daily sugar intake by the Malaysian Ministry of Health is estimated to be 86 g/day, making seaweed jam a suitable choice for daily consumption due to its total sugar content of 7.8 g per 100 g [55].

The energy content of seaweed jam sample 4 was 479 kJ per 100 g, which is significantly higher than the previous research value of 11.46 kJ per 100 g [11]. The observed discrepancy in health outcomes between sample 4 may be linked to its high carbohydrate and fat content. Energy deficiency resulting from inadequate calorie intake can lead to weight loss and health deterioration, potentially having severe consequences. To meet daily energy needs, the Malaysian Ministry of Health recommends that adults consume 2310 - 2740 kcal/day [55]. Considering that seaweed jam contains only 7.8 g of sugar per 100 g, it can be safely incorporated into a balanced diet.

3.4 Glycemic Index

The glycemic index and glycemic load for sample 4 of seaweed jam were analysed and calculated based on 10 people for 15,30,45,60,75,90, and 120 minutes. Table 6 below shows a result for glycemic index and glycemic load for 120 minutes after seaweed jam consumption where the result indicated a reduced value for Glycemic index and glycemic load.

Table 6 Result for glycemic index and glycemic load for sample 4

Time (min)	Glycemic index (GI)	Glycemic load (GL)
15	49.15	11.00
30	54.70	12.25
45	49.06	10.98
60	45.42	10.17
75	40.78	9.13
90	40.00	8.96
120	37.00	8.28

In Table 6, the glycaemic index (GI) for sample 4 consistently declined from minutes 15 to 120. The reduction in GI values, from 49.15 to 37.00, falls into the low GI category according to the Australian Standard (2007). The glycaemic index (GI) measures how specific foods affect blood sugar levels. Sample 4 showed a gradual decrease in GI from 49.15 to 37.00 over the course of 15 to 120 minutes. This decline is considered low, indicating that the food has a minimal impact on blood sugar. The reduction in GI may be attributed to the combination of two different sugars which gula apong and gula kabung. A study has confirmed that gula kabung has a lower GI due to its slower digestion rate compared to refined cane sugar [41].

The study observed a consistent reduction in GI after 60 minutes of consuming the test food. Surprisingly, there was a slight increase in GI at the 30-minute mark, which may be attributed to the inclusion of white bread in the meal. White bread has a high GI value of 100. Nevertheless, after 120 minutes, the GI value decreased significantly to 37. This falls within the same range as previously reported for gula kabong (35–42) [35]. Additionally, a comparative study has found that gula apong has a lower glycaemic index than sugarcane, along with higher levels of minerals and antioxidants [42].

The glycaemic load (GL) complements the glycaemic index (GI) by accounting for both the speed of glucose conversion and the amount of carbohydrates in a food item. Researches had suggested that GL is more accurate in managing blood glucose, especially for sensitive individuals [43]. Sample 4 likely has a moderate glycaemic load (8-11), and seaweed jam with various palm sugars to have moderate effect on blood glucose and can contribute to overall health due to its low GI and GL values [44].

3.5 Statistical Simple Lattice Mixture Design

The combination of elements that produced the best response was determined by considering the effects of each component. High R-squared, low standard deviation, and low expected sum of squares all indicated that the best model was fitted. The appropriate models' p-values were less than 0.05, whereas the lack of fit p-values were more than 0.05 [44]. Linear and quadratic models are considered, and the results indicated that the best-fitted model was quadratic for the pH and texture profile analyzer (TPA). However, pH and total soluble solid (TSS) were better represented by linear models. Sensory attributes such as taste, aroma, and overall acceptability followed linear models, while color and aftertaste were best described by quadratic models.

All the models are significant with a $p < 0.05$. However, the pH value and color for sensory attributes were not significant, with p-value greater than 0.05. The fact that colour is not significant is probably due to the addition of red artificial colour to improve the colour of seaweed the jam while pH value might be due to the addition of citric acid acting as a buffer to standardise the pH of the seaweed jam. For proper gelatinization, citric acid was added to the blackberry jam to adjust the pH values [45]. Furthermore, the addition of citric acid to jams could influence the texture and overall quality of the jams [46].

Furthermore, in order to determine the model's applicability, an analysis of lack of fit was conducted for every response. According to Table 7, all models had a non-significant lack of fit at $p > 0.05$, which indicated that not a significant lack of fit is good, resulting in the model fitting with less error [47]. The models provide sufficient fit R^2 values for models ranging from 0.3471 to 0.8622. and had the same R^2 values for the effect of grape pomace used in chocolate spread which in 0.8975 [48].

3.6 Optimization of Mixture Proportion using Simple lattice Mixture Design

The optimization process was carried out using the desirability multiple response approach. For a simultaneous optimization, each response must have a low and high value assigned to each goal, including the terms 'none', 'maximum', 'minimum', 'target' or 'in range' [50]. In this study, the responses of pH value, TPA and sensory

analysis of seaweed jam with various palm sugars were maximized while TSS and moisture content were minimized. From the optimization result generated by Design Expert (Stat-Ease, Inc., Trial Version 13), seaweed jam with 50% gula apong and 50% gula kabong should be used. Research has stated that desirability scores of 0.0 are considered undesirable while scores of 1.0 are considered very desirable [49]. Thus, the desirability value in this response was 0.614 (Fig. 1) which nearly closed at 1.000 and indicating that all criteria were met. Additionally, the desirability value in this study was found to be close to the desirability value from previous research on a model of kiwifruit jam where the value was 0.662 [49]

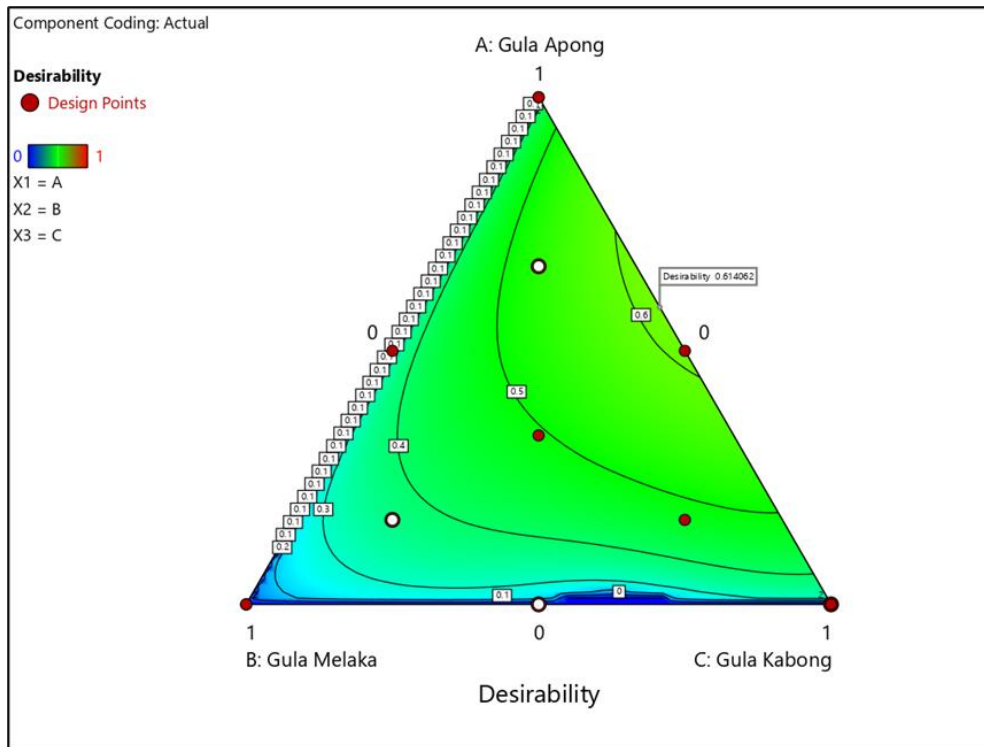


Fig. 1 Optimization based on sensory and physicochemical properties and its desirability

Table 7 below shows each parameter calculated from the optimized mixture proportions for the seaweed jam with various palm sugars. Referring to the table below, the TSS and moisture content are 39.763 and 57.244 respectively. The pH value, TPA and sensory analysis are 3.9, 264.323 and 6.79 respectively. Hence run 4, which is prepared by optimizing the mixture proportions, demonstrated superior responses among the various palm sugar concentrations tested in the preparation of seaweed jam.

Table 7 Goal setting and value obtained for each parameter meter of the optimized seaweed jam

Parameter	Goal	Value for optimized seaweed jam
TSS	Minimize	39.76
pH	Maximize	3.90
Moisture content	Minimize	57.24
TPA	Maximize	264.32
Sensory analysis	Maximize	6.79

4. Conclusion

The seaweed jam that was optimized using a simple lattice mixture design based on sensory acceptability is run 4 which consists of 50% gula apong and 50% gula kabong because it stood out as the most preferred choice with scores of 7. Run 4 that is optimized can be classified as a low-fat food and has higher levels of total sugar, sodium, and energy. Thus, this sample has a low GI value and a low GL. Further study should be conducted to improve the pre-treatment of dried seaweed from hot water to steam and determine other nutritional compositions such as ash content, minerals and vitamin.

Acknowledgement

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

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:** Syahira Anisha, Faridah Kormin; **data collection:** Syahira Anisha; **analysis and interpretation of results:** Syahira Anisha **draft manuscript preparation:** Syahira Anisha, Faridah Kormin Z. All authors reviewed the results and approved the final version of the manuscript*

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