

OPTIMIZATION OF ATC ADDITION FROM *Kappaphycus alvarezii* TO IMPROVE TEXTURE AND SENSORY QUALITY OF KEKIAN

Optimasi Penambahan Atc dari *Kappaphycus alvarezii* untuk Meningkatkan Tekstur dan Mutu Sensori Kekian

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ABSTRACT

This study evaluated the effect of Alkali-Treated Carrageenophyte (ATC) derived from *Kappaphycus alvarezii* on the quality characteristics of kekian, a traditional surimi-based product. ATC was incorporated at four different concentrations (0%, 5%, 10%, and 15%) and analyzed based on proximate composition, sensory acceptance, texture properties, and microbiological quality. The results showed that ATC significantly influenced moisture content and texture, while its effect on ash, fat, protein, and carbohydrate content was not statistically significant. Increasing ATC concentration reduced moisture content, indicating enhanced water-binding capacity of carrageenan, while ash and carbohydrate content increased due to mineral and polysaccharide contributions. Sensory evaluation revealed that the addition of 5% ATC resulted in the highest overall acceptance in terms of appearance, aroma, taste, and texture. Texture analysis (folding and bite tests) confirmed that this formulation produced the optimal gel structure. Higher concentrations (10% and 15%) led to decreased sensory quality, likely due to excessive gel formation, darker color, and stronger seaweed aroma. Microbiological analysis indicated that all treatments met food safety standards, with total plate counts below the maximum allowable limit. Overall, ATC from *Kappaphycus alvarezii* demonstrates strong potential as a functional food ingredient for improving the texture and consumer acceptance of surimi-based products, with an optimal concentration of 5%.

Keyword: ATC, carrageenan, *Kappaphycus alvarezii*, kekian, texture

ABSTRAK

Penelitian ini bertujuan untuk mengevaluasi pengaruh penambahan Alkali Treated Carrageenophyte (ATC) dari rumput laut *Kappaphycus alvarezii* terhadap karakteristik mutu kekian sebagai produk berbasis surimi. ATC ditambahkan dalam empat konsentrasi, yaitu 0%, 5%, 10%, dan 15%, kemudian dianalisis berdasarkan komposisi proksimat, tingkat penerimaan sensori, karakteristik tekstur, serta kualitas mikrobiologi. Hasil penelitian menunjukkan bahwa

penambahan ATC berpengaruh signifikan terhadap kadar air dan tekstur, namun tidak berpengaruh nyata terhadap kadar abu, lemak, protein, dan karbohidrat. Peningkatan konsentrasi ATC menyebabkan penurunan kadar air yang menunjukkan adanya peningkatan kemampuan pengikatan air oleh karaginan, sementara kadar abu dan karbohidrat meningkat akibat kontribusi mineral dan polisakarida. Uji sensori menunjukkan bahwa penambahan ATC sebesar 5% menghasilkan tingkat penerimaan tertinggi berdasarkan parameter kenampakan, aroma, rasa, dan tekstur. Hasil uji tekstur (lipat dan gigit) juga menunjukkan bahwa formulasi ini menghasilkan struktur gel yang optimal. Penambahan ATC pada konsentrasi lebih tinggi (10% dan 15%) cenderung menurunkan kualitas sensori akibat tekstur yang terlalu padat, warna lebih gelap, serta aroma rumput laut yang lebih kuat. Analisis mikrobiologi menunjukkan bahwa seluruh perlakuan memenuhi standar keamanan pangan dengan nilai Angka Lempeng Total di bawah batas maksimum yang ditetapkan. Secara keseluruhan, ATC dari *Kappaphycus alvarezii* berpotensi sebagai bahan tambahan pangan fungsional dalam meningkatkan kualitas tekstur dan penerimaan konsumen pada produk berbasis surimi, dengan konsentrasi optimum sebesar 5%.

Kata kunci: ATC, karaginan, *Kappaphycus alvarezii*, kekian, tekstur

INTRODUCTION

Seaweed is one of the leading fisheries commodities with high economic value, particularly *Kappaphycus alvarezii*, which is widely utilized as a source of carrageenan. Carrageenan is produced through the extraction of polysaccharides from red algae (Rhodophyceae) using water or alkaline solutions as solvents (Ega *et al.*, 2016). It functions as a stabilizer, thickener, gelling agent, and emulsifier in the food industry (Fathoni & Arisandi, 2020). However, the utilization of seaweed in Indonesia remains largely limited to raw material exports. Approximately 90% of Indonesian seaweed is exported in raw form, while 50.7% of imported seaweed products are already processed (Sjahrudin *et al.*, 2023). This indicates that the domestic utilization of seaweed has not been optimized, particularly in terms of value-added processing.

One strategy to enhance value addition is through diversification of seaweed-based food products. Alkali Treated Carrageenophyte (ATC) is produced from *K. alvarezii* through alkaline treatment aimed at reducing sulfate groups and improving gel-forming ability (Ega *et al.*, 2016). ATC can be produced using various methods, including conventional heating, microwave-assisted extraction, and ultrasonic technology. The conventional method involves heating seaweed in potassium hydroxide (KOH) solution, which facilitates polysaccharide extraction and accelerates the conversion of 6-sulfate groups into 3,6-anhydro-D-galactose, thereby enhancing gel strength (Fauziah *et al.*, 2024). ATC can be directly applied as a food additive to improve product texture.

Kekian is a processed fishery product in which texture is a key quality parameter (Wibowo *et al.*, 2015). Consumers generally prefer a chewy and compact texture without compromising flavor. In kekian production, surimi serves as the primary protein source responsible for gel formation. A common issue is suboptimal texture due to imbalanced proportions of flour and main ingredients. Therefore, the addition of functional food additives is necessary to improve structure and texture quality.

ATC flour derived from *Kappaphycus alvarezii* has strong potential due to its gel-forming and water-binding properties, which can enhance elasticity, stability, and consumer acceptance. This study aimed to evaluate the effect of ATC addition on the quality of kekian products based on proximate analysis (moisture, ash, fat, protein, and carbohydrate), sensory (hedonic) evaluation, gel strength (folding and bite tests), and microbiological analysis (Total Plate Count) across four different ATC concentrations.

MATERIALS AND METHODS

Time and Location

The study was conducted from February 15 to May 15, 2025, at the Politeknik Ahli Usaha Perikanan, Jakarta.

Material and Equipment

The materials used consisted of main and supporting ingredients. The main materials included Nile tilapia (*Oreochromis niloticus*) as a surimi source and dried *Kappaphycus alvarezii*. Supporting ingredients included tapioca flour, salt, garlic, pepper, sugar, and other additives. Chemical reagents used for analysis included sulfuric acid (H₂SO₄), sodium hydroxide (NaOH), potassium hydroxide (KOH), n-hexane, and 8% KOH solution for ATC production.

The equipment used included processing tools such as a blender, digital scale, and steamer. Analytical instruments included an oven, desiccator, furnace, Soxhlet apparatus, micropipette, Petri dishes, test tubes, Erlenmeyer flasks, hot plate, magnetic stirrer, micrometer screw gauge, colony counter, stomacher, autoclave, incubator, and measuring cylinders.

Experimental Design

This study employed a single-factor experimental design with varying ATC concentrations:

- F0: 0% ATC
- F1: 5% ATC
- F2: 10% ATC
- F3: 15% ATC

Each treatment was conducted in duplicate.

Preparation of ATC

Dried *K. alvarezii* was washed, soaked, and boiled in 8% KOH solution at 80°C for 2 hours. The seaweed was then washed to neutral pH, cut, dried in an oven at 50°C for 48 hours, ground, and sieved through a 100-mesh sieve.

Preparation of Kekian

Tilapia was filleted, minced, and mixed with additives and ATC flour according to treatment levels using a food processor. The mixture was wrapped in tofu skin and steamed for 15–20 minutes, then cooled for 10 minutes before analysis.

Analysis Parameters

Raw materials were evaluated organoleptically according to SNI standards. Proximate analysis included moisture, ash, fat, protein, and carbohydrate (by difference). Sensory evaluation (hedonic test) involved 30 semi-trained panelists assessing appearance, aroma, taste, and texture. Texture was evaluated using folding and bite tests, while microbiological quality was assessed using Total Plate Count (TPC).

Data Analysis

Data were analyzed using one-way analysis of variance (ANOVA) at a 95% confidence level to evaluate the effect of varying ATC concentrations on the quality of kekian, followed by Duncan's multiple range test. All results are expressed as mean ± standard deviation.

RESULT

The research results are presented in tables covering the quality characteristics of raw materials, the chemical composition of Alkali Treated Carrageenophyte (ATC) flour, and the quality of kekian products under each treatment. The data includes the results of organoleptic tests, proximate analysis, sensory (hedonic) evaluation, texture analysis, and microbiological testing. Each table presents the mean values along with the standard deviation for each observed parameter.

Yield of Nile Tilapia and Seaweed

Yield refers to the calculation of fish minced meat obtained to determine the proportion of raw material utilized prior to processing. Yield is calculated by weighing the initial material before processing (initial weight), followed by weighing the material after processing (final weight) (Lumaela *et al.*, 2023). The observed yields of Nile tilapia and seaweed are presented in Table 1.

Tabel 1. The yield

Observation	Tilapia Fish Yield	Dried Seaweed Yield
1	26.101	20.940
2	27.336	21.433
Average	26.718	21.187

Raw Material Quality

Organoleptic Evaluation of Tilapia Fish

The average results of the organoleptic assessment of tilapia fish as raw material, conducted by six trained panelists, are presented in Table 2.

Table 2. Organoleptic values of tilapia fish

Observation	Organoleptic Interval Value	Score	SNI Standard 2729:2013
1	$8.34 \leq \mu \leq 8.51$	8	7
2	$8.31 \leq \mu \leq 8.47$	8	

Organoleptic Evaluation of Dried Seaweed

The results of the organoleptic assessment of dried seaweed raw material (*Kappaphycus alvarezii*) are presented in Table 3. In addition to organoleptic quality testing, observations were also conducted on chemical characteristics, including moisture content and CAW, which were analyzed in duplicate and are presented in Table 4.

Table 3. Organoleptic values of dried seaweed

Observation	Organoleptic Interval Value	Score	SNI Standard 2690:2018
1	$8.13 \leq \mu \leq 8.32$	8	7
2	$8.01 \leq \mu \leq 8.36$	8	

Table 4. Results of moisture content and CAW analysis of dried seaweed

Parameter	Dried Seaweed	SNI 2690 : 2018
Moisture %	46.87 ± 0.38	Max. 30
CAW %	71.11 ± 0.11	Min. 50

Proximate Composition of ATC Flour

The results of the chemical characteristics analysis of ATC flour, including moisture, ash, fat, protein, and carbohydrate contents, are presented in Table 5.

Table 5. Chemical characteristics of ATC flour

Parameter	ATC Flour
Moisture %	11.10 ± 0.50

Ash %	11.53 ± 0.39
Fat %	0.24 ± 0.02
Protein %	2.81 ± 0.11
Carbohydrates %	74.32 ± 0.24

Hedonic Test of Kekian

The hedonic characteristics of the final product were evaluated to determine the panelists' preference for kekian with the addition of ATC flour. The assessment included appearance, aroma, taste, and texture. The hedonic test was conducted by 30 semi-trained panelists. The results of the hedonic evaluation are presented in Table 6.

Table 6. Hedonic test results of kekian

Code	Appearance	Aroma	Taste	Texture
F0	7.09 ± 0.10 ^a	7.20 ± 0.07 ^a	7.56 ± 0.14 ^a	7.40 ± 0.07 ^a
F1	7.18 ± 0.08 ^b	7.47 ± 0.07 ^a	7.58 ± 0.04 ^b	7.47 ± 0.07 ^a
F2	7.05 ± 0.04 ^c	7.13 ± 0.07 ^a	7.38 ± 0.19 ^c	7.20 ± 0.07 ^a
F3	6.98 ± 0.04 ^d	6.80 ± 0.24 ^a	7.40 ± 0.46 ^d	7.11 ± 0.10 ^a

Table 6 shows that F1 with 5% ATC flour addition had the highest hedonic scores for appearance, aroma, taste, and texture compared to the other formulations, namely F0 (0% ATC flour), F2 (10% ATC flour), and F3 (15% ATC flour).

Proximate Composition of Kekian

The quality evaluation of kekian was conducted to determine the effect of different concentrations of ATC flour addition on product quality. Proximate analysis was carried out based on parameters including moisture, ash, fat, protein, and carbohydrate contents. The results are presented in Table 7.

Table 7. Proximate composition of kekian products

Formulation	Moisture %	Ash %	Fat %	Protein %	Carbohydrates %
F0	61.84±0.11 ^a	2.22±0.23	1.09±0.01	14.36±0.37	20.97±0.33
F1	60.46±0.20 ^b	2.38±0.12	1.16±0.02	14.56±0.28	21.43±0.23
F2	60.24±0.21 ^c	2.42±0.09	1.07±0.08	14.69±0.16	21.40±0.28
F3	60.15±0.41 ^d	2.52±0.02	1.13±0.01	14.64±0.23	21.55±0.23

Texture Characteristics

Texture evaluation of kekian products was carried out using the folding test and the bite test. These tests were conducted to assess the textural quality and gel elasticity of the product. Thus, the texture and gel quality of kekian with different concentrations of ATC flour addition could be determined. The folding test and bite test were conducted in accordance with SNI 2372.6:2009. The results of both tests are presented in Table 8.

Table 8. Results of folding test and bite test

Formulation	Folding Test Value	Bite Test Value
F0	2.59±0.12	7.42±0.12
F1	2.75±0.11	7.67±0.00
F2	2.25±0.11	7.25±0.11

F3

2.25±0.07

7.10±0.14

DISCUSSION

Yield of Nile Tilapia and Seaweed

The yield of Nile tilapia (26.72%) indicates moderate efficiency in raw material utilization and falls within the typical range for freshwater fish. Yield is influenced by the proportion of edible portions and processing techniques, as well as the freshness level of the fish. Differences in postmortem conditions affect muscle texture and water content, which in turn influence yield values (Nurfitriyani *et al.*, 2024).

In contrast, the yield of dried seaweed (21.19%) is relatively high compared to literature reports (9–14% of wet weight) (Tahiluddin *et al.*, 2025). This discrepancy suggests that the drying process was not fully optimal, resulting in higher residual moisture content. This highlights a trade-off between yield and quality, where higher yield does not necessarily reflect better material quality. Excess moisture may negatively affect storage stability and increase susceptibility to microbial contamination.

Raw Material Quality

The organoleptic evaluation confirmed that both Nile tilapia and dried seaweed met Indonesian National Standards (SNI), indicating acceptable freshness and initial quality. This is crucial, as raw material quality significantly influences gel formation in the final product. Fresh fish contains intact myofibrillar proteins capable of forming strong and stable gel networks (Wicaksana *et al.*, 2014).

However, the moisture content of dried seaweed (46.87%) greatly exceeded the SNI limit (maximum 30%), indicating inadequate drying. Compared to previous studies reporting moisture content of 4.64–8.25% (Katili *et al.*, 2019), this value is considerably higher. Elevated moisture content may reduce shelf life and increase the risk of microbial growth.

On the other hand, the CAW value (71.11%) met the SNI requirement (minimum 50%), indicating good cleanliness and purity of the seaweed. Thus, while chemical quality (moisture) requires improvement, the physical cleanliness of the raw material was satisfactory.

Proximate Characteristics of ATC Flour

The proximate composition of ATC flour demonstrates its suitability as a functional food ingredient. The relatively low moisture content (11.10%) indicates good storage stability, likely due to the combined effects of alkaline treatment and drying. The ash content (11.53%) reflects a substantial mineral presence, although slightly lower than reported values for semi-refined carrageenan (13–45%) (Ilhamdy *et al.*, 2019). This difference may result from mineral loss during washing after alkali treatment.

Low fat and protein contents confirm that ATC primarily functions as a hydrocolloid rather than a nutritional protein source. The reduction in protein content is likely due to solubilization and removal during alkaline processing. Interestingly, this reduction is advantageous, as it enhances carrageenan purity and improves gel-forming capacity.

The high carbohydrate content (74.32%) indicates a dominant presence of carrageenan polysaccharides. Compared to untreated seaweed (22–31%) (Erlania *et al.*, 2013), this substantial increase confirms the effectiveness of alkaline treatment in concentrating polysaccharide fractions. The formation of 3,6-anhydro-D-galactose during alkali treatment further contributes to improved gel strength (Furada *et al.*, 2012).

Hedonic Evaluation of Kekian

The hedonic test results revealed that the F1 formulation (5% ATC) achieved the highest overall acceptance. Significant differences ($p < 0.05$) were observed in appearance and taste, while aroma and texture were not significantly affected ($p > 0.05$).

These findings indicate the presence of an optimal concentration of ATC in the formulation. Carrageenan enhances texture through gel formation; however, excessive concentrations may negatively affect sensory attributes, including darker color, stronger seaweed odor, and overly firm texture (Ma'arif *et al.*, 2021).

This is consistent with previous findings that hydrocolloids such as carrageenan act as stabilizers, binders, and thickeners, thereby influencing product texture and overall acceptability (Indiarto *et al.*, 2012). Therefore, the application of ATC must be carefully optimized to balance functional benefits and sensory quality.

Proximate Quality of Kekian

The decrease in moisture content with increasing ATC concentration indicates improved water-binding capacity due to carrageenan. As a hydrophilic polysaccharide, carrageenan forms a gel matrix that immobilizes water within the product structure. This phenomenon enhances water retention stability rather than increasing free water content. Ash content increased with ATC addition, reflecting the mineral contribution from seaweed. This is consistent with the known high mineral content of seaweed-derived products (Ilhamdy *et al.*, 2019).

Fat content remained low and relatively unchanged, confirming that ATC does not contribute significantly to lipid content. Similarly, protein content showed only slight increases, likely due to concentration effects rather than direct contribution from ATC. Protein levels remained primarily influenced by surimi as the main ingredient.

Carbohydrate content increased with ATC addition due to the high polysaccharide content of carrageenan. This aligns with previous studies reporting carbohydrate levels exceeding 70% in seaweed-enriched products (Rizkaprilisa *et al.*, 2023).

Texture Characteristics

Texture analysis demonstrated that ATC significantly improved gel characteristics, particularly at optimal concentrations. The folding and bite test results indicated that the F1 formulation produced the best gel structure.

Carrageenan contributes to the formation of a three-dimensional gel network that interacts with myofibrillar proteins from surimi. During heating, myosin undergoes denaturation and forms an actomyosin network, which is reinforced by carrageenan as a hydrocolloid (Lalopua & Onsu, 2021). This interaction enhances gel strength and elasticity.

However, higher ATC concentrations (F2 and F3) resulted in decreased texture quality. This phenomenon can be attributed to over-gelation, where excessive carrageenan creates a rigid and less elastic structure. Thus, the effect of ATC on texture is non-linear, with an optimal concentration that maximizes gel strength without compromising elasticity.

Microbiological Quality (TPC)

The Total Plate Count (TPC) value of $< 2.5 \times 10^2$ CFU/g indicates that the product is microbiologically safe and well below the SNI limit (5×10^4 CFU/g). This reflects good handling practices, raw material quality, and hygienic processing conditions. Microbial load is influenced by raw material freshness, sanitation during processing, and environmental conditions (Nauli *et al.*, 2024). The low TPC value confirms that the production process maintained adequate food safety standards.

CONCLUSION

The addition of Alkali Treated Carrageenophyte (ATC) derived from *Kappaphycus alvarezii* significantly influences the quality characteristics of kekian, particularly moisture content, texture, and sensory acceptance. The raw materials used met organoleptic quality standards; however, the moisture content of dried seaweed exceeded recommended limits, indicating the need for improved drying processes. The produced ATC flour exhibited high carbohydrate content, confirming its role as a functional hydrocolloid, particularly in gel formation and water binding.

In kekian products, ATC addition significantly affected moisture content but had no substantial impact on ash, fat, protein, and carbohydrate levels. Sensory evaluation demonstrated that the formulation containing 5% ATC (F1) achieved the highest consumer acceptance in terms of appearance, aroma, taste, and texture, supported by optimal texture properties. Higher ATC concentrations negatively affected sensory quality due to excessive gel formation and undesirable changes in color and aroma. From a food safety perspective, all treatments met microbiological standards, with TPC values well below the maximum allowable limit. Overall, ATC shows strong potential as a functional food additive in fish-based processed products, particularly for improving texture. The optimal concentration identified in this study is 5%, which provides the best balance between functional performance and sensory acceptance.

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