

Carrageenan as a Functional Strategy to Enhance Quality and Consumer Acceptance in Marinated Chicken Breast

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Abstract. Today's consumers are redefining meat consumption by seeking products that combine premium quality with sustainability and affordability, without compromising sensory appeal or nutritional integrity. In this context, the present study investigated the impact of carrageenan incorporation at varying concentrations on the quality attributes of chicken breast marinades as a ready-to-cook meat product. The inclusion of 1.5% carrageenan significantly ($p < 0.05$) enhanced fat ($2.26 \pm 0.42\%$) while inclusion of 0.8% improved ash contents ($6.06 \pm 0.27\%$). Increasing carrageenan concentrations were also associated with elevated pH and viscosity, indicating improved functional stability. Colour analysis revealed that carrageenan-treated samples exhibited a darker appearance relative to the control. Furthermore, cooking loss was significantly reduced ($p < 0.05$) in carrageenan-enriched formulations, reflecting superior water-holding capacity. Texture profile analysis demonstrated marked improvements ($p < 0.05$) in hardness, cohesiveness, gumminess, chewiness, and resilience, highlighting the role of carrageenan in structural enhancement. Sensory evaluation confirmed that panellists preferred samples containing 0.5–1.5% carrageenan, suggesting this concentration range optimally balanced functional benefits with consumer acceptability. Collectively, these findings establish carrageenan as a valuable functional ingredient for improving the physicochemical, textural, and sensory qualities of chicken marinades, thereby aligning product innovation with evolving consumer expectations for quality and functionality in meat-based foods.

Keywords: chicken marinades, carrageenan, functional foods

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1 Introduction

Currently, consumer demand is shifting toward meat products that are not only high in quality but also environmentally sustainable and cost-effective, while maintaining desirable sensory and nutritional attributes. However, conventional heat treatments commonly employed in meat processing can negatively impact product quality. Specifically, heat processing promotes moisture loss through water evaporation, while the contraction of muscle fibres further reduces the water-holding capacity of the meat [1].

Marinating is essential in the meat industry to meet growing consumer demand for flavourful, tender, convenient, and safe ready-to-cook meat products while enhancing processing efficiency and product yield. In addition, marination is a pre-cooking process in which meat is immersed in marinades composed of various ingredients for a specified time, intended to improve food quality by preventing quality loss such as shrinkage, oxidative off-flavors, microbial contamination, and discoloration in meat and meat products [2].

Carrageenan, a sulphated polysaccharide obtained from marine red algae, is known for its biodegradability, safety, and good solubility in water [2]. These properties make it an important hydrocolloid in food production, where it is widely used in meat, dairy, and cereal based products. Its main functions include forming gels, thickening, stabilizing, emulsifying, and retaining water, all of which improve texture, stability, and shelf-life of food products [3].

Moreover, carrageenan can be applied in sauce formulations to enhance viscosity, and when combined with modified starch, it facilitates the achievement of optimal viscosity levels [4]. In addition, Khare et al. [2] reported that the combined use of carrageenan, citric acid, and cinnamon oil in an edible coating markedly improved the preservation of chicken meat by extending its shelf-life under refrigerated storage. Similarly, Yu et al. [5] reported that the incorporation of carrageenan into surimi at concentrations ranging from 0 to 2.0% (w/w) markedly influenced textural attributes, with 1.5% (w/w) yielding optimal gel strength and texture.

2 Materials and Methods

2.1 Raw materials

Chicken breasts, chili sauce, tomato sauce, oyster sauce, honey, sugar, salt, and chili powder were purchased from supermarkets in Selangor, Malaysia. The chicken breasts were vacuum-packed and stored in a freezer at $-18\text{ }^{\circ}\text{C}$ until further use, while the other ingredients were kept in a dry place until needed.

2.2 Preparation of chicken marinades

The marinades pastes were prepared by homogenizing and mixing water, chili sauce, tomato sauce, oyster sauce, salt, sugar, honey, black pepper, and chili powder. The paste was then separated into six different beakers. Next, beakers were labelled F0, F0.2, F0.5, F0.8, F1.0 and F1.5 with addition of carrageenan with six different concentrations which are 0, 0.2, 0.5, 0.8, 1.0, and 1.5%, respectively. The paste in each beaker was homogenised with a mixer. The homogenised marinades were simmered for 5 minutes until butter melt. Then, the marinades were homogenised again using a mixer. Cleaned chicken breast was immersed and coated with each of the marinades. The marination process takes 24 hours and stored at $4\text{ }^{\circ}\text{C}$ [6].

Table 1. Formulations of chicken marinades with different percentage of carrageenan

Materials (g)	Formulation					
	F0	F0.2	F0.5	F0.8	F1.0	F1.5
Chili sauce	84	84	84	84	84	84
Tomato sauce	84	84	84	84	84	84
Oyster sauce	84	84	84	84	84	84
Honey	14.68	14.68	14.68	14.68	14.68	14.68
Sugar	16.44	16.44	16.44	16.44	16.44	16.44
Salt	5.64	5.64	5.64	5.64	5.64	5.64
Chili powder	4.33	4.33	4.33	4.33	4.33	4.33
Black pepper	7.24	7.24	7.24	7.24	7.24	7.24
Butter	42	42	42	42	42	42
Water	105	105	105	105	105	105
Carrageenan powder	0	0.89	2.24	3.58	4.47	6.71

2.3 Proximate analyses

The proximate analyses of chicken marinades samples were conducted on its moisture content, protein, fat and ash content. Moisture content was determined using AOAC Official Method 985.14 by setting the drying temperature to 200 °C and the samples were dried for 15 minutes. For protein content, Kjeldahl method was conducted using AOAC 981.10 and the total nitrogen was multiplied by a protein factor of 6.25. In addition, Soxhlet extraction method (AOAC 954.02) was used to determine the fat content by running the extraction of samples for 8 hours until the dried fat obtained. Moreover, ash content was determined by dry ashing (AOAC 942.05) at 550 °C to constant weight using a gravimetric method.

2.4 Water holding capacity (WHC)

At 4 °C, about 15 g of each chicken flesh sample were centrifuged for 40 minutes at 2330×g. Using the following equation, the WHC were determined as a percentage of bound water [5]

$$WHC (\%) = \frac{W_{ac}}{W_{ab}} \times 100\% \tag{1}$$

where W_{ac} is the weight of chicken sample after centrifugation and W_{ab} is the weight prior to centrifugation.

2.5 Cooking loss

Cooking loss of samples were determined using method by Yu et al. [5] with some modifications. Each sample were weighed twice which were before proceeding to heat treatment at 200 °C for 30 minutes in a convection oven and after cooling process to room temperature. The difference in weight of the samples was then determined as cooking loss.

2.6 Colour analysis

The colour of each sample in lightness (L^*), redness (a^*) and yellowness (b^*) was evaluated using Chromameter CR400 (Konica Minolta, Japan). The measurement of the samples was taken at the center and two edges of the samples [7].

2.7 pH analysis

pH of each sample was determined using dagger electrode fitted with a pH meter. The electrode was pierced into the sample piece. The open junction of electrode was ensured to be completely immersed into the sample piece for accurate reading [8].

2.8 Texture profile analysis (TPA)

Texture profile analysis was done using texture analyzer (TAXT2i SMS Stable Micro Systems, UK) based on method Nicomrat et al. [9] with some modifications. 25 kg load cell was applied at a crosshead speed of 2 mm/s. A compression plate of 50 × 38 mm was used. Each cooked sample was cut with a dimension of 3 cm × 3 cm. All samples were evaluated in terms of hardness, cohesiveness, adhesiveness, chewiness, springiness, resilience, and gumminess.

2.9 Viscosity

Viscosity of chicken marinades were analysed using a RVT viscometer (Brookfield, Massachusetts, USA), following the procedure described Bono et al. [10] with minor modifications. The measurements of samples were performed using spindle No. 6 at 10 rpm. The results were expressed in centipoises, cP.

2.10 Sensory analysis

Sensory analysis involving 30 panelists was conducted. A 9-point hedonic scale was assimilated to rate the samples in attributes of colour, appearance, aroma, taste, chewiness, juiciness and overall acceptability. 1 point indicates the lowest score and 9 points indicates the highest score. The samples were cut into slices with 2.0 cm thickness and placed on a white polystyrene plate. The plates were labelled with three-digit codes and presented in random order to the panelists for evaluation. The evaluation was done in a properly designed and lighted room [11].

2.11 Statistical analysis

All analysis was conducted in triplicates. The data obtained was presented as mean ± standard deviation. Statistical analysis of variance (ANOVA) was performed using the SPSS software package for Windows, version 25 (IBM SPSS Statistics Inc., USA). A one-way ANOVA followed by Tukey's post hoc test was used to determine significant differences at $p < 0.05$ [11].

3 Results and Discussions

3.1 Proximate analyses

Proximate analyses were performed to determine the moisture, protein, fat, and ash contents of the chicken marinades. As shown in Table 2, no significant differences ($p > 0.05$) were observed among the samples, indicating that carrageenan incorporation did not influence the moisture content of the chicken marinades.

In addition, no significant differences ($p > 0.05$) were observed in protein content among samples with carrageenan incorporation. This outcome is consistent with the findings of Nayak et al. [12] who similarly reported no significant changes in protein content upon the addition of carrageenan to chicken nuggets.

Regarding fat content as presented in Table 2, treatments F0.5 and F1.5 exhibited the highest values, at 2.30 ± 0.11 and $2.26 \pm 0.42\%$, respectively. These findings suggest that the incorporation of carrageenan into the marinades effectively minimized fat loss, thereby enhancing fat retention in the product. This observation is consistent with the results of Nayak and Pathak [13] who reported improved fat retention in chevon patties formulated with carrageenan.

Moreover, F0.8 and F1.0 formulations presented the highest values of ash content which are 6.06 ± 0.27 and $5.91 \pm 0.31\%$, respectively, as shown in Table 2. A similar trend was reported by Sumartini and Putri [14], who observed that carrageenan incorporation led to higher ash content in noodle products.

Table 2. Proximate analysis of chicken marinades with different percentage of carrageenan

Sample	Moisture (%)	Protein (%)	Fat (%)	Ash (%)
F0	64.79 ± 2.93	31.97 ± 0.12	$1.64^b \pm 0.17$	$5.37^{bc} \pm 0.91$
F0.2	65.14 ± 1.27	35.86 ± 0.24	$1.24^b \pm 0.09$	$4.81^d \pm 0.19$
F0.5	65.53 ± 0.93	35.89 ± 2.46	$2.30^a \pm 0.11$	$5.26^{cd} \pm 0.11$
F0.8	66.56 ± 3.54	32.44 ± 1.11	$1.58^b \pm 0.01$	$6.06^a \pm 0.27$
F1.0	66.46 ± 0.14	32.51 ± 1.85	$1.47^b \pm 0.16$	$5.91^a \pm 0.31$
F1.5	63.84 ± 1.53	35.63 ± 2.25	$2.26^a \pm 0.42$	$5.82^{ab} \pm 0.16$

Values are expressed in mean±standard deviation (n=3). Means within the same column followed by different superscript lowercase letters indicate significant differences at $p < 0.05$ according to Tukey’s multiple comparison test

3.2 Water holding capacity (WHC) and cooking loss

As shown in Table 3, present findings indicate no significant differences ($p > 0.05$) were observed in water holding capacity among samples which indicates that carrageenan has no effect in water holding capacity of chicken marinades.

In contrast, the F1.5 formulation demonstrated the lowest cooking loss among all treatments, with values reduced from 34.51 ± 4.37 to $25.39 \pm 5.29\%$ following the incorporation of 1.5% carrageenan. A comparable trend was observed by Lin et al. [15], who reported that carrageenan inclusion in frankfurter formulations significantly diminished

cooking loss, decreasing from 6.87% to 3.51%. Together, these findings reinforce the functional role of carrageenan in minimizing moisture and fat loss during thermal processing.

Table 3. WHC and cooking loss of chicken marinades with different percentage of carrageenan

Sample	WHC (%)	Cooking loss (%)
F0	91.33 ± 3.52	34.51 ^{ab} ± 4.37
F0.2	89.29 ± 2.05	38.95 ^a ± 5.80
F0.5	89.90 ± 1.91	31.07 ^{abc} ± 3.81
F0.8	90.06 ± 2.81	35.81 ^{ab} ± 2.60
F1.0	91.63 ± 9.21	29.17 ^{bc} ± 1.84
F1.5	94.44 ± 2.39	25.39 ^c ± 5.29

Values are expressed in mean±standard deviation (n=3). Means within the same column followed by different superscript lowercase letters indicate significant differences at $p < 0.05$ according to Tukey's multiple comparison test

3.3 Colour and pH analysis

Table 4 summarizes the colour parameters (L^* , a^* and b^*) of marinated chicken breast prepared with varying levels of carrageenan. An overall trend was observed in which higher carrageenan concentrations produced a darker appearance in the marinated samples. The lowest L^* value ($p < 0.05$) was recorded in F1.0. In addition, F0.5 exhibits the highest a^* value ($p < 0.05$), redness while F1.0 shows the lowest b^* value ($p < 0.05$), blueness. Similarly, He and Wang [7] observed that carrageenan coated samples exhibited bright red colour during refrigerated storage.

The pH value of marinated chicken breasts incorporated with 1.5% carrageenan shows the highest value and significantly differ ($p < 0.05$) from the rest of samples whereas the sample control has the lowest value of pH ($p < 0.05$). This finding aligns with Kim et al. [8], that incorporation of hydrocolloids led to an elevation in the pH of meat products, resulting in final pH values ranging from 6.43 to 6.88.

Table 4. Colour and pH analysis of chicken marinades with different percentage of carrageenan

Sample	Colour			pH
	L*	a*	b*	
F0	63.53 ^a ± 0.03	12.03 ^{ab} ± 0.07	32.15 ^a ± 0.07	5.32 ^e ± 0.10
F0.2	62.9 ^a ± 0.79	11.69 ^b ± 0.29	32.56 ^a ± 0.95	5.87 ^d ± 0.04
F0.5	56.66 ^c ± 1.23	13.85 ^b ± 1.09	32.28 ^a ± 2.71	5.91 ^{cd} ± 0.01
F0.8	48.56 ^d ± 0.44	11.26 ^b ± 2.36	22.67 ^b ± 2.55	6.11 ^b ± 0.09
F1.0	44.86 ^e ± 0.02	11.87 ^{ab} ± 0.07	19.61 ^c ± 0.03	6.02 ^{bc} ± 0.05
F1.5	59.76 ^b ± 0.82	12.16 ^{ab} ± 0.37	31.48 ^a ± 0.12	6.31 ^a ± 0.08

Values are expressed in mean±standard deviation (n=3). Means within the same column followed by different superscript lowercase letters indicate significant differences at $p < 0.05$ according to Tukey’s multiple comparison test

3.4 Texture Profile analysis (TPA)

Texture profile analysis of marinated chicken breast are shown in Table 5. The hardness of F1.5 is significantly increased ($p < 0.05$) as compared to F0. This results is aligned with Nicomrat et al. [9] who reported that addition of 1.5% carrageenan has the highest hardness value. In addition, there are no significant differences ($p > 0.05$) observed in springiness among samples. Moreover, cohesiveness, gumminess and chewiness followed a similar pattern, with values increasing from F0 to F0.8, and subsequently declining in F1.0 and F1.5. The reduction observed at higher carrageenan levels may be attributed to excessive concentrations promoting over-crosslinking or polysaccharide aggregation, which in turn disrupts the uniformity of the structural network [3]. Resilience also differed significantly ($p < 0.05$) between F1.5 and F0, indicating an improvement with the addition of carrageenan. Similar findings reported by Yu et al. [5], whereas resilience of surimi product is higher when incorporated with carrageenan as compared to control sample. In general, carrageenan incorporated with chicken marinades has improved in textural properties.

Table 5. TPA of chicken marinades with different percentage of carrageenan

Parameter	Sample					
	F0	F0.2	F0.5	F0.8	F1.0	F1.5
Hardness (g)	5160.48 ^{ab} ± 128.24	5880.24 ^a ± 1313.70	3843.93 ^{bc} ± 665.57	2548.57 ^c ± 555.28	4927.87 ^{ab} ± 152.09	5820.72 ^a ± 24.84
Springiness (%)	0.65 ^a ± 0.02	0.57 ^a ± 0.08	0.60 ^a ± 0.06	0.67 ^a ± 0.09	0.60 ^a ± 0.07	0.56 ^a ± 0.04
Cohesiveness	0.47 ^c ± 0.02	0.54 ^{bc} ± 0.03	0.53 ^{bc} ± 0.01	0.65 ^a ± 0.02	0.59 ^{ab} ± 0.00	0.56 ^b ± 0.04
Gumminess (g)	2474.41 ^{cd} ± 181.17	3179.41 ^{bc} ± 484.14	1860.58 ^d ± 572.07	4365.67 ^a ± 159.13	3701.66 ^{ab} ± 742.58	2706.12 ^{bcd} ± 128.77
Chewiness (g)	1611.48 ^{ab} ± 178.65	1844.03 ^{ab} ± 548.58	2107.33 ^{ab} ± 1073.28	2965.73 ^a ± 538.07	2344.44 ^{ab} ± 12.16	1522.12 ^b ± 89.37
Resilience	0.19 ^b ± 0.01	0.22 ^{ab} ± 0.01	0.23 ^{ab} ± 0.02	0.26 ^a ± 0.04	0.27 ^a ± 0.01	0.21 ^{ab} ± 0.02

Values are expressed in mean±standard deviation (n=3). Means within the same row followed by different superscript lowercase letters indicate significant differences at $p < 0.05$ according to Tukey's multiple comparison test

3.5 Viscosity

The viscosity of the marinades exhibited a progressive increase, with significant differences ($p < 0.05$) observed among formulations as the concentration of carrageenan increased, as presented in Table 6. The present findings support the established use of carrageenan in sauces and marinades, where its viscosity-enhancing properties contribute to improved product functionality [4]. The progressive increase in marinade viscosity observed with higher carrageenan concentrations reflects this characteristic, suggesting that carrageenan effectively modifies flow behaviour to achieve desirable coating and retention properties in the marinated chicken.

Table 6. Viscosity of chicken marinades with different percentage of carrageenan

Sample	Viscosity (cP)
F0	6849.67 ^f ± 16.50
F0.2	9083.00 ^e ± 17.00
F0.5	9199.67 ^d ± 16.50
F0.8	10430.00 ^c ± 20.00
F1.0	12730.00 ^b ± 20.00
F1.5	13746.67 ^a ± 41.63

Values are expressed in mean±standard deviation (n=3). Means within the same column followed by different superscript lowercase letters indicate significant differences at $p < 0.05$ according to Tukey's multiple comparison test

3.6 Sensory Analysis

Sensory evaluation was conducted by 30 panellists to analyse marinated chicken breasts in attributes of colour, appearance, aroma, taste, chewiness, juiciness and overall acceptability. As tabulated in Table 7, F1.0 has the highest score ($p < 0.05$) in attributes of colour, appearance, aroma, taste and chewiness. It can be concluded that panellists preferred marinated chicken breast with darker colour as presented in Table 4. In terms of juiciness, F1.5 exhibited the highest score ($p < 0.05$) which is 6.94 ± 1.41 . There are no significant differences ($p > 0.05$) were observed among formulations F0.5 to F1.5, indicating that the panellists were unable to perceive variations associated with different levels of carrageenan incorporation. However, panellists preferred samples that incorporated with carrageenan as compared to control sample. Overall, the mean scores for all sensory attributes exceeded the threshold for acceptability, with values above 6 across all samples and attributes [11].

Table 7. Sensory analysis of marinated chicken breasts with different percentage of carrageenan

Attributes	Sample					
	F0	F0.2	F0.5	F0.8	F1.0	F1.5
Colour	6.25 ^c ± 1.81	6.59 ^{bc} ± 1.66	7.38 ^{ab} ± 1.40	7.19 ^{ab} ± 1.57	7.75 ^a ± 1.27	7.13 ^{ab} ± 1.23
Appearance	6.59 ^b ± 1.54	6.84 ^{ab} ± 1.39	7.31 ^{ab} ± 1.37	7.31 ^{ab} ± 1.33	7.56 ^a ± 1.31	7.06 ^{ab} ± 1.19
Aroma	6.16 ^c ± 1.66	6.19 ^c ± 1.51	7.63 ^a ± 1.15	6.50 ^{bc} ± 1.84	7.31 ^a ± 1.59	7.16 ^{ab} ± 1.22
Taste	6.50 ^{bc} ± 2.20	6.13 ^c ± 1.93	7.38 ^a ± 1.64	7.81 ^a ± 1.14	7.50 ^a ± 1.36	7.16 ^{ab} ± 1.11
Chewiness	6.59 ^{ab} ± 1.43	6.31 ^b ± 1.30	7.00 ^{ab} ± 1.70	7.16 ^a ± 1.22	7.13 ^a ± 1.51	7.13 ^a ± 1.51
Juiciness	5.84 ^{bc} ± 1.93	5.41 ^c ± 2.13	6.34 ^{abc} ± 2.17	6.69 ^{ab} ± 1.28	6.22 ^{abc} ± 1.79	6.94 ^a ± 1.41
Overall acceptability	6.34 ^b ± 1.92	6.06 ^b ± 1.90	7.19 ^a ± 1.83	7.34 ^a ± 1.28	7.38 ^a ± 1.31	7.47 ^a ± 1.07

Values are expressed in mean±standard deviation (n=3). Means within the same row followed by different superscript lowercase letters indicate significant differences at $p < 0.05$ according to Tukey’s multiple comparison test

4 Conclusions

In conclusion, the present study revealed that carrageenan incorporation affects the physicochemical and sensory attributes of marinated chicken breasts. The addition of carrageenan enhanced fat retention, contributed to elevated ash content through its inherent mineral composition, and markedly improved textural characteristics. Progressive increases in carrageenan concentration were associated with higher pH and viscosity, while cooking loss was effectively reduced owing to improved water-holding capacity during thermal processing. Sensory evaluation further confirmed that marinated samples enriched with carrageenan were more favourably perceived by panellists compared to the control, underscoring its potential as a functional ingredient in meat product formulation.

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