AgriHealth
Journal of Agri-food, Nutrition and Public Health
ISSN 2722-0656 (Print) 2722-0648 (Online)

AgriHealth: Journal of Agri-food, Nutrition and Public Health. 5(1), 76-84, 2024
URL: https://jurnal.uns.ac.id/agrihealth/article/view/85331
DOI: http://dx.doi.org/10.20961/agrihealth.v5i1.85331

Physical, Chemical, and Sensory Characteristics of Star Fruit (*Averrhoa carambola* L.) Jelly Candy with Various Concentrations of Carrageenan-Konjac and Carrageenan-Pectin

Bara Yudhistira[1]*, Siti Rahma Hamidah[1] and Fuangfah Punthi[2]

[1]Department of Food Science and Technology, Faculty of Agriculture, Universitas Sebelas Maret, Surakarta, Indonesia; [2]Department of Food Science and Biotechnology, National Chung Hsing University, Taichung, Taiwan

Received: March 14, 2024; **Accepted**: May 7, 2024

Abstract

Star fruit, a widely consumed fruit in Indonesia, is utilized in jelly sweets as a functional food promoting health. Nevertheless, the exorbitant price of gelatin, a gelling agent compatible with halal requirements, has resulted in the substitution of carrageenan, a comparable substance with a fragile consistency. This study investigated the physical, chemical, and sensory properties of star fruit jelly candy using different concentrations of gelling agents. This study employed a fully randomized design to investigate the effects of various concentrations and types of gelling agents, namely carrageenan-konjac and carrageenan-pectin, at concentrations of 1.5%, 2.0%, and 2.5%, respectively. The findings indicate that various gelling agents impact the characteristics of hardness, gumminess, chewiness, water content, antioxidants, and pH. Different amounts of gelling agents impact the firmness, stickiness, texture, separation of liquid, moisture level, mineral content, acidity, moisture availability, and crude fiber content. The variations in outcomes of this study are determined by the hydrocolloid's water content, which can bind water. Subsequently, the duration of processing and the level of temperature exert an influence on these parameters, hence impacting the physical qualities. The findings indicate that the combination of carrageenan and konjac substantially affects star fruit jelly candy's physical and chemical characteristics. The optimal formula for creating star fruit jelly candy is to employ a 2.5% concentration of carrageenan-konjac.

Keywords: carrageenan; jelly candy; konjac; pectin; star fruit

INTRODUCTION

Starfruit is a plant that is commonly found growing freely in Indonesia. Data on star fruit production in 2021 to 2022 shows an average production amount of 128,632 to 137,450 tons (Statistics Indonesia, 2024). The abundance of star fruit is due to its high productivity, which produces about 150 kg of fruit per tree per season and can flower and bear fruit throughout the year. Star fruit contains antioxidants (around 70% of the total antioxidant activity) and fiber (approximately 13% of pectin, 27% of hemicelluloses, and 60% of cellulose), which are suitable for the digestive process (Lakmal et al., 2021). Star fruit has a sweet taste with a bit of sourness and contains lots of water.

Furthermore, star fruit, which is widely produced in Indonesia, has not been appropriately utilized because generally, people only use this

* **Corresponding author**: barayudhistira@staff.uns.ac.id

Cite this as: Yudhistira, B., Hamidah, S. R., & Punthi, F. (2024). Physical, Chemical, and Sensory Characteristics of Star Fruit (*Averrhoa carambola* L.) Jelly Candy with Various Concentrations of Carrageenan-Konjac and Carrageenan-Pectin. *AgriHealth: Journal of Agri-food, Nutrition and Public Health*, *5*(1), 76-84. doi: http://dx.doi.org/10.20961/agrihealth.v5i1.85331

as fruit that is consumed directly or only processed into juice, chips, sweets, and syrup (Imaduddin et al., 2017). Currently, there is a trend towards a shift in people's consumption patterns, especially in Indonesia, who choose food and drinks that are practical and also healthy. Candy is a popular food product among children and teenagers; jelly candy is one of them. In Indonesia, consumption levels of jelly candy range from 20 to 30 g per capita. Jelly candy is very popular with the public and contains good nutritional value, is safe to consume, and is economical (Rahim et al., 2020). The use of fruit as an ingredient in jelly candy is expected to provide health effects as a functional food, which is currently a development trend in the food industry (Astuti et al., 2019; Yudhistira et al., 2022).

In the previous study, the fusion of carrageenan and natural pectin from red dragon fruit peel offers fresh perspectives on the gelling agents used to make jelly candies. The optimal ratio and concentration for jelly candy, which combined carrageenan and red dragon fruit peel pectin, is about a 2:1 ratio of 4.5%. The jelly candy had a hardness value of 421.59±7.94 g and a moisture content of 45.83±2.68% (Soedirga and Marchellin, 2022). Furthermore, dried roselle calyx and sugar are used to make jelly candy. The optimally prepared jelly candy has a moisture content of 19.52% and an antioxidant capacity of 16863.83 $\mu g\ ml^{-1}$. Roselle calyx can be eaten as a healthy alternative to sweet delights and is used as a natural colorant in producing jelly candy (Halim et al., 2022). These previous studies show that jelly candy can be developed from various fruits. In this case, the star fruit has the potential to produce jelly candy. The use of star fruit as a raw material in jelly candy is one of the diversification efforts that can give star fruit a longer shelf life and allow it to enjoy the nutritional content of star fruit. In general, jelly candy is made with gelatin as its gelling agent.

Gelatin is a protein obtained from the hydrolysis of collagen, which naturally occurs in bones or animal skin. Commercial gelatin is usually obtained from fish, cattle, and pigs. So far, most gelatin ingredients are still imported. Apart from the relatively high price, the halalness of imported gelatin is often doubted (Fajarini et al., 2018), so it is necessary to use other ingredients that function as gel formers, such as halal gelatin (carrageenan). Carrageenan as a gelling agent has a weakness; the gel formed has a brittle and less elastic texture, so other additional ingredients are needed to improve the nature of carrageenan (Karmila et al., 2023), such as pectin and konjac. This research is expected to provide information about the best concentration of the gelling agent mixture (carrageenan-konjac and carrageenan-pectin) to produce star fruit jelly candy of good quality based on the analysis of physical, chemical, and sensory characteristics. This gelling agent combination improves the properties of jelly candy, so it has the potential to be applied on a larger scale in the food industry.

MATERIALS AND METHOD

Materials

The research utilized star fruit, sucrose from Gulaku (Sugar Group Companies, Indonesia), fructose syrup from Rose Brand (Tunas Baru Lampung Tbk, Indonesia), water, carrageenan from Indo Gum (a product of Indofood Chem, Indonesia), konjac from Konnyaku (a product of Subur Kimia Jaya, Indonesia), and pectin from Pektin Apel (a product of Tepung Pektin Kita, Indonesia). The star fruit utilized in this study is a fully mature star fruit that exhibits a yellowish-white coloration after 65 days of flowering. Select a star fruit that is pristine and devoid of any signs of decay. All the substances utilized in this study are of food-grade quality.

Star fruit jelly candy-making

The star fruit was prepared by peeling, cutting, removing the seeds, and crushing it using a blender. Water and fruit weight with a 1:1 ratio were added to generate star fruit juice. Next, the juice underwent filtration and pasteurization on a stovetop for 4 minutes at 80 °C. During the process of pasteurization, the following ingredients were added: 20% fructose syrup, 20% sucrose, 50% water from fruit juice, carrageenan-konjac (2:1), and carrageenan-pectin (2:3) with concentrations of 1.5%, 2%, and 2.5%, respectively (Isnanda et al., 2016). Once the liquid was subjected to pasteurization, it was transferred into a receptacle and allowed to solidify into a gel-like substance over 1 hour at ambient temperature. Subsequently, the jelly was sliced into 2 cm x 2 cm x 1.5 cm dimensions, placed orderly on a baking pan covered with plastic wrap, and subjected to drying in a cabinet dryer at a temperature of 65 °C for 12 hours.

Physical, chemical, and sensory analysis

Physical analysis included tests of hardness, cohesiveness, springiness, gumminess, and chewiness performed using a texture profile analyzer instrument. Syneresis was determined by comparing the weight of jelly candy before and after storage (AOAC, 2012). Chemical analysis such as water content was determined using the thermal gravimeter method (AOAC, 2012), ash content using the dry ignition method (AOAC, 2012), water activity (Aw) content using the Aw meter (AOAC, 2012), pH using the pH meter (Lewin, 1959), crude fiber content using the gravimetric method (Lewin, 1959), and antioxidant activity using the DPPH method (Subagio et al., 2002).

Data analysis

The data collected for chemical, physical, and sensory investigation were subjected to statistical analysis using the one-way ANOVA approach to determine the influence of different gelling agents and the effect of varied concentrations. Suppose the data yields a statistically significant result. In that case, the analysis conducts the real difference test using Duncan's Multiple Range Test (DMRT) at a significance threshold of $\alpha = 0.05$ and utilizing the IBM SPSS Modeler 16.0 software for data analysis.

RESULTS AND DISCUSSION

The physical characteristics of star fruit jelly candy

The hardness test results on star fruit jelly candy can be seen in Table 1. The different types of gelling agents used showed significant differences at concentrations of 1.5% and 2.0%, while at 2.5%, there was a non-significant difference, except for formulation of carrageenan-konjac, especially for hardness, cohesiveness, and syneresis properties. There was a non-significant difference between the different concentrations of carrageenan-konjacs and carrageenan-pectins used. Adding hydrocolloids to jelly drinks provides a synergistic effect, increasing the gel's strength. The higher the concentration of hydrocolloid added is directly proportional to the higher the gel strength (Atmaka et al., 2021). Hardness properties in jelly candy are also influenced by drying time. The drying causes material to lose to the product's water content, increasing the total solids. The total solids contained in the material can increase the value of material hardness (Nuh et al., 2020). Compared to native Kappa/κ-carrageenan, the microstructure of acid anhydride esterified κ-carrageenan is more three-dimensional, but the network structure of native κ-carrageenan is flatter. In addition, when the carbon chain length and DS acid's anhydride rise, the sample's gel network structure becomes more regular and three-dimensional. According to Dong et al. (2019), the structural integrity of the gel mesh was found to be more favorable to the water-holding capacity. As a result, the sample's water-holding capacity gradually rises when the carbon chain length of the anhydride replacement and the anhydride replacement grow. The intermolecular chain-to-chain distance lengthens when the electrostatic repulsion between the chains of κ-carrageenan molecules increases in response to an increase in the negative charge carried by the molecules. Water molecules interact with the hydrophilic groups of κ-carrageenan molecules by preferentially fitting between them (Xu et al., 2024).

As shown in Table 1, the different types and concentrations of gelling agents used did not significantly affect the cohesiveness of star fruit jelly candy. κ-carrageenan is the type of gelling agent that produces a firm gel, so the higher the concentration of carrageenan, the more elastic and hard the gel produced, so it makes star fruit jelly candy more cohesive (Sari et al., 2018). The results for gumminess showed that the different types of gelling agents used had significant differences at concentrations of 1.5% and 2.5%, while at 2.0%, there was a non-significant difference. The results showed that the different concentrations of gelling agents used significantly differed. In contrast, carrageenan-pectin shows no significant difference in gumminess properties. The results of gumminess correspond with the research of Atmaka et al. (2021). The higher the gelling agent concentration, the higher the jelly candy's elasticity level.

The different types of gelling agents used for the springiness value showed a significant difference at a concentration of 2.5%. In comparison, there was a non-significant difference at concentrations of 1.5% and 2.0%, and the different concentrations of gelling agents used also showed non-significant differences. The gelling agent influences star fruit jelly candy's elasticity. The formulation of carrageenan-pectin

Table 1. The physical characteristics of star fruit jelly candy with carrageenan-konjac and carrageenan-pectin

Formulation	Parameter					
	Hardness (gf)	Cohesiveness	Gumminess (gf)	Springiness (mm)	Chewiness (kgf mm)	Syneresis (%)
Carrageenan-konjac 1.5%	458^{Bb}	0.6325^{Aa}	280.8^{Bb}	1.4425^{Aa}	408.765^{Bc}	0.6^{Aa}
Carrageenan-konjac 2.0%	462.625^{Bb}	0.6475^{Aa}	299.21^{Ab}	1.51^{Aa}	438.595^{Ac}	0.802^{Aab}
Carrageenan-konjac 2.5%	481.125^{Ab}	0.7075^{Aa}	339.805^{Bc}	1.5425^{Ba}	527.8675^{Bc}	1.144^{Ab}
Carrageenan-pectin 1.5%	315.125^{Aa}	0.5775^{Aa}	182.245^{Aa}	1.335^{Aa}	249.0525^{Aa}	0.935^{Ab}
Carrageenan-pectin 2.0%	341.75^{Aa}	0.66^{Aa}	221.69^{Aa}	1.4025^{Aa}	308.82^{Ab}	1.062^{Ab}
Carrageenan-pectin 2.5%	436.75^{Ab}	0.67^{Aa}	293.66^{Ab}	1.4675^{Aa}	430.6275^{Ac}	1.373^{Ab}

Note: Different notations in the same column show a significant difference at $\alpha = 0.05$. Uppercase for the effect of type gelling agent and lowercase for the effect of concentration gelling agent

shows a non-significant difference in springiness properties. The elasticity of star fruit jelly candy with carrageenan-konjac has a higher value than carrageenan-pectin. κ-carrageenan exhibits synergistic effects with glucomannan, similar to konjac. Its combination can increase the strength and elasticity of the gel and reduce the level of syneresis (Karmila et al., 2023).

The yield stress of a material in the event of plasticity and the material's stiffness, which may be rate-dependent, are the sources of the hardness. The material's recoverable or irrecoverable strain, which is a function of its mechanical characteristics and the test parameters, determines the springiness of the material. It has been discovered that cohesiveness and springiness are closely associated unless the material has structural flaws. Adhesiveness relies on the test conditions and material stiffness and is merely an indirect indicator of the adherence between the material and the compression plate (Jonkers et al., 2022).

A previous study found that konjac glucomannan affects texture. The observed phenomenon was ascribed to the elevated drying temperatures of 70 and 80 °C, which led to the swift evaporation of water and a rise in molecular motion—impeded the regular arrangement of konjac glucomannan and agar chains, ultimately diminishing the films' molecular interaction strength and mechanical properties. However, at 40 and 50 °C, the films' texture values were lower than those of the film dried at 60 °C. It is due to the agar chains' strong tendency to self-assemble into double helices at temperatures below 60 °C, which results in weaker interactions with the chains of konjac glucomannan and likely causes micro-phase separation in the blended solution of konjac glucomannan and agar (Qin et al., 2023).

Long-chain polymers comprise pectin and are created when α-1,4 glycosidic linkages join α-D-pyran galacturonic acid residues. These polymers have several branching topologies and lengthy molecular chains. During drying, pectin forms crosslinks with other components in plump strawberries, giving rise to a firmer, three-dimensional network structure. As a result, there is a higher water content since the water is released more slowly. The moisture content gradually dropped until the samples' free water was eliminated after the drying step. Extracting the last of the weakly bound water from the matrix was challenging. As a result, as the drying process progressed, the moisture content change curve tended to flatten (Hu et al., 2024).

The results showed that the different types of gelling agents used for the chewiness value showed significant differences at concentrations of 1.5% and 2.5%. In comparison, there was a non-significant difference at concentrations of 2.0%. Treatments that do not show fundamental differences in hydrocolloids cannot bind water, characterized by low water holding capacity

(WHC). One of the factors that causes WHC is the difference in reaction time and process temperature. Previous research shows that at 25 °C, the WHC of composite gels rose as the reaction time increased, suggesting that the more extended reaction time encouraged the binding of proteins or polysaccharides with water. Agar has been demonstrated in an earlier study to aid in retaining unbound water and enhance the WHC. When the concentration of κ-carrageenan was increased from 0.00 g 100 ml^{-1} to 0.04 g 100 ml^{-1} at 4 °C, the WHC of the composite gels decreased significantly ($p < 0.05$) from 60 to 32%. At 4 °C, the composite gels' appearance amply demonstrated water exudation. It could be because the shape of κ-carrageenan changes, resulting in a rough network with big holes and less area for water to be absorbed (Zhang et al., 2023).

There were significant differences in various concentrations of carrageenan-pectin but non-significant differences in different concentrations of carrageenan-konjac used. The chewiness of star fruit jelly candy containing carrageenan-konjac is greater than that containing carrageenan-pectin due to the synergistic effect between κ-carrageenan and konjac flour. This combination can increase the gel's strength (hardness) and elasticity (Rismandari et al., 2017). The elasticity of the gel will improve with more use of glucomannan (Karmila et al., 2023) so that the required chewing power is higher. Syneresis is the process of water being released that occurs due to an increase in the double helix structure of the gel, which causes shrinkage of the gel (Atmaka et al., 2021). The results showed a significant difference in the various concentrations of gelling agents used, but the types used did not show any significant difference.

The chemical characteristics of star fruit jelly candy

Based on Table 2, of the 6 formulas, only concentrations of 1.5% carrageenan-pectin jelly candy did not meet the SNI standard. According to SNI 3547.2-2008 (2008) concerning confectionery, the water content quality requirements on jelly candy products are a maximum of 20% (Yudhistira et al., 2018). The different types of gelling agents used for the water content showed significant differences at concentrations of 2.0% and 2.5%, while at concentrations of 1.5%, there was no significant difference. Besides that, there were significant differences in the various concentrations of gelling agents used. The addition of carrageenan in jelly candy will make more total solids. It causes the value of jelly candy water levels to be lower (Rismandari et al., 2017). The moisture content is inversely proportional to the value of cohesiveness, hardness, springiness, gumminess, and chewiness (Fatmawati et al., 2022). There are notable variations in the textural properties, particularly regarding how konjac flour is used in jelly candy. According to a previous study, the WHC value slightly increases and the syneresis rate (SR) value significantly decreases with increasing concentrations of tapioca starch (TS) and corn starch (CS) in konjac glucomannan hydrogel. The CS has a more significant effect than TS in increasing the hydrogel's ability to hold water before and after freeze-thaw treatment (Li et al., 2023).

Given that composite hydrogel with high strength typically has a significant immobilization impact on water, this phenomenon appears to be related to gel hardness (Zheng et al., 2019). More water is retained in the gelatinized starch in the composite gel, as seen by the increase

Table 2. The chemical characteristics of star fruit jelly candy with carrageenan-konjac and carrageenan-pectin

Formulation	Parameter					
	Water content (%)	Ash (%)	Aw	pH	Crude fiber (%)	Antioxidant activity (%)
Carrageenan-konjac 1.5%	19.129^{Aa}	0.98^{Aa}	0.748^{Aa}	4.18^{Ba}	0.669^{Aa}	4.415^{Bb}
Carrageenan-konjac 2.0%	18.476^{Ab}	1.321^{Ab}	0.695^{Ab}	4.38^{Bb}	0.773^{Ab}	4.799^{Ab}
Carrageenan-konjac 2.5%	17.454^{Ac}	1.51^{Ab}	0.645^{Ac}	4.44^{Bb}	0.907^{Ab}	4.942^{Bc}
Carrageenan-pectin 1.5%	20.46^{Ab}	1.026^{Aa}	0.755^{Ab}	4.0^{Ab}	0.641^{Aa}	4.319^{Aa}
Carrageenan-pectin 2.0%	19.529^{Bbc}	1.296^{Aab}	0.705^{Ab}	4.15^{Ac}	0.716^{Aa}	4.702^{Ab}
Carrageenan-pectin 2.5%	18.623^{Bc}	1.484^{Ab}	0.68^{Ac}	4.28^{Ac}	0.811^{Aa}	4.751^{Ac}

Note: Different notations on the same column show significant differences at α = 0.05. Uppercase for the effect of type gelling agent and lowercase for the effect of concentration gelling agent in WHC with increasing starch content (Tee and Siow, 2017). The water content of jelly candy produced by konjac is less than pectin because κ-carrageenan forms synergism with galactomannan like konjac, which can increase the strength and elasticity of the gel and reduce the level of syneresis (Rismandari et al., 2017).

The ash content of jelly candy is strongly influenced by the mineral content of the foodstuffs used (Diandra et al., 2022). The ash content of star fruit is 1.45 to 1.49% (Imaduddin et al., 2017). The results showed a non-significant difference in the different types of gelling agents used, but there were significant differences in the various concentrations used. It can be seen in Table 2 that the higher the gelling agent concentration used, the more the ash content increases. It is consistent with Sari et al. (2022) and Rismandari et al. (2017), which revealed that the higher the concentration of carrageenan, pectin, and konjac used, the higher the ash content.

The pH test results for star fruit jelly candy are categorized as acidic (below 7) since star fruit contains ascorbic acid (vitamin C) of 35 mg 100 g^{-1} (Hitesh and Tejpal, 2016). The higher gelling agent concentration used causes the pH to increase. The Aw value of star fruit jelly candy ranged from 0.680 to 0.748. The more gelling agent concentrations were added, the lower the Aw value of jelly candy (Hutami et al., 2020).

Crude fiber in jelly candy comes from ingredients, other ingredients, or additives used in making jelly candy. In this study, researchers used star fruit with a fiber content of 0.80 to 0.90 g 100 g^{-1} of fruit (Muthu et al., 2016). In addition to the increase in the concentration of the gelling agent, there is also a rise in the crude fiber content. Carrageenan, konjac, and pectin contain fiber (Sari et al., 2018). The different types of gelling agents used to increase the antioxidant content of star fruit jelly candy showed significant differences at concentrations of 1.5% and 2.5%, whereas there was a non-significant difference at concentrations of 2.0%. Besides that, there were significant differences in the various concentrations of gelling agents used. The source of antioxidants in star fruit jelly candy comes from star fruit as a raw material because it contains L-ascorbic acid (vitamin C) and gallic acid (Hitesh and Tejpal, 2016).

CONCLUSIONS

The different types of gelling agents (carrageenan-konjac or carrageenan-pectin) used in star fruit jelly candy showed significant differences in hardness, gumminess, chewiness, water content, antioxidants, pH, and overall. Based on the results, carrageenan-konjac overall is better than carrageenan-pectin in terms of physical and chemical properties. Especially for carrageenan-konjac, 2.5% is the best formula, which is recommended for use in producing star fruit jelly candy. The different concentrations of gelling agents used in star fruit jelly candy showed significant differences in hardness, gumminess, chewiness, syneresis, water content, ash, pH, Aw, crude fiber, antioxidants, and overall. The differences in the physical properties of jelly candies are caused by differences in hydrocolloids (carrageenan-konjac and carrageenan-pectin) in binding water. Apart from that, the processing time and temperature influence these parameters.

ACKNOWLEDGEMENTS

Authors are grateful for the fundamental steps Ir. Nur Her Riyadi Parnanto, M.S., took in development and research related to candy.

REFERENCES

AOAC. (2012). *Official method of analysis: Association of analytical chemists*, pp. 121–130. 19th Edition. Washington DC. Retrieved from https://www.scirp.org/reference/ReferencesPapers?ReferenceID=1819676

Astuti, Z. M., Nusara, A. A., Anggraini, C. V., Wimarnaya, V. W., Fadhila, N., & Yudhistira, B. (2019). Prospek pengembangan es gabus buah dan sayur, cita rasa jadul kaya vitamin. *Jurnal Kewirausahaan dan Bisnis*, *24*(13), 12–18. https://doi.org/10.20961/jkb.v24i13.30646

Atmaka, W., Prabawa, S., & Yudhistira, B. (2021). Pengaruh variasi konsentrasi kappa karagenan terhadap karakteristik fisik dan kimia gel cincau hijau (*Cyclea barbata* L. Miers). *Warta Industri Hasil Pertanian*, *38*(1), 25–35. https://doi.org/10.32765/wartaihp.v38i1.6093

Diandra, N., Ginting, Z., Kurniawan, E., Muhammad, M., & Bahri, S. (2022). Pembuatan permen jeli dari sari kulit semangka dengan penambahan kadar gula. *Chemical Engineering Journal Storage (CEJS)*, *2*(4), 16–25. https://doi.org/10.29103/cejs.v2i4.6605

Dong, Y., Wen, C., Li, T., Wu, C., Qi, H., Liu, M., ... & Song, S. (2019). The effects of amino acids on the gel properties of potassium iota carrageenan. *Food hydrocolloids*, *95*, 378–384. https://doi.org/10.1016/j.foodhyd.2019.04.023

Fajarini, L. D. R., Ekawati, I. G. A., & Timur Ina, P. (2018). Pengaruh penambahan karagenan terhadap karakteristik permen jelly kulit anggur hitam (*Vitis vinifera*). *Jurnal Ilmu dan Teknologi Pangan (ITEPA)*, *7*(2), 110–116. https://doi.org/10.24843/itepa.2018.v07.i02.p05

Fatmawati, F., Halik, A., Sutanto, S., Laga, S., & Pance, Y. (2022). Studi formula permen jelly gelatin dengan buah naga merah *Hylocereus polyrhizus* L. *Jurnal Ilmiah Ecosystem*, *22*(2), 267–277. https://doi.org/10.35965/eco.v22i2.1522

Halim, Y., Evelyne, C., Rosa, D., & Ramli, S. (2022). Development of roselle (*Hibiscus sabdariffa* L.) calyx jelly candy. *Caraka Tani: Journal of Sustainable Agriculture*, *37*(2), 357–372. https://doi.org/10.20961/carakatani.v37i2.61537

Hitesh, K., & Tejpal, A. (2016). Star fruit: A fruit for healthy life. *Journal of Pharmacognosy and Phytochemistry*, *5*(3), 132–137. Retrieved from https://www.phytojournal.com/archives/2016/vol5issue3/PartB/5-3-27-507.pdf

Hu, J., Sun, X., Xiao, H., Liu, C., Yang, F., Liu, W., Wu, Y., Wang, Y., Zhao, R., & Wang, H. (2024). Effect of guar gum, gelatin, and pectin on moisture changes in freeze-dried restructured strawberry blocks. *Food Chemistry*, *449*(3601), 139244. https://doi.org/10.1016/j.foodchem.2024.139244

Hutami, R., Handayani, A., & Rohmayanti, T. (2020). Karakteristik sensori dan fisikokimia permen jelly ubi cilembu *(Ipomoea batatas* (L). Lam) Cv. Cilembu dengan gelling agent karagenan dan gelatin. *Jurnal Ilmiah Pangan Halal*, *1*(2), 66–74. https://doi.org/10.30997/jiph.v1i2.3099

Imaduddin, A. H., Susanto, W. H., & Wijayanti, N. (2017). The influence of ripeness level of star fruit (*Averrhoa carambola* L.) and addition of sugar. *Jurnal Pangan dan Agroindustri*, *5*(2), 45–57. Retrieved from https://jpa.ub.ac.id/index.php/jpa/article/view/529

Isnanda, D., Novita, M., & Rohaya, S. (2016). Pengaruh konsentrasi pektin dan karagenan terhadap permen jelly nanas (*Ananas comosus* L. Merr). *Jurnal Ilmiah Mahasiswa Pertanian*, *1*(1), 912–923. https://doi.org/10.17969/jimfp.v1i1.1114

Jonkers, N., van Dommelen, J. A. W., & Geers, M. G. D. (2022). Intrinsic mechanical properties of food in relation to texture parameters. *Mechanics of Time-Dependent Materials*, *26*(2), 323–346. https://doi.org/10.1007/s11043-021-09490-4

Karmila, M., Pratiwi, I. D. P. K., & Widarta, I. W. R. (2023). Pengaruh konsentrasi glukomanan (*Amorphophallus konjac*) terhadap karakteristik jelly drink wedang jahe (*Zingiber officinale*). *Itepa: Jurnal Ilmu dan Teknologi Pangan*, *12*(4), 871–881. https://doi.org/10.24843/itepa.2023.v12.i04.p10

Lakmal, K., Yasawardene, P., Jayarajah, U., & Seneviratne, S. L. (2021). Nutritional and medicinal properties of star fruit (*Averrhoa carambola*): A review. *Food Science and Nutrition*, *9*(3), 1810–1823. https://doi.org/10.1002/fsn3.2135

Lewin, S. Z. (1959). pH meters. *Journal of Chemicals Education*, *36*(9), 1–11. https://doi.org/10.1021/ed036pA477

Li, J., Zhu, M., Gu, L., Su, Y., Yang, Y., Chang, C., & Han, Q. (2023). Freeze-thaw stability of konjac glucomannan hydrogels supplemented with natural tapioca/corn starch. *Lwt*, *182*, 114841. https://doi.org/10.1016/j.lwt.2023.114841

Muthu, N., Lee, S. Y., Phua, K. K., & Bhore, S. J. (2016). Nutritional, medicinal and toxicological attributes of star-fruits (*Averrhoa carambola* L.): A review. *Bioinformation*, *12*(12), 420–424. https://doi.org/10.6026/97320630012420

Nuh, M., Barus, W. B., Miranti, Yulanda, F., & Pane, M. R. (2020). Studi pembuatan permen jelly dari sari buah nangka. *Jurnal Penelitian dan Pengabdian Masyarakat*, *9*(1), 193–198. Retrieved from https://jurnal.uisu.ac.id/index.php/wahana/article/viewFile/2877/1910

Qin, J., Xiao, M., Wang, S., Peng, C., Wu, X., & Jiang, F. (2023). Effect of drying temperature on microstructural, mechanical, and water barrier properties of konjac glucomannan/agar film produced at industrial scale. *Lwt*, *173*, 114275. https://doi.org/10.1016/j.lwt.2022.114275

Rahim, E. M., Fadhilla, R., Ronitawati, P., Swamilaksita, P. D., & Harna, H. (2020). Penambahan ekstrak serai (*Cymbopogon citratus*) dan ekstrak tomat (*Solanum lycopersicum*) terhadap nilai gizi, kandungan Fe, dan vitamin C pada permen jelly. *Jurnal Nutrisia*, *21*(2), 75–82. https://doi.org/10.29238/jnutri.v21i2.145

Rismandari, M., Winarni, T., Amalia, U., Soedarto, J. P., & Tengah, J. (2017). The characteristics of jelly candy with addition of iota carrageenan from seaweed *Eucheuma spinosum*. *Saintek Perikanan*, *12*(2), 103–108. https://doi.org/10.14710/ijfst.12.2.103-108

Sari, A. A., Kritiani, E. B., & Haryati, S. (2018). Karakteristik fisik, kimia dan organoleptik permen jelly labu siam (*Sechium edule*) dengan variasi konsentrasi rumput laut (*Eucheuma cottonii*). *Jurnal Teknologi Pangan dan Hasil Pertanian*, *13*(1), 1–14. https://doi.org/10.26623/jtphp.v13i1.2371

Sari, E. M., Fitriani, S., & Ayu, D. F. (2022). Penggunaan sari buah kelubi dan gelatin dalam pembuatan permen jelly. *Jurnal Teknologi dan Industri Pertanian Indonesia*, *14*(2), 63–71. https://doi.org/10.17969/jtipi.v14i2.23309

Soedirga, L. C., & Marchellin. (2022). Physicochemical properties of jelly candy made with pectin from red dragon fruit peel in combination with carrageenan. *Caraka Tani: Journal of Sustainable Agriculture*, *37*(1), 1–14. https://doi.org/10.20961/carakatani.v37i1.53798

Statistics Indonesia. (2024). *Produksi belimbing Indonesia*. Retrieved from https://www.bps.go.id/id/statistics-table/2/NjIjMg==/produksi-tanaman-buah-buahan.html

Subagio, A., Hartanti, S., Windrati, W. S., Fauzi, M., & Herry, B. (2002). Hidrolisat tempe hasil hidrolisis protease. *Teknologi dan Industri Pangan*, *8*(3), 204–210. Retrieved from https://jurnalpenyuluhan.ipb.ac.id/index.php/jtip/article/view/4432/3720

Tee, E. T., & Siow, L. F. (2017). Effect of tapioca and potato starch on the physical properties of frozen spanish mackerel (*Scomberomoru guttatus*) fish balls. *International Food Research Journal*, *24*(1), 182–190. Retrieved from https://research.monash.edu/en/publications/effect-of-tapioca-and-potato-starch-on-the-physical-properties-of

Xu, X., Jiang, F., Lin, K., Fang, J., Chen, F., Ru, Y., Weng, H., Xiao, Q., Yang, Q., & Xiao, A. (2024). Anhydride esterification to regulate water migration and reduce ice crystal formation in κ-carrageenan gel during freezing. *Food Hydrocolloids*, *150*, 109726. https://doi.org/10.1016/j.foodhyd.2023.109726

Yudhistira, B., Affandi, D. R., & Nusantari, P. N. (2018). Effect of green spinach (*Amaranthus tricolor* L.) and tomato (*Solanum lycopersicum*) addition in physical, chemical, and sensory properties of marshmallow as an alternative prevention of iron deficiency anemia. *IOP Conference Series: Earth and Environmental Science*, *102*, 012007. https://doi.org/10.1088/1755-1315/102/1/012007

Yudhistira, B., Punthi, F., Lin, J. A., Sulaimana, A. S., Chang, C. K., & Hsieh, C. W. (2022). S-allyl cysteine in garlic (*Allium sativum*): Formation, biofunction, and resistance to food processing for value-added product development. *Comprehensive reviews in food science and food safety*, *21*(3), 2665–2687. https://doi.org/10.1111/1541-4337.12937

Zhang, Y., Song, B., Wang, X., Zhang, W., Zhu, H., Pang, X., Wang, Y., Xie, N., Zhang, S., & Lv, J. (2023). Rheological properties and microstructure of rennet-induced casein micelle/κ-carrageenan composite gels. *Lwt*, *178*, 114562. https://doi.org/10.1016/j.lwt.2023.114562

Zheng, H., Beamer, S. K., Matak, K. E., & Jaczynski, J. (2019). Effect of κ-carrageenan on gelation and gel characteristics of Antarctic krill (*Euphausia superba*) protein isolated with isoelectric solubilization/precipitation. *Food Chemistry*, *278*, 644–652. https://doi.org/10.1016/j.foodchem.2018.11.080