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Effects of Carrageenan and Isolated Soy Protein Addition on the Physicochemical and Sensory Properties of Chicken Sausages

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Abstract

The global demand for healthier meat products has increased due to consumer concerns over synthetic additives and interest in functional ingredients. This study investigated the effects of carrageenan and isolated soy protein (ISP) on the physicochemical and sensory properties of chicken sausages. Sausages were formulated with either 2% or 4% carrageenan or ISP and evaluated for moisture content, water activity (a_w), water holding capacity (WHC), pH, color (L*, a*, b*), and sensory attributes (taste, aroma, texture, overall acceptability). Results indicated no significant differences in moisture content, a_w, WHC, or color among treatments. However, the addition of 4% carrageenan significantly increased the pH. Sensory evaluation showed that while carrageenan treatments maintained favorable sensory scores, a high concentration of ISP (4%) resulted in a significantly lower texture and acceptability score. These findings suggest that carrageenan is a more suitable natural additive than ISP for improving certain quality characteristics of chicken sausages without compromising consumer preferences.

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Introduction

Nowadays, the global demand for meat and meat products has increased significantly due to its benefits to the human body as a primary source of protein and essential amino acids. A major goal of the meat industry in recent years has been to develop healthier meat products, since most consumers have been aware of the benefits of consuming healthier food (Ahmad et al., 2010a). Accordingly, there is an increasing demand for substituting synthetic additives with functional compounds that are perceived as safer and more consumer-friendly. Adding functional ingredients to substitute synthetic additives is perceived to be more consumer-friendly and healthy.

Carrageenan and isolated soy protein (ISP) have emerged as promising alternatives. Carrageenan is a natural polysaccharide derived from red seaweed, such as the *Chondrus crispus* species of seaweed (*Rhodophyceae*) (Udo et al., 2023) which is known for its ability to improve water-holding capacity, enhance texture, and increase the yield of meat products. While Isolate soy protein (ISP) is a plant-based protein and known for its ability as emulsifier, and is often used to improve the structure and nutritional profile of meat products like sausages (Serdaroğlu et al., 2005). These natural additives could be used together to enhance the physical and sensory qualities of sausages. Carrageenan improves water and fat retention in sausages, maintaining the juiciness and texture of the sausages (Xue-qin Gao et al., 2015; Çelebi and Erge, 2024). It can increase the hardness of sausages, which can negatively impact sensory acceptance if used in high amounts (Çelebi and Erge, 2024). In addition, it enhances emulsion stability and contributes to better textural properties (Arora et al., 2017). ISP and carrageenan improve emulsion stability, which is crucial for the uniform distribution of fat and water within the sausage (Xue-qin Gao et al., 2015; Çelebi and Erge, 2024).

Research conducted by Akesowan (2008) revealed that the addition of ISPin pork sausage improved the sensory quality, specifically juiciness and firmness. Furthermore, the addition of carrageenan at low levels, 0.2% and 0.5%, increased the gel elasticity of turkey meat sausage (Ayadi et al., 2009) Therefore, this study aims to explore the effects of carrageenan and ISP on the physicochemical quality of chicken sausage.

Materials and Methods

Materials

Chicken meat was obtained from a traditional market in Tembalang, salt, sugar, tapioca flour, nutmeg powder, garlic, carragenan, isolate soy protein (ISP), baking powder, egg white, cooking oil, pepper, flavor enhancer, coconut milk, skim milk, and cold water.

Preparation of sausage

Ground chicken meat was mixed with salt (2.5 g) and sugar (2 g) until the mixture became fibrous and sticky. Tapioca flour (36 g), nutmeg powder (1.5 g), garlic (4.5 g), carrageenan (2% or 4%) or isolated soy protein/ISP (2% or 4%), baking powder (1.2 g), egg white (20 g), cooking oil (1 tablespoon), pepper (1.5 g), flavor enhancer (4.5 g), coconut milk (40 ml), skim milk (20 g), and cold water (30 ml) were then added and thoroughly mixed until a homogeneous dough was formed. The dough was filled into casings by pressing to eliminate air pockets. Each sausage was shaped into approximately 6 cm in length and tied. The sausages were then cooked by boiling or steaming for 15 minutes, followed by draining.

Moisturecontent

A 3 gram portion of the sample was dried in a hot air oven at 102°C for 24 hours until a constant weight was achieved. Moisture content was determined based on the difference between the initial weight and the final (dry) weight of the sample (AOAC, 2005).

$$Moisture\ content\ (\%) = \frac{(W1 - W2)}{W1} \times 100\%$$

W1 : weight (g) of sample before drying
W2 : weight (g) of sample after drying

pH determination

The sample was weighed (3 g) and homogenized in 20 mL of distilled water. The mixture was allowed to stand briefly to ensure uniform dispersion. The pH was measured using a pH meter (Bakhsh et al., 2021).

Water Holding Capacity (WHC) determination

A 5 gram portion of the sample was centrifuged at 4000 rcf for 30 minutes at 4°C. Water holding capacity (WHC) was calculated as the percentage of retained water using the following equation (Ayadi et al., 2009):

$$WHC\ (\%) = \frac{W_{ac}}{W_{bc}} \times 100\%$$

Notes:
W_{ac} : sample weight after centrifugation
W_{bc} : sample weight before centrifugation

Water Activity (a_w) determination

The water activity (a_w) was determined using an a_w-meter after the sample was ground to a homogeneous consistency using a mortar

Color determination

Color analysis was conducted using a digital colorimeter. The values for lightness (L*), redness (a*), and yellowness (b*) were recorded. Three independent measurements were taken at random locations on the surface of each sample to ensure accuracy and representativeness.

Organoleptic test

A sensory evaluation was conducted to assess taste, aroma, texture, and overall acceptability of the samples. The evaluation involved five treatments: S0 (control), S1 (2% carrageenan), S2 (4% carrageenan), S3 (2% ISP), and S4 (4% ISP). Panelists evaluated each attribute using a 4-point scale. Taste was evaluated on a four-point scale ranging from 1 (not savory) to 4 (very savory). Aroma was assessed from 1 (no meat-like aroma) to 4 (intense meat-like aroma). Texture was rated based on tenderness, with scores ranging from 1 (not tender) to 4 (very tender). Overall acceptability was scored from 1 (dislike very much) to 4 (like very much).

Data Analysis

The data were first tested for normality and homogeneity of variance using the Shapiro–Wilk test and Levene's test, respectively. If the data were normally distributed and exhibited homogeneity of variances ($p > 0.05$), a one-way Analysis of Variance (ANOVA) was conducted, followed by Duncan's multiple range test for post hoc comparisons. Conversely, if the data did not meet the assumptions of normality or homogeneity ($p < 0.05$), the non-parametric Kruskal–Wallis test was applied. When significant differences were found ($p < 0.05$), Dunn's test was used for pairwise comparisons. All statistical analyses were performed using IBM SPSS Statistics version 25.

Results and Discussion

The physicochemical characteristics of the chicken sausage, including moisture content, water activity (a_w), and water holding capacity (WHC) in Table 1. It showed no statistically significant differences across treatments ($P > 0.05$). The moisture content ranged from 57.97% to 60.99%. The control had the highest value of moisture content, while sausage with ISP 4% (S4) showed the lowest value. According to the Standar Nasional Indonesia, meat sausages should contain no more than 67% moisture (SNI, 2015). The moisture

Table 1. Physicochemical characteristics of chicken sausage with the addition of carrageenan and isolate soy protein (ISP)

Sample	Moisture	a_w	WHC	pH
S0	60.99 ± 7.14^{a}	0.81 ± 0.05^{a}	93.79 ± 3.56^{a}	7.37 ± 0.27^{a}
S1	59.18 ± 2.14^{a}	0.81 ± 0.05^{a}	93.39 ± 2.38^{a}	7.45 ± 0.26^{ab}
S2	59.01 ± 2.37^{a}	0.80 ± 0.05^{a}	93.58 ± 3.40^{a}	7.70 ± 0.20^{b}
S3	58.52 ± 0.97^{a}	0.80 ± 0.04^{a}	92.64 ± 3.47^{a}	7.32 ± 0.25^{a}
S4	57.97 ± 1.29^{a}	0.80 ± 0.05^{a}	94.49 ± 1.91^{a}	7.37 ± 0.23^{a}

*S0: control, S1: 2% carrageenan, S2: 4% carrageenan, S3: 2% ISP, S4: 4% ISP contents observed in this study were all below this threshold, indicating that the products meet the national quality requirements for meat sausages. The slight decrease in moisture in treated samples compared to the control (S0) may be attributed to the interaction between the additive ingredients and the meat matrix, potentially enhancing water-binding capacity and reducing free water. Comparable results were reported by Ahmad et al. (2010b), moisture content of buffalo meat emulsion sausage with ISP exhibited lower value than controls. However, regarding the addition of carrageenan, the result of this study differed from the study conducted by Moon (2008), sausages with carrageenan showed higher moisture content compared to controls.

Table 2. Color values (L, a, b*) of chicken sausage with the addition of carrageenan and isolate soy protein (ISP)

Sample	L*ns	a*ns	b*ns
S0	18.14 ± 4.87	0.99 ± 0.49	3.56 ± 1.85
S1	19.07 ± 4.90	1.20 ± 0.40	3.96 ± 1.28
S2	17.52 ± 4.92	1.19 ± 0.52	3.53 ± 1.84
S3	17.66 ± 3.93	1.08 ± 0.44	3.48 ± 1.32
S4	16.87 ± 2.79	1.09 ± 0.35	3.42 ± 0.90

*S0: control, S1: 2% carrageenan, S2: 4% carrageenan, S3: 2% ISP, S4: 4% ISP

The water activity of chicken sausage with all treatments is shown in Table 1. The study indicated no significant difference in water activity between control and treated samples. Water activity of the study ranged from 0.80 to 0.81. The addition of carrageenan and ISP did not result in an improvement in water activity due to their role in improving texture and emulsion stability rather than directly influencing moisture retention or water activity. This result agrees with Sha et al. (2020), the addition of isolated soy protein (ISP) 5% in fermented sausage did not effectively change the water migration. Another study was conducted by Velemir et al. (2020), the addition of ISP (0.5% and 1.5%) did not significantly affect the water activity (a_w). Another study on emulsified sausage with carrageenan also did not report significant changes in water activity (Soto and Güémes-Vera, 2016)

Table 1 shows the WHC of the chicken sausage samples obtained from all treatments. It was found that there was no significant difference in WHC among samples (p>0.05). The result of the addition of carrageenan and SPI in chicken sausage ranged from 92.64 to 94.49. The result of our study was in agreement with the study of (Barbut, 1992; Foegeding, 1987),the addition of carrageenan has no or a very limited effect on the water holding capacity of meat gel products. The effect of carrageenan on WHC can vary depending on the concentration and processing conditions. For example, in restructured pork meat, carrageenan with the concentration of more than 1.5% did not show a direct effect on WHC (Hong et al., 2008). In the study of duck meat sausages, the addition of SPI did not have a significant impact on WHC compared to the control. In contrast, a study conducted by Y. Li et al. (2021), the addition of ISP 2% enhanced the water holding capacity of meat.

The result of pH of the sample can be observed in Table 1. The results indicated that the addition of 4% carrageenan to the chicken sausage led to a significant difference in pH value compared to the control and ISP treated samples. The increase in pH in meat treated with carrageenan is due to its ability to bind small ions such as H^+, thereby reducing the concentration of free hydrogen ions in the system. Additionally, electrostatic interactions between the negatively charged carrageenan and meat proteins affect ion distribution, contributing to the rise in pH (Xue qin Gao et al., 2015). While the addition of ISP in chicken sausage had no significant difference in pH value.

Table 2 shows the result of color in chicken sausage treated with carrageenan or ISP. Overall, there is no significant difference found in all color parameter values (L*, a*, and b*) among samples. This might be due to carrageenan and ISP, which primarily function as water-binding and texturizing agents and are relatively inert in terms of color, as it does not participate in pigment interactions or contribute visually perceptible hues to the meat matrix (Moon, 2008; Xue qin Gao et al., 2015; Majzoobi et al., 2017). The result of this study is supported by Gao et al. (2015), who explained that the addition of carrageenan or ISP or the mixture of carrageenan and ISP had no significant difference in L* and b*, but showed an increase in *a** value on ground pork patties. Therefore, under the experimental conditions applied in this study, neither carrageenan nor ISP significantly affected the lightness, redness, or yellowness of the chicken sausage.

The sensory evaluation results are shown in Table 3. It indicated that the addition of carrageenan or ISP at varying concentrations influenced panelists' perceptions of chicken sausage quality. In terms of taste, sample S2 (4% carrageenan) received the highest mean score (3.00 ± 0.68), however, it was not significantly different from S0 (control) and S1 (2% carrageenan). The finding aligns with previous research indicating that carrageenan addition had no significant impact on the taste of turkey meat sausages (Ayadi et al., 2009).. Conversely, sample S4 (4% ISP) was significantly different from S2 (4% carrageenan), it showed the lowest taste score (2.62 ± 0.82), indicating that excessive levels of ISP may negatively impact taste. This may be attributed to beany flavor in high concentration of SPI

Table 3. Sensory quality of chicken sausage with the addition of carrageenan and isolate soy protein (ISP)

Sample	Taste	Aroma	Texture	Overall acceptability
S0	2.92 ± 0.54^{ab}	2.83 ± 0.76^{a}	2.52 ± 0.59^{b}	2.78 ± 0.74^{b}
S1	2.74 ± 0.67^{ab}	2.48 ± 0.79^{b}	2.78 ± 0.60^{b}	2.80 ± 0.77^{b}
S2	3.00 ± 0.68^{a}	2.65 ± 0.74^{ab}	2.49 ± 0.77^{b}	2.69 ± 0.77^{b}
S3	2.74 ± 0.83^{ab}	2.54 ± 0.79^{ab}	2.45 ± 0.88^{b}	2.74 ± 0.85^{b}
S4	2.62 ± 0.82^{b}	2.34 ± 0.89^{b}	1.94 ± 0.85^{a}	2.20 ± 0.83^{a}

*S0: control, S1: 2% carrageenan, S2: 4% carrageenan, S3: 2% ISP, S4: 4% ISP treated product. The beany flavor, a common off-flavor in SPI, can be particularly noticeable and undesirable in meat products (J. Li et al., 2024)

For aroma, the control group (S0) achieved the highest score (2.83 ± 0.76), while the lowest value was recorded in S4 (2% ISP) (2.34 ± 0.89). The result showed a significant difference (p < 0.05) between S0 and S1–S4, where higher concentrations of ISP may slightly reduce aroma desirability, possibly due to the interaction of ISP with volatile compounds. Additionally, the presence of ISP could have contributed to a less favorable mouthfeel or aftertaste that subtly influenced panelists' perception of aroma. This phenomenon was supported by a study conducted by Homco-Ryan (2004), which reported that the addition of SPI increased the grain-like odor and reduced the pork odor intensity in emulsified meat products. Furthermore, SPI has also been reported to produce volatile off-flavor compounds during storage in meat products (Nagassa et al., 2025)

A significant difference was observed in the texture attribute, where S4 (2% ISP) scored significantly lower (1.94 ± 0.85) compared to all other treatments. This might be due to high concentration of ISP led to a dense or rubbery texture due to over-gelation. This is consistent with the study of (Danowska-Oziewicz, 2014), who reported that a high level of ISP can lead to increased hardness and cohesiveness, resulting in a dense or rubbery texture. The gelation process of ISP involves the formation of protein aggregates and networks, which can become overly dense if the concentration is too high (Choi et al., 2025)

Regarding overall acceptability, S4 (2% ISP) was rated the lowest (2.20 ± 0.83), significantly different from the control (S0) and carrageenan groups, reflecting the cumulative negative impact of high ISP concentration on multiple sensory dimensions. This might be due to ISP introducing a beany or off-flavor that detracts from the overall taste of the sausage (Rentfrow et al., 2004). This is a critical factor in consumer acceptability, as flavor is a primary driver of preference. Meanwhile, the control and carrageenan treatments (S0–S2) showed no significant differences in overall liking, which means that carrageenan addition up to 4% is acceptable for consumer preference.

Conclusion

This study reported that carrageenan and isolated soy protein (ISP) can be incorporated into chicken sausage formulations without significantly altering most physicochemical properties, including moisture content, water activity, WHC, and color. The addition of 4% carrageenan increased pH significantly, likely due to its ion-binding capacity. From a sensory perspective, carrageenan-treated sausages retained acceptable taste, aroma, texture, and overall liking, indicating consumer suitability. Conversely, sausages containing 4% ISP exhibited a decline in texture and overall acceptability, suggesting that high ISP levels may negatively impact sensory characteristics. Therefore, carrageenan can be used as a more promising natural additive for improving the quality and consumer appeal of chicken sausages.

References

Ahmad, S., Rizawi, J.A., Srivastava, P.K. 2010. Effect of soy protein isolate incorporation on quality characteristics and shelf-life of buffalo meat emulsion sausage. Journal of Food Science and Technology 47(3): 290–294. DOI:10.1007/s13197-010-0045-x.

Ahmad, S., Rizawi, J.A., Srivastava, P.K. 2010. Effect of soy protein isolate incorporation on quality characteristics and shelf-life of buffalo meat emulsion sausage. Journal of Food Science and Technology 47(3): 290–294. DOI:10.1007/s13197-010-0045-x.

Akesowan, A. 2008. Effect of soy protein isolate on quality of light pork sausages containing konjac flour. African Journal of Biotechnology 7(24): 4586–4590. Retrieved from http://www.academicjournals.org/AJB

AOAC. 2005. Official methods of analysis of AOAC International (18th ed.). Maryland: AOAC.

Arora, B., Kamal, S., Sharma, V.P. 2017. Effect of Binding Agents on Quality Characteristics of Mushroom Based Sausage Analogue. Journal of Food Processing and Preservation 41(5): e13134. DOI:10.1111/jfpp.13134.

Ayadi, M.A., Kechaou, A., Makni, I., Attia, H. 2009. Influence of carrageenan addition on turkey meat sausages properties. Journal of Food Engineering 93(3): 278–283. DOI:10.1016/j.jfoodeng.2009.01.033.

Bakhsh, A., Lee, S.-J., Lee, E.-Y., Hwang, Y.-H., Joo, S.-T. 2021. Evaluation of Rheological and Sensory Characteristics of Plant-Based Meat Analog with Comparison to Beef and Pork. Food Science of Animal Resources 41(6): 983–996. DOI:10.5851/kosfa.2021.e50.

Barbut, S., M.G.S. 1992. Use of carrageenans and xanthan gum in reduced fat breakfast sausages. LWT-Food Science and Technologies 25(6): 509–513.

Çelebi, U., Erge, A. 2024. An approach to produce healthier meat products: effect of k-carrageenan and inulin on quality characteristics of bologna-type chicken sausages. International Journal of Gastronomy and Food Science 36 100907. DOI:10.1016/j.ijgfs.2024.100907.

Choi, H.W., Hahn, J., Kim, H.-S., Choi, Y.J. 2025. Microstructural and textural characteristics of blend gels and high-moisture meat analogs of soy protein isolate and faba bean protein concentrate. Food Chemistry 467 142184. DOI:10.1016/j.foodchem.2024.142184.

Danowska-Oziewicz, M. 2014. Effect of Soy Protein Isolate on Physicochemical Properties, Lipid Oxidation and Sensory Quality of Low-Fat Pork Patties Stored in Vacuum, MAP and Frozen State. Journal of Food Processing and Preservation 38(2): 641–654. DOI:10.1111/jfpp.12014.

Foegeding, E.A., R.S.R. 1987. Rheological and water holding properties of gelled meat batters containing iota carrageenan, j-carrageenan or xanthan gum. Journal of Food Science 52(3): 549–553.

Gao, Xue qin, Zhang, W. gang, Zhou, G. hong. 2015. Emulsion stability, thermo-rheology and quality characteristics of ground pork patties prepared with soy protein isolate and carrageenan. Journal of the Science of Food and Agriculture 95(14): 2832–2837. John Wiley and Sons Ltd. DOI:10.1002/jsfa.7023.

Gao, Xue-qin, Zhang, W., Zhou, G. 2015. Emulsion stability, thermo-rheology and quality characteristics of ground pork patties prepared with soy protein isolate and carrageenan. Journal of the Science of Food and Agriculture 95(14): 2832–2837. DOI:10.1002/jsfa.7023.

Homco-Ryan, C. 2004. Effects of modified corn gluten meal on quality characteristics of a model emulsified meat product. Meat Science 67(2): 335–341. DOI:10.1016/j.meatsci.2003.10.021.

Hong, G., Min, S., Ko, S., Choi, M. 2008. Effect of high pressure treatments combined with various levels of κ-carrageenan on cold-set binding in restructured pork. International Journal of Food Science & Technology 43(8): 1484–1491. DOI:10.1111/j.1365-2621.2008.01718.x.

Li, J., Shen, Q., Albahi, A., Liang, H., Li, J., Li, B. 2024. Chitosan mitigates the beany flavor and improves the functional properties of soy protein isolate via the electrostatic interaction. Food Hydrocolloids 155 110164. DOI:10.1016/j.foodhyd.2024.110164.

Li, Y., Kang, Z., Sukmanov, V., Ma, H. 2021. Effects of soy protein isolate on gel properties and water holding capacity of low-salt pork myofibrillar protein under high pressure processing. Meat Science 176 108471. DOI:10.1016/j.meatsci.2021.108471.

Majzoobi, M., Talebanfar, S., Eskandari, M.H., Farahnaky, A. 2017. Improving the quality of meat-free sausages using κ-carrageenan, konjac mannan and xanthan gum. International Journal of Food Science and Technology 52(5): 1269–1275. Blackwell Publishing Ltd. DOI:10.1111/ijfs.13394.

Moon, S.-S., J.S.-K., H.K.-H., & K.I.-S. 2008. Effects of replacing backfat with fat replacers and olive oil on the quality characteristics and lipid oxidation of low-fat sausage during storage. Food Science and Biotechnology 17(2): 396–401.

Nagassa, M., He, S., Liu, S., Luo, S., Li, X., Wu, Z., Song, J., Jiang, S., Sun, H. 2025. The development of volatile off-flavor compounds in soy protein isolates and plant meat during storage. Food Chemistry 481 144025. DOI:10.1016/j.foodchem.2025.144025.

Rentfrow, G., Brewer, M.S., Weingartner, K.E., Mckeith, F.K. 2004. Sensory Characteristics of Beef and Pork Processed Meats Containing Nonsolvent Extracted Texturized Soy Protein. Journal of Muscle Foods 15(4): 225–234. DOI:10.1111/j.1745-4573.2004.06303.x.

Serdaroğlu, M., Yıldız-Turp, G., Abrodímov, K. 2005. Quality of low-fat meatballs containing Legume flours as extenders. Meat Science 70(1): 99–105. DOI:10.1016/j.meatsci.2004.12.015.

Sha, L., Liu, S., Liu, D. 2020. Effects of soybean protein isolate on protein structure, batter rheology, and water migration in emulsified sausage. Journal of Food Processing and Preservation 44(9):. DOI:10.1111/jfpp.14711.

SNI. 2015. Sosis daging. Retrieved from www.bsn.go.id

Soto, S., Güémes-Vera, N. 2016. Effect of fat, add water, carragennan and phosphates on carp (Cyprinus carpio) meat emulsioned product. Agrociencia 4(50):. Retrieved from https://www.researchgate.net/publication/305701929

Udo, T., Mummaleti, G., Mohan, A., Singh, R.K., Kong, F. 2023. Current and emerging applications of carrageenan in the food industry. Food Research International 173 113369. DOI:10.1016/j.foodres.2023.113369.

Velemir, A., Mandić, S., Vučić, G., Savanović, D. 2020. Effects of non-meat proteins on the quality of fermented sausages. Foods and Raw Materials 8(2): 259–267. DOI:10.21603/2308-4057-2020-2-259-267.