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ORIGINAL ARTICLE

Evaluation of phytochemical, nutritional and sensory properties of high fibre bun developed by utilization of *Kappaphycus alvarezii* seaweed powder as a functional ingredient

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Abstract *Kappaphycus alvarezii* (Kapparezii) is red seaweed with various health benefits. While bread and bun are an excellent convenient food to deliver functional properties to consumers. The objectives of this study are to (i) determine the nutritional properties and phytochemical contents of buns added with Kapparezii seaweed powder (KSWP) (ii) identify the best three of five formulations through quantitative descriptive analysis (QDA) and (ii) evaluate the sensory attributes and overall acceptability of bun with added KSWP hedonic test. Five formulations with different proportions of KSWP inclusion namely A (0%), B (3%), C (6%), D (9%) and E (12%) were formulated. Bake loss were found to decrease (14.93–9.64%) with increased KSWP. The KSWP concentration had a significant effect ($p < 0.05$) on the phytochemical constituents of the bun with total phenolic content (TPC) (35.07 gallic acid equivalent (GAE), mg/100 g) and 2,2-diphenyl-1-picryl-hydrazyl (DPPH) activity (49.02%) were at maximum readings when 12% KSWP was incorporated into the flour. Increment of KSWP in bun reduced the moisture (35.57–24.59%) and protein content (12.51–9.60%) significantly ($p < 0.05$), because KSWP increases the water absorption and reduces the network produced by gluten. Carbohydrate (49.96–63.26%), ash (0.91–1.62%), fat (1.05–1.67%) and dietary fiber (4.51–13.63%) composition increased significantly ($p < 0.05$) with KSWP addition due to the presence of polyunsaturated fatty acids, macro- and micro-minerals in the KSWP. The QDA scores for all attributes revealed samples A and B were significantly different ($p < 0.05$) compared to C, D and E. Samples A, B and C have been identified as the best three formulations for further analysis using hedonic test. As for the hedonic test, significant difference ($p < 0.05$) was observed only for the attribute of seaweed odour. Sample C was highly accepted by the panellists. The addition of KSWP at a lower concentration has met the expectation of the consumers by altering the sensory properties, quality characteristics and nutritional properties of the bun.

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1. Introduction

Malaysian-German Chamber of Commerce and Industry (2016) stated that there has been a demand for baked goods in the Malaysian market due to the products being popularly consumed during breakfast, tea or even lunch in place of the traditionally consumed rice and noodles. The most eaten food by children at breakfast was bread and buns which was 27.2% (Hui-Chin et al., 2015). As bread and buns are common components in our daily diet, it becomes one of the convenient foods to deliver functional properties such as fibre and antioxidants. This is a trend as consumers nowadays are more concerned on healthy food and lifestyle. Buns are popular yeast-leavened bakery products just like the conventional bread. The raw materials and procedures are similar to bread except buns are rounded and moulded in different sizes and shapes (Sandeep et al., 2015).

According to the Malaysian-German Chamber of Commerce and Industry (2016), many younger generations in Malaysia, who have largely been exposed the Western cultures, have acquired the habit of eating bread and drinking coffee, and are increasingly accepting bread as a staple food. Baked foods such as white and wholemeal breads are very popular among Malaysian, as these can easily be consumed with spreads such as butter, peanut butter, jam and cheese. Wholemeal bread is generally perceived as being the healthier choice due to its fibre content. It is highly preferred by consumers due to increasing awareness of the health benefits. Although rice is the staple food for Malaysians which is consumed by 97% of the population twice daily, bread is also listed as one of the ten items consumed daily by 17.11% of consumers and weekly by 56.92% of consumers (Norimah et al., 2008).

Sensory quality is a very important criterion that determines consumer acceptance and demand for newly developed food products. Therefore, it is very crucial to develop a product that meets consumer expectations with optimized sensory attributes (Puri et al., 2016). The QDA has been used to create a sensory profile of attributes and to evaluate the differences in the intensities of sensory attributes in bread samples (Sandell et al., 2015). Algae are the largest and most diverse group of plant-like organisms ranging from unicellular to multicellular forms. The largest and most complex marine algae are called seaweeds. *Kappaphycus alvarezii* is a red alga also called *Eucheuma cottoni*. Many varieties of *Kappaphycus* and *Eucheuma* are found cultivated and harvested in the farms around Sabah, East Malaysia, which are high in carotenoids, dietary fibre, proteins, essential fatty acids, vitamins and minerals and have been exploited mainly in the industrial production of phytocolloids such as agar-agar, alginate and carrageenan. Three patents have been filed in Malaysia on the use of Kapparezii seaweeds for enhancing hair growth, wound-healing and anti-cancer nutraceuticals (Phang et al., 2010). According to Bouga and Combet (2015) in Japan, *Kappaphycus* spp. is utilized as raw material in the production of jam, cheese, wain, tea, soup and noodles. As in Malaysia, many healthy products have been produced from the *Kappaphycus* spp. such as health drinks, cordials, jelly cups, jams, chili sauce and shampoo (Phang 2010).

Hydrocolloids in seaweed can be a great source of natural antioxidants. Oxidative stress is a condition that occurs due to the imbalance between reactive oxygen species (ROS) and antioxidants. This disruption could be because of either ROS accumulation or antioxidant depletion (Bakir et al., 2020; Bungau et al., 2019). Seaweed was chosen in this study because it has significant potential to help build the safe, sustainable and prosperous future we want (Wernberg & Straub 2016). Apart from it, in the Malaysian National Agro-Food Policy (2011–2020) (NAP4), under the program of Entry Point Project 3 known as EPP 3 (venturing into Commercial Scale Seaweed Farming in Sabah), seaweed was identified as one of the high-value commodities (Safari 2015).

The selection of *Kappaphycus alvarezii* was subjected to the theme of "Capitalizing on Malaysia's Competitive Advantage" whereby its natural abundance in Malaysia. Sabah is well-known as an important site for the commercial production of *Kappaphycus alvarezii* in Malaysia (Kunjuraman & Hussin 2017). However, the awareness of the benefits of Kapparezii is still very low among consumers (Wanyonyi et al., 2017). Very limited research has been done on the application of *Kappaphycus alvarezii* as a functional ingredient in the food industry (Rajasulochana et al., 2009). Therefore, KSWP was incorporated into the bun due because as of now there is no high-fibre bun which is produced and marketed by major industries who are producing baked goods in Malaysia. Besides, bun is an excellent convenient food often eaten as a grab-and-go food. The objectives of this study are (i) determination of nutritional properties of buns added with KSWP (ii) identification of the best three of five formulations through QDA and (iii) evaluation of quality parameters and overall acceptability of the KSWP added bun through the hedonic test.

2. Material and methods

2.1. Materials

The dried food grade Kapparezii seaweed, originally from Sabah was pre-packed by Green Leaf Synergy (M) Sdn. Bhd. The Kapparezii was received in full form but pre-dried, light yellow in colour with fungal earthy odour. All the other chemicals that were used in this research were purchased from Scienfield Expertise, Shah Alam, Selangor Malaysia.

2.2. Kapparezii seaweed powder preparation

Kapparezii were thoroughly washed with tap water to remove epiphytes, salt, sand and impurities. The cleaned Kapparezii was soaked in distilled water overnight (24 h) to leach out the yellowish colour of the seaweed. The soaked Kapparezii was then strained and cut into 1 cm long pieces before they were placed on a drying tray in a single layer and dried in a cabinet dryer (Protech Model FAC-350) at 40 °C for 24 h prior to its milling process in a Universal Cutting Mill (Fritsch UCM Model Pulverisette 19) with masher size of 3.0 mm and 0.25 mm. The seaweed was milled to form fine powder before its incorporation into flour which was used to make the buns (Sasue & Kasim 2016).

2.3. Preparation of bun incorporated with Kapparezii powder

Five different ratios of the flour formulations namely A (0% KSWP), B (3% KSWP), C (6% KSWP), D (9% KSWP) and E (12% KSWP) were mixed to determine the optimum tolerability of KSWP incorporated into bun formulation. The ratios of flour and KSWP are shown in Table 1. The formulation of high fibre bun is simplified as in Table 2. The KSWP of > 10% will alter the quality, characteristics as well as acceptability of the bun (Prabhasankar 2009). However, too low KSWP concentration will not be sufficient to increase the nutritional properties of buns. So, by looking into the previous works (Pathak 2016; Mamat et al., 2012), the current research was conducted using low to high (3–12%) KSWP concentration to determine the best formulation that can increase the nutritional properties as well as increase the quality and acceptability of the bun.

Ingredients for bun formulation were prepared as listed in Table 2 and weighed. The flour and yeast were mixed and kept aside. Then, in a separate bowl sugar, melted butter, lightly beaten eggs, milk, salt and bread improver were mixed with

Table 1 Ratios of five different flour blends for bun production.

Formulation	Composition (g)		Seaweed composition (%)
	Flour	KSWP	
A	125.00	0	0
B	121.3	3.8	3
C	117.5	7.5	6
D	113.8	11.3	6
E	110.0	15.0	12

A: 0% KSWP, B: 3% KSWP, C: 6% KSWP, D: 9% KSWP, E: 12% KSWP.
KSWP = Kapparezii seaweed powder.

Table 2 The formulation of bun.

Ingredients	Amount (g)	Percentage (%)
Flour	125.0	50.7
Water	67.5	27.0
Sugar	17.5	7.1
Butter	15.0	6.1
Egg	12.5	5.1
Milk	5.0	2.0
Yeast	2.0	0.8
Salt	1.4	0.6
Improver	0.6	0.3

warm water thoroughly. This process was followed by the mixing of the wet and dry mixture and the kneading process. Then, the dough was fermented and after an hour it was folded to allow the gas to be expelled from the dough subsequently distribute the yeast for further growth.

Dough was rounded into a smooth layer and was allowed to proof for another 10–20 mins. Rounded dough was placed into an aluminium muffin mould and left for final proofing for 45 mins. Dough was baked in a convection oven (Meck Electric Oven-120L, Malaysia) at 200 °C for 20 mins. Buns were removed from the oven, depanned, cooled for 24 h at room temperature (Gisslen 2009) and stored in airtight containers for further analysis.

Buns used to conduct phytochemical and nutritional properties were prepared in a single batch (26 buns × 45 g) for each formulation. Similarly during the QDA session, 10 buns (20 g/each) from each formulation was prepared in a single batch and served to the panelists. Likewise, all the buns used for the hedonic test for each sample were prepared in a single batch (65 buns × 15 g) as well.

2.4. Test conducted on the bun incorporated with Kapparezii seaweed powder

2.4.1. Bake loss

Bake loss is defined as the amount of water and organic material (sugars fermented and released as carbon dioxide) lost during baking which leads to a reduction in weight. Bake loss of the bun samples was conducted according to (Alvarez-Jubete et al., 2010). The weight of the bun dough before baking (W_d) and the weight of the baked bun after cooling for 1 hr. The bake loss was obtained according to the equation below:

$$\text{Bakeweightloss}(\%) = (W_d - W_b)/W_d \times 100$$

2.4.2. Free radical scavenging activity

A free radical scavenging activity test was conducted where the buns were homogenized and extracted according to the method described by Jaiswal et al., (2012). The assay was performed in a 96-well round-bottom microplate with a 1:1 ratio of 100 µL of DPPH and 100 µL of the sample. The mixtures were incubated in a dark condition for 30 mins prior to the absorbance measurement at 516 nm in a spectrophotometer (SPECTROstar$^{\text{Nano}}$, Offenburg, Jerman). The controls contained all the reaction reagents except the sample. Analyses were carried out in triplicate ($n = 3$).

$$\text{Scavengingcapacity}(\%) = [A_{control} - A_{test}/A_{control}] \times 100$$

where $A_{control}$ is the DPPH solution without the sample and A_{test} is the DPPH solution with the test sample.

2.4.3. Total phenolic content

The total phenolic content (TPC) was measured using the Folin-Ciocalteau method as outlined by Taga, Miller & Pratt (1984). A total of 100 µL of samples or standard were added to 2 mL of natrium carbonate (2%, w/v) followed by the addition of 50% Folin-Ciocalteau reagent. The mixtures were allowed to rest for 30 mins at room temperature in dark condition. Spectrophotometer (SPECTROstar$^{\text{Nano}}$, Offenburg, Jerman) was used to measure the absorbance at 765 nm. The TPC was expressed as mg GAE per 1 g dry basis (db) (mg GAE/g db). Analyses were conducted in triplicate ($n = 3$).

2.4.4. Nutritional compositions

The chemical composition of moisture, ash, protein and fat with solvent extraction (submersion) method was determined according to the Association of Official Agricultural Chemists (AOAC) (1990) standard method. Carbohydrate content was determined by difference. The total caloric content was determined by the calculation shown below. All analyses were carried out in triplicate ($n = 3$).

$$\text{Caloriccount} = [W_A \times 4(\text{cal/g})] + [W_B \times 4(\text{cal/g})] + [W_C \times 9(\text{cal/g})]$$

where W_A is carbohydrate content in the sample (g), W_B is protein content in the sample (g) and W_C is fat content in the sample (g).

To determine the protein content, 1 g of the homogenised bun sample was weighed together with catalyst salt into digestion tubes. A total of 12 mL of concentrated sulphuric acid (H_2SO_4) was carefully added into the tube and shaken gently prior to the digestion process in Tecator™ Digestor (FOSS, Denmark) at 420 °C for 60 mins until clear blue/green solution was obtained. Samples were cooled for 10–20 mins then followed by the distillation process in Kjeltec™ 8200 Auto Distillation Unit (FOSS, Denmark) and the percentage of protein was calculated by the following formula:

$$\text{Protein content}(\%) = [0.1 \times (V_s - V_b)/W_s] \times 14 \times 6.25 \times 100$$

where V_s is volume of sample titration (mL), V_b is volume of blank titration (mL) and W_s is weight of the sample (g).

Moisture content was determined by weighing the empty crucible. Approximately 1 g of samples was weighed (W_b) in the dish and placed in an oven at 105 °C for 24 h. The dried samples were then cooled in a desiccator and weighed (W_a). The moisture content was calculated using the following equation:

$$\text{Moisture content}(\%) = (W_b - W_a/W_b) \times 100$$

In the determination of ash content, the weight of the empty crucible was recorded, and 5 g samples (W_s) were placed in the crucible prior to the heating process in a fume hood. Then samples were placed in a cooled muffle furnace and heated overnight at 550 °C. The percentage of ash content calculated as the formula below:

$$\text{Weight of total ash}(W_a) = (\text{weight of crucible} + \text{ash}) - (\text{weight of crucible})$$

$$\text{Ash content}(\%) = W_a/W_s \times 100$$

Fat composition was determined in Soxtec^{TM} 2043 (FOSS, Denmark). The weight of the pre-dried extraction thimble was recorded. Approximately 2 g of sample (W_s) was added into the extraction thimble and plugged with glass wool. The extraction was carried out for 2 to 2.5 h, followed by a boiling process for 45 mins (130 °C) and finally rinsing process was carried on for about 35 mins. The flask with the content was dried in a hot air oven (Memmert, Jerman) at 105 °C, cooled in a desiccator and finally weighed (W_f). The weight of the extracted crude fat and the percentages were calculated, based on the equation given below:

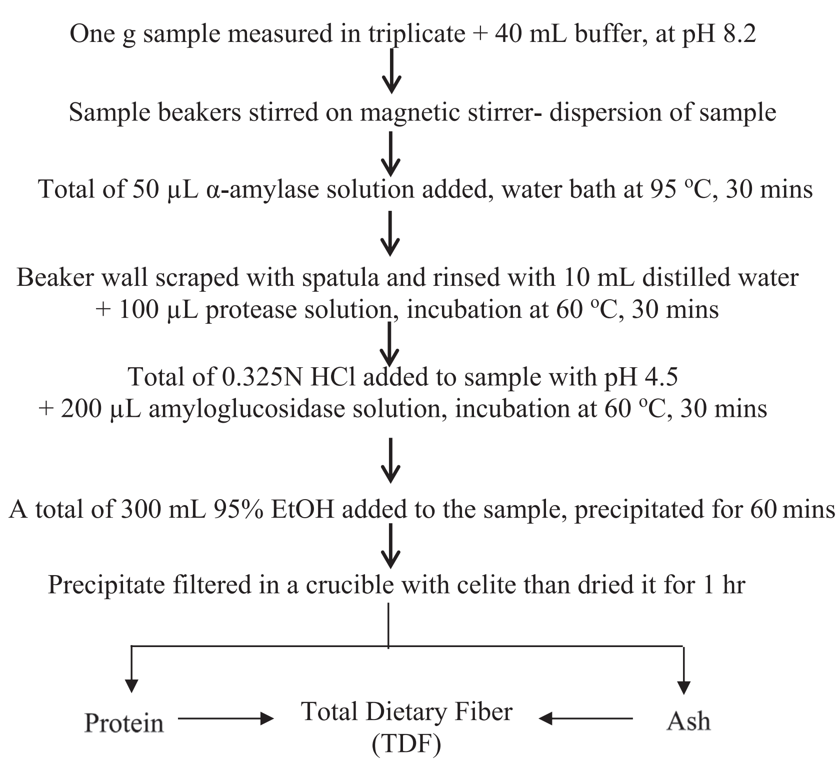
$$\text{Fat content}(\%) = W_f(g)/W_s(g) \times 100$$

The total dietary fibre (TDF) was determined based on AOAC (1997): Method 985.29. The TDF was determined on for the buns in triplicate ($n = 3$). The methods involved in the TDF determination is simplified as in the flow chart below:

2.4.5. Sensory evaluation

Ethical approval (UKM PPI/111/8/JEP-2019–215) was obtained to conduct this study. All participants involved were briefed verbally and in writing of the test procedures and panellists provided written consent. Attributes for sensory terminologies for QDA of buns with added KSWP were developed by ten trained panellists from the Department of Food Science, Universiti Kebangsaan Malaysia (UKM), using QDA methodology (Aris et al., 2023; Kasim et al., 2022; Kasim et al., 2021; Sandell et al., 2015). They were recruited from electronic advertisement to the students and staffs based on interest and commitment to participate. A panel of ten to twelve is sufficient to conduct the QDA analysis recommended by Stone, Bleibaum and Thomas (2012). Panellists were trained by a facilitator without involvement and interference with the panel discussion. During training, references (commercial buns) were used for generating sensory terminologies which were used later in the QDA form. Once the terminologies have been developed, the ten panellists were trained to evaluate the four samples of KSWP added bun and the control. Different reference samples (Table 3) were used to establish the definitions of each sensory attribute, to reduce the amount of time required to train panelist as well as calibrate the panels in the use of the intensity scale (Chapman et al., 2001). Finally, after intense training, the ten trained panellists were asked to mark the intensity of attributes on the QDA scale, which consisted of a linear scale extended up to 15 cm. Panellists were asked to mark a vertical line on the scale with the code of the sample close to the line (Priya et al., 2017).

The best three formulations that were selected from QDA were used to conduct the hedonic test. The best three bun formulations were evaluated using a 15 cm scale with a scale that starts from 1 cm which was "dislike extremely", the midpoint



was “neither like nor dislike” and 15 cm was “like extremely”. Sixty-five consumer panellists comprised of students and staffs from the Department of Food Sciences, Universiti Kebangsaan Malaysia (UKM) took part in the hedonic test. The panellist were instructed to evaluate colour (crust and crumb), porosity, odor, texture (springiness, softness and moistness), flavour and overall acceptability. The samples were coded with three digit number and presented in a random sequence to the panellists (Pathak et al., 2017).

2.5. Statistical analysis

Data were analyzed using Statistical Package for Social Sciences (SPSS Inc., Chicago, USA). version 23.0. The statistical test used was Analysis of Variance (ANOVA). Difference between the control bun and KSWP added buns were identified using Tukey test at 95% confidence level with $p < 0.05$. Mean scores that were obtained from SPSS were recorded to form tables and figures.

3. Results and discussion

The addition of KSWP had a significant effect on the baking loss and nutritional characteristics of the bun. The sensory properties of the bun that was evaluated by QDA and hedonic test were also significantly affected by the addition of KSWP.

3.1. Textural properties of the bun with added Kapparezii powder

Fig. 1 showed the bun formulated with the inclusion of 0, 3, 6, 9 and 12% KSWP from the overall flour concentration. As shown in Table 4, the hardness of KSWP added buns increased significantly as the KSWP increased from 3 to 12% (62.4–160.8%). There was no significant difference between hardness in the texture of samples B and C due to the fact that the percentage KSWP was too low to alter the texture of the bun. However, the hardness has increased ($p < 0.05$) in the 3, 6, 9 and 12% KSWP treated bun samples compared to the control sample.

This is due to the fact that KSWP in the buns was high in dietary fiber thus reduced the yeast activity, restricted the expansion of air cells (Pathak et al., 2016) producing rigid and hard textured buns. Fig. 2, depicts the internal texture of the treated buns where the increase in KSWP from 0−12% reduced the size of pores. Seaweeds are well known for their high fibre composition and hygroscopic properties (Chin, Huda and Yang, 2012). A similar research from Cox and Abu Ghannam (2013) showed 5–15% concentration of seaweed added in breadsticks have increased the texture of the treated samples from 69.85 N/mm to 108.84 N/mm. Similarly, noodles prepared by substituting wheat with 0, 1, 3, 5 and 7% *Gracilaria* SWP have caused a significant increase in the texture (Keyimu, 2013).

3.2. Bake loss

Bake loss is the major loss detected in bun and bread making process (Ozola et al., 2012; Sandeep et al., 2015). Fig. 3 showed the changes in bake loss values of the KSWP added buns that were formulated. Control bun (0% KSWP inclusion) showed the highest percentage of bake loss (14.9%) and followed by buns with 3, 6, 9 dan 12% KSWP with a percentage of bake loss of 13.3, 12.9, 12.8 and 9.6% respectively. Significant difference ($p < 0.05$) was found in all the samples except for 6% and 9% KSWP added buns. There was a significant gradual decrease in the baking loss when the amount of KSWP was increased in the flour blend.

Table 3 References used to train the panelists.

No	Descriptors	Intensity	Reference samples
1	**Bun surface**	Smooth	*Massimo* bun (commercial bun) from the market
		Rough	French loaf
2	**Porosity of the crumb (pore size)**	Small	Potato bun
		Big	Burger bun
3	**Buttery aroma (crumb and crust)**	Weak	Burger bun
		Strong	Butter
4	**Seaweed aroma**	Weak	Normal bun
		Strong	KSWP
5	**Texture (by feeling it with hands)**		
(a)	Softness- force required to compress sample between fingers	Soft	Burger bun
		Hard	French loaf
(b)	Springiness- swiftness of returning to the initial shape after moderate pressure applied to the center of the bun	Less springy	White bread
		Springier	Burger bun
(c)	Crookedness- presence of cracks on the surface of the samples	Never crack	Potato bun
		More cracks	French loaf
6	**Texture (by taking the first bite in the mouth)**		
	Moistness- amount of saliva secreted in the oral cavity during sample chewing	Dry	Burger bun
		Moist	Potato bun
7	**Seaweed flavor**	Weak	White bread
		Strong	Seaweed bun

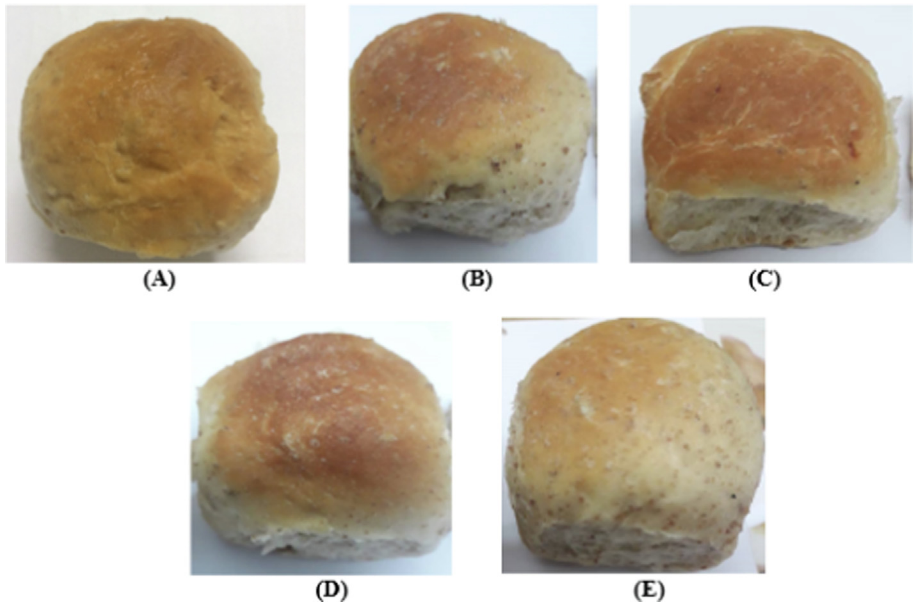


Fig. 1 KSWP added buns added with 0% KSWP (A), 3% KSWP (B), 6% KSWP (C), 9% KSWP (D) and 12% KSWP (E).

Table 4 Texture measurements of the bun.

Samples	Texture (N/mm)
A	62.4 ± 0.7[d]
B	68.7 ± 0.8[c]
C	71.3 ± 1.2[c]
D	98.7 ± 1.2[b]
E	160.8 ± 1.5[a]

Texture, TPC and DPPH in buns added with 0% KSWP (A), 3% KSWP (B), 6% KSWP (C), 9% KSWP (D) and 12% KSWP (E).
The superscript letters [a-d] in the column denote values that statistically ($p < 0.05$) differ from one another. KSWP = Kapparezii seaweed powder.

According to Mamat et al., (2014), there are two factors contributing to the findings obtained which was the ability of hydrocolloids in seaweed to absorb more water. This could suppress the amount of steam generated during baking resulting in a decrease in the baking loss after the baking process. Secondly, the increase in the addition of seaweed powder, which can disrupt the gluten network that contributes to the low expansion of the bun subsequently decreasing the baking loss. A similar trend was observed in bread added with extruded maize flour (Ozola et al., 2012) and bun formulated with *makhana* flour (lotus seed flour) (Sandeep et al., 2015), where authors stated that, extruded maize flour and *makhana* flour with higher water absorption capacity caused a gradual decrease in the baking loss.

3.3. The DPPH radical scavenging activity

The DPPH radical scavenging activity results are presented in Fig. 4. Substitution of flour with 12% KSWP had significantly increased ($p < 0.05$) the DPPH activity to 49.0%, with the increment of 10.2% as compared to the control sample with only 38.8% DPPH activity (49.0–38.8% = 10.2%). Data shown in Fig. 4 clearly indicated that there was a significant difference ($p < 0.05$) in the DPPH activity of buns formulated with KSWP compared to the control sample.

A similar trend was evident in the study conducted by Cox and Abu-Ghannam (2013), whereby DPPH activity was maximized when 17.07% seaweed *Himanthalia elongata* was incorporated into the flour to produce breadsticks. In a study conducted by Prabhasankar et al., (2009), the pasta that was incorporated with 30% brown seaweed increased the DPPH activity from 6.83 to 9.79% which was significantly lower than the activity in the present study. This indicates that the addition of KSWP in the bun would provide a good source of antioxidants. Hence, seaweeds are identified as natural and safe antioxidative agents which are considered a source of bioactive compounds as they are able to produce a great varieties of secondary metabolites and are characterized by a broad spectrum of biological activities (Hashim et al., 2018; Azzimi et al., 2018; Meenakshi et al., 2011).

3.4. Total phenolic content (TPC)

The addition of KSWP to the buns have significantly increased the TPC ($p < 0.05$) in all the test samples (TPC_B = 15.0 mg/100 g, TPC_C = 25.6 mg/100 g, TPC_D = 29.4 mg/100 g and TPC_E = 35.1 mg/100 g) (Fig. 4). An increase of 23.3 mg/100 g was seen when the overall flour concentration was substituted with 12% KSWP as compared to the control sample (35.1 mg/100 g−11.8 mg/100 g = 23.3 mg/100 g). This clearly showed that the seaweed bun contains higher levels of total phenols which can be classified as healthy food for consumers. The results from the current research indicate that seaweed powder can be incorporated in convenience food to increase its antioxidant potential.

A similar study has been conducted by Prabhasankar et al., (2009) where they studied the influence of adding brown sea-

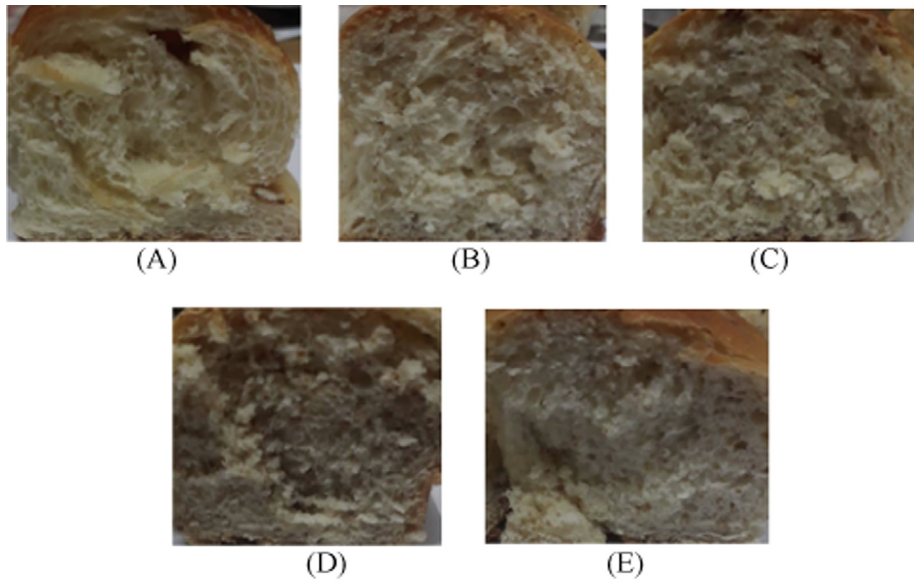


Fig. 2 Effect of 0–12% addition of KSWP on the internal texture of bun samples. A = 0% KSWP, B = 3% KSWP, C = 6% KSWP, D = 9% KSWP and E = 12% KSWP.

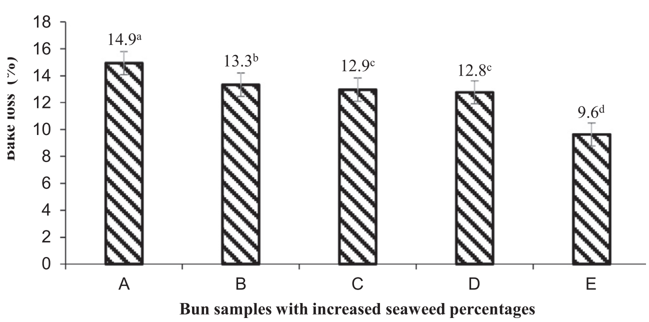


Fig. 3 Changes in the values of bake loss of weight in buns added with 0% KSWP (A), 3% KSWP (B), 6% KSWP (C), 9% KSWP (D) and 12% KSWP (E).

weed, *Sargassum marginatum* to pasta. The TPC in cooked pasta increased from 9 to 13 mg GAE/100 g (an increase of 30.8%) with a 5% addition of brown seaweed. Comparing with the similar seaweed concentration in the present study, the results of 6% incorporation of KSWP in bun has led to an increase of 53.9% of TPC from 11.8 (A) to 25.6 mg GAE/100 g db (C) [(25.6 mg/100 g−11.8 mg/100 g ÷ 25.6 mg/100 g) × 100 = 53.9%]. Our study supported the statement of Cian et al., (2014) who concluded that the bio-accesibility of bioactive compounds provided by red edible seaweeds may help food technologists to tailor new bio-functional foods.

3.5. Nutritional compositions

Table 5 showed the proximate composition of buns incorporated with different percentages of KSWP. The results showed that the protein content found in all five samples was within the range of 9.6–12.5%. The protein composition reduced significantly ($p < 0.05$) with the increase of KSWP inclusion. The increase in the amount of KSWP in the buns decreases the protein content due to the reduction in the network produced by the gluten. This finding was supported by Keyimu (2013), in

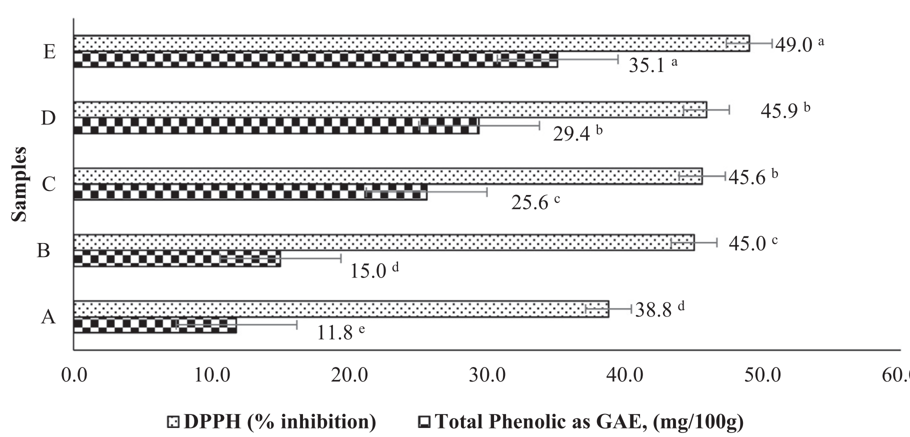


Fig. 4 The DPPH and TPC values in buns (n = 5) added with 0% KSWP (A), 3% KSWP (B), 6% KSWP (C), 9% KSWP (D) and 12% KSWP (E).

Table 5 Proximate composition of buns added with 0, 3, 6, 9 and 12% Kapparezii seaweed powder.

Samples	Protein	Fat	Carbohydrate	Ash	Moisture	Energy	Dietary fibre
A	12.5 ± 0.1^{a}	1.1 ± 0.1^{b}	50.0 ± 0.4^{d}	0.9 ± 0.1^{c}	35.6 ± 0.2^{a}	259 ± 1.2^{c}	4.5 ± 0.4^{d}
B	12.5 ± 0.1^{a}	1.2 ± 0.1^{b}	49.6 ± 0.5^{d}	1.3 ± 0.1^{b}	35.4 ± 0.6^{a}	259 ± 2.2^{c}	6.3 ± 0.1^{c}
C	11.7 ± 0.3^{b}	1.7 ± 0.2^{a}	50.3 ± 0.5^{c}	1.2 ± 0.1^{bc}	35.1 ± 0.5^{a}	263 ± 2.7^{c}	7.5 ± 0.3^{b}
D	10.2 ± 0.2^{c}	1.1 ± 0.1^{b}	55.9 ± 0.3^{b}	1.2 ± 0.2^{bc}	31.6 ± 0.3^{b}	275 ± 1.0^{b}	8.0 ± 0.2^{b}
E	9.6 ± 0.2^{d}	1.0 ± 0.1^{b}	62.7 ± 0.3^{a}	1.8 ± 0.2^{a}	24.8 ± 0.3^{c}	298 ± 1.1^{a}	13.6 ± 0.4^{a}

Sample A = 0%, B = 3%, C = 6%, D = 9% and E = 12% KSWP added buns. All the macronutrients were expressed in percentage (g/100 g) except energy in kcal/100 g Mean value ± standard deviation; different superscripts letters from $^{a\text{-}d}$ in a column denote mean values that statistically ($p < 0.05$) differ from one another. KSWP = Kapparezii seaweed powder.

the study of developing Asian noodles using different concentrations of seaweed aiming at increasing the nutritional quality. The author observed that, an increase in the KSWP from 0, 1, 3, 5 and 7% had decreased the protein content from 41.9−36.5%. The addition of KSWP could have disrupted the gluten network that contributed to the reduction in protein content (Mamat et al., 2014).

As for the fat content, the 0, 3 and 6% KSWP added bun spiked in the range from 1.1 to 1.7%. This result showed a significant difference ($p < 0.05$) in sample C with samples A, B, D and E. Figueira et al., (2011), studied that bread enriched with 2, 3, 4 and 5% of algae had increased the fat content from the range 1.2 to 2.8%. The current result was also in accordance with the study by Keyimu (2013) whereby 1% *Gracilaria* seaweed powder (SWP) incorporation had increased the fat content in the noodle from 0.3% to 0.6% as compared to control. According to Rajapakse and Kim (2011), seaweed is a good source of health-promoting polyunsaturated fatty acid (PUFA), compared to other foods derived from plant and animal sources. Red seaweed is rich in eicosapentaenoic acid (EPA) and omega 6 (ω-6) fatty acids.

Results obtained showed that carbohydrate content was highest than other proximate content. Sample E with 12% KSWP showed the highest carbohydrate content (62.7%) followed by samples D (55.9%), C (50.3%), A (50.0%) and B (49.6%). Significant difference ($p < 0.05$) was found between samples A and B with samples C, D and E. The addition of KSWP has improved the carbohydrate content. In a study conducted by Masturah et al., (2015) on sensory and physicochemical properties of brown rice bar formulated with *Hoodia gordonii* and *Kappaphycus* SWP, the carbohydrate content was higher for rice bar with the addition of KSWP (66.6%) compared to the control (62.1%). This is due to carbohydrates being the primary component in dried seaweed that composed up to 76% (Holdt and Kraan, 2011).

The ash content of sample A (Table 5) was the lowest (0.9%). This shows that ash contents increased significantly ($p < 0.05$) with the addition of KSWP from 0 to 12% (1.8%). Keyimu, (2013) also stated that, the addition of *Gracilaria* powder increases the ash content from 0.6 to 1.2%. Menezes et al., (2015) findings also support the current research findings whereby ash content significantly increased (2.5%) in bread formulation with the presence of 7.5% of macroalgae. Ash or mineral content increased proportionally with the increase of KSWP due to the presence of algal biomass (Rajapakse and Kim, 2011).

The addition of KSWP from 3−12%, decreases the moisture content of the bun in the range of 35.4–24.8% respectively. No significant difference ($p > 0.05$) between samples A, B and C was observed but was significantly different ($p < 0.05$) with samples D and E. This is due to high levels of KSWP increasing the water absorption. This finding agrees with Jumaidin et al., (2016), where the addition of seaweed decreased the water content of the thermoplastic that was formed. The KSWP contributed to the high water-absorbing capacity as it competed for water with other constituents. According to Friend et al., (1993), this is due to the hydroxyl groups in the hydrocolloid structure, which allow water interactions through hydrogen bonding.

The dietary fibre content increased significantly ($p < 0.05$) in the range of 4.5 to 13.6% with the increase of KSWP concentration in the bun samples. Seaweed is a well-known source of dietary fibre. According to Kristensen and Jensen (2011), seaweed-added food products tend to have higher dietary fibre. This statement was proven by research that was conducted by Mamat et al., (2016) which shows a significant increase in the dietary fibre content (1.5–4.3%) of buns added up to 8% of KSWP. The dietary fibre composition in *Kappaphycus alverazii* can be as high as 69.3% (Santoso et al., 2006). This explains the increase in the dietary fibre content of bun samples B, C, D and E. Various research have proved that the increase in the percentage of KSWP eventually increased the dietary fibre content in the final product (Mohammad et al., 2019; Putri et al., 2019; Firdaus et al., 2017).

3.6. Sensory evaluation

3.6.1. Panel selection for sensory evaluation

Ten trained panelists were recruited for the QDA session. Sixty-five consumer panellists consists of students and staffs from the Department of Food Sciences, Universiti Kebangsaan Malaysia (UKM) took part in a hedonic test involving 21.5% men and 78.5% women. The percentages of Malays, Chinese, Indians and other races involved in this study were 43.1, 40, 15.4 and 1.5% respectively. The majority of the subjects (76.9%) were in the age rage of 18 to 23 while 13.8% were in the range of 24 to 30 years and 9.2% were above 30 years old. A total of 81.5% of panellists was involved in the hedonic test. They have consumed and tasted seaweed and seaweed-based products compared to 18.5% of panels who were not aware of seaweed taste and attributes.

3.6.2. Sensory attributes evaluation through quantitative descriptive analysis

The best three of five formulations were identified through QDA for the evaluation of sensory attributes and overall

Table 6 Descriptors with definition generated by panellists for QDA of test samples.

Attributes	Definition
Appearance (crust)	
Color	Degree of perceived brown color of crust
Bun surface	Degree of smoothness of the crust
Appearance (crumb)	
Porosity	Size of holes in the crumb
Color	Intensity of color
Aroma	
Buttery	Aroma associated with butter
Seaweed	Odor intensity once opening the packing
Texture (by feeling it with hands)	
Softness	Force to compress sample between finger
Springiness	Swiftness returning to the initial shape
Crookedness	Presence of cracks on the surface of the sample
Texture (by taking the first bite in the mouth)	
Moistness	Saliva secreted during sample chewing
Flavor	
Seaweed taste	Degree of perceived intensity after chewing
Overall acceptability	Degree of acceptability of the samples

acceptability through the hedonic test. Table 6 showed the definitions of descriptors that were generated by the trained panellists to evaluate the bun samples that were used as the basis for QDA. The list of descriptors and intensity of scale for evaluating the seaweed-added buns was finally refined after a consensus discussion among the panel members based on the given reference samples (Table 3). Various reference samples from the industry were used to train the panel members in evaluating the buns with seaweed addition.

The overall acceptability and attribute intensities for appearance, aroma, flavour and texture of the KSWP added buns were revealed in Table 7. The addition of KSWP at the lowest percentage of 3% (sample B) showed no significant difference ($p > 0.05$) with the control sample (A) for most of the attributes except for aroma and moistness. While sample E with the highest percentage of added KSWP showed a contrasting result compared with the control sample with a significant difference ($p < 0.05$) for most of the attributes evaluated except for colour and moistness. No significant difference ($p > 0.05$) was observed between samples D and E for all the attributes.

Brasil et al., (2011), conducted QDA of bread added with inulin which resulted in the generation of similar descriptors as generated in this study for attributes such as volume, crust colour, porosity and texture. He reported good quality bread has been produced by introducing 6% inulin. The authors also

Table 7 Mean panellist's ratings of overall Kapparezii seaweed powder added bun quality and attribute intensities for QDA ($n = 10$).

Attributes	Buns with added KSWP				
	A	B	C	D	E
Crust appearance					
Color	9.0 ± 0.1^{ab}	7.9 ± 2.7^{b}	10.9 ± 1.6^{a}	10.3 ± 2.9^{a}	8.6 ± 3.4^{ab}
Bun surface	3.3 ± 0.2^{b}	3.7 ± 1.2^{b}	8.4 ± 2.6^{a}	9.2 ± 3.2^{a}	9.5 ± 2.8^{a}
Crumb appearance					
Porosity	5.0 ± 0.1^{b}	6.2 ± 3.0^{bc}	6.7 ± 2.3^{abc}	7.5 ± 2.9^{ab}	8.7 ± 2.9^{a}
Color	9.2 ± 0.0^{ab}	6.5 ± 3.32^{a}	9.0 ± 3.9^{ab}	8.7 ± 4.2^{ab}	10.1 ± 4.1^{b}
Aroma					
Buttery	11.0 ± 0.1^{a}	8.6 ± 3.5^{b}	7.3 ± 3.1^{b}	4.7 ± 2.2^{c}	4.4 ± 2.9^{c}
Seaweed	2.0 ± 0.1^{c}	$4.3 \pm 2.9b^{b}$	5.1 ± 2.4^{ab}	5.8 ± 4.0^{ab}	8.1 ± 4.2^{a}
Texture (by feeling it with hands)					
Softness	5.4 ± 0.1^{c}	5.1 ± 2.5^{c}	8.4 ± 3.1^{b}	10.6 ± 1.8^{a}	9.9 ± 2.7^{a}
Springiness	11.0 ± 0.1^{a}	8.9 ± 3.5^{ab}	9.4 ± 3.0^{ab}	7.6 ± 1.7^{b}	7.4 ± 3.1^{b}
Crookedness	3.3 ± 0.4^{c}	5.5 ± 3.4^{bc}	7.2 ± 2.4^{ab}	8.2 ± 2.7^{a}	8.7 ± 2.7^{a}
Texture (by taking the first bite in the mouth)					
Moistness	5.8 ± 0.2^{b}	8.8 ± 2.5^{a}	6.6 ± 3.17^{ab}	4.1 ± 3.1^{b}	4.5 ± 3.7^{b}
Flavor					
Seaweed	1.1 ± 0.1^{b}	3.0 ± 3.0^{ab}	3.1 ± 1.3^{ab}	4.3 ± 3.1^{a}	4.7 ± 4.6^{a}
Overall acceptability	10.3 ± 0.1^{a}	10.2 ± 2.8^{a}	8.9 ± 3.3^{ab}	6.4 ± 3.0^{b}	6.3 ± 3.6^{b}

Sample A = 0%, B = 3%, C = 6%, D = 9% and E = 12% KSWP added buns. The ratings of the samples were done on a 15 cm scaled QDA form. Mean.
value ± standard deviation; different superscripts letters from $^{a-c}$ in a row denote mean values that statistically ($p < 0.05$) differ from one another.
KSWP = Kapparezii seaweed powder.

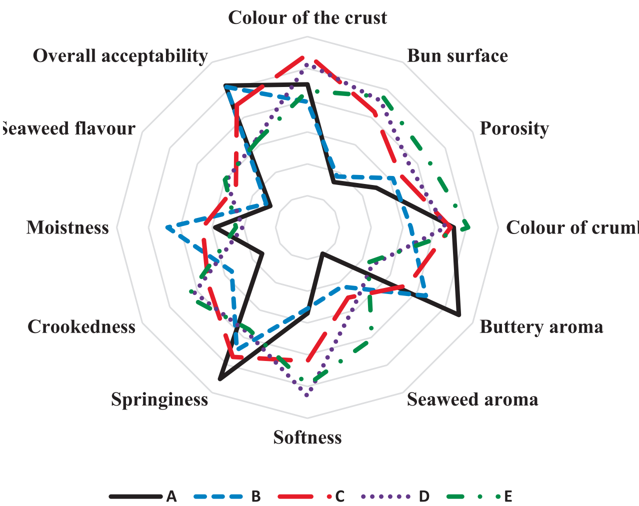


Fig. 5 Descriptors concerning KSWP added bun evaluation ($n = 5$). A = 0% KSWP, B = 3% KSWP, C = 6% KSWP, D = 9% KSWP and E = 12% KSWP.

noted no significant difference ($p > 0.05$) in the sensorial attributes scores of standard breads (0% inulin) and 6% inulin bread. Their findings were similar to the result obtained in this research whereby the 6% KSWP inclusion bun showed no significant difference ($p > 0.05$) with the control bun for all the attributes except for bun surface, buttery aroma, softness and crookedness (Table 7).

The presented radar chart (Fig. 5) showed samples A, B and C were selected as the best three formulations with smoother, softer, moist bun with mild seaweed flavour and aroma as well as the stronger buttery aroma. Samples A and B with spikes radiating outwards, shows the highest mean score for overall acceptability followed by samples C, D and E. Some of the descriptors that played vital roles in the overall acceptability of buns were bun surface, seaweed and buttery aroma, softness and moistness. Based on the acceptance scores, it can be concluded that samples B and C with 3% and 6% KSWP inclusion had satisfactory acceptance and were selected for the hedonic test together with the control sample (0% KSWP). This result is aligned with Cox and Abu-Ghannam (2013), have reported that there was no significant difference ($p > 0.05$) between the seaweed breadsticks and the control. Thus, concluded that fibre-rich seaweed bakery products which acceptable to consumers can potentially be used to increase seaweed consumption among non-seaweed consumers. However, the inclusion of KSWP of > 6% in the bun formula decreased the sensory characteristics and overall acceptability of the bun. Some food products with added fibre are often rated as unacceptable by sensory panellists once they exceeded a certain concentration (Cox and Abu-Ghannam, 2013). Prabhasankar et al., (2009) found that there was a significant difference in pasta with a 10% replacement of semolina with seaweeds compared to the control.

3.6.3. Hedonic test

When developing functional bakery products, it is important to design a product with physiological effects that will be accepted by consumers in terms of appearance, taste and texture (Fadzilah et al., 2020; Siró et al., 2008). One of the limiting factors for consumer acceptability is organoleptic properties.

Table 8 Means of sensory attributes of control and test samples from hedonic test ($n = 65$).

Attributes	Samples		
	A	B	C
Appearance (crust)			
Color	9.8 ± 3.1^{a}	9.7 ± 3.3^{a}	9.9 ± 3.5^{a}
Bun surface	9.7 ± 3.05^{a}	9.78 ± 3.2^{a}	9.6 ± 3.5^{a}
Appearance (crumb)			
Porosity	9.7 ± 3.05^{a}	9.6 ± 2.8^{a}	9.9 ± 2.9^{a}
Color	10.2 ± 2.7^{a}	9.9 ± 2.8^{a}	9.7 ± 3.5^{a}
Aroma			
Buttery	9.30 ± 3.0^{a}	9.1 ± 3.0^{a}	8.9 ± 3.1^{a}
Seaweed	10.1 ± 6.4^{a}	8.5 ± 2.9^{a}	8.4 ± 3.0^{a}
Texture (by feeling it with hands)			
Softness	8.9 ± 2.9^{a}	9.1 ± 3.0^{a}	9.4 ± 3.3^{a}
Springiness	9.2 ± 3.0^{a}	9.4 ± 3.1^{a}	9.7 ± 3.2^{a}
Surface cracking	9.1 ± 3.3^{a}	8.9 ± 2.9^{a}	9.5 ± 3.0^{a}
Texture (by taking the first bite in the mouth)			
Moistness	8.5 ± 2.6^{a}	8.7 ± 2.7^{a}	9.5 ± 3.1^{a}
Flavour			
Seaweed	9.9 ± 3.1^{a}	8.9 ± 3.3^{ab}	8.6 ± 3.0^{b}
Overall acceptability	9.7 ± 2.8^{a}	9.5 ± 2.8^{a}	10.6 ± 3.4^{a}

Sample A = 0%, B = 3%, C = 6% KSWP added buns. The ratings of the samples were carried out on a 15 cm scaled hedonic form. Mean value ± standard deviation; different superscripts letters from $^{a\text{-}b}$ in a row denote mean values that statistically ($p < 0.05$) differ from one another. KSWP = Kapparezii seaweed powder.

Therefore, appearance, colour (crust and crumb), aroma, texture, and overall acceptability were performed in this study and the results of the hedonic test were revealed in Table 8.

There was a significant difference ($p < 0.05$) between samples A (9.9) and C (8.6) for the attribute seaweed flavour. However, no significant difference ($p > 0.05$) was obtained for crust and crumb colour, surface smoothness, porosity, buttery and seaweed odour, softness, springiness, surface cracking, moistness and overall acceptability between all three samples. This clearly showed that the buns with KSWP were accepted by panellists. The inclusion of KSWP at a very low percentage (3% and 6%) did not have profound effects on the sensory properties except for seaweed flavour. Prager (2016) stated that, seaweeds are not much accepted by consumers due to their fish-like smell and uncommon taste. The uncommon taste is due to the release of dimethylsulfide (DMS) from the decomposition of seaweed (Neta and Narain, 2018). The results concluded that sample C was highly preferred by respondents even though no significant difference ($p > 0.05$) were observed for all samples.

4. Conclusion

This study showed that Kapparezii, a marine source that is found abundantly in the coastal regions of Malaysia could be used as a functional ingredient in bun production. A significant gradual decrease ($p < 0.05$) was identified (14.9–9.6%) in the baking loss with an increase in the KSWP concentration (0–12%). As for the DPPH radical scavenging activity, it showed a significant increase ($p < 0.05$) in between sample A with test samples B, C, D and E while the TPC result showed a significant increase in between all the tested samples. Hence, Kapparezii added bun would be a good source of antioxidant. Test samples A, B and C with the highest mean score for overall acceptability (10.3, 10.2 and 8.9) respectively were chosen for the subsequent hedonic test. Up to 6% KSWP could be used to replace wheat flour in the bun and most accepted organoleptically (10.6) in the hedonic test and nutritionally as they contain an appreciable amount of protein (11.7%), fat (1.7%), carbohydrate (50.3%), ash (1.2%) and dietary fibre (7.5%). It can be concluded that the addition of KSWP at a lower concentration of 3 and 6% has met the expectation of the consumers without altering the sensory properties of the test samples (B and C) compared to the control sample (A) but preserving the quality characteristics and nutritional properties of the tested buns.

Data Availability Statement

No data were used elsewhere to support this study and it was entirely a new set of data.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: [Zalifah Mohd Kasim reports financial support, administrative support, article publishing charges, and statistical analysis were provided by National University of Malaysia.].

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