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THE EFFECT OF SEAWEED (*Eucheuma Cottonii*) SUBSTITUTION ON THE CHARACTERISTICS OF TILAPIA (*Oreochromis Niloticus*) NUGGETS

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Abstract

Tilapia nuggets are an instant food with high protein and mineral content. Adding tapioca flour to the nuggets increases gel rigidity when cooling, making the texture harder. However, to optimize the nutritional value and texture of tilapia nuggets, seaweed can be added. This study aimed to determine the best formulation for tilapia nuggets that meet SNI 7758 quality standards. Research methods included observation, literature study, questionnaire, and experiment. The results show that substituting Eucheuma Cottonii seaweed for tapioca flour significantly improved sensory, physical, and chemical test parameters. The best formulation, N1, with an effectiveness index value of 77.1, met the quality standards of SNI 7758. It received an appearance score of 7.73, odor score of 7.40, taste score of 7.73, texture score of 7.33, texture hardness of 666 gr, water content of 59.95%, ash content of 2.31%, protein content of 13.94%, and fat content of 0.76%. Therefore, adding seaweed to the formulation of tilapia nuggets can enhance their nutritional value and texture.

Keywords: *Tilapia, Fish Nuggets, Seaweed*

1. INTRODUCTION

One way to fulfill nutritional needs, particularly protein and mineral requirements, is by incorporating fish nuggets into the menu. Fish nuggets are a type of processed food made from fish that has been crushed and mixed with other ingredients. Tilapia has been chosen as the primary ingredient in making fish nuggets due to its low cholesterol and high nutritional value, containing 18.7 g protein and 1 g fat per 100 g of material. Moreover, tilapia's mild flavor makes it easy to process into fish products such as fish nuggets (Simanjuntak & Pato, 2020).

Aside from fish meat, binders are also required to combine the ingredients into a useful dough. Tapioca starch is commonly used to create nuggets (Taus, Tahuk, & Kia, 2022). The addition of tapioca flour increases the formation of amylose and fat complexes in tapioca granules that break down when heated. The flour granules expand as a whole, absorb more water, and make the gel firmer when cooled, resulting in the structure of the nugget dough becoming harder (Agustini, Darmanto, Wijayanti, & Riyadi, 2016).

The structural problem of hardened flour or starch can be mitigated by incorporating other binders. Recent research has revealed that seaweed is used as a substitute for wheat flour in Indonesian waters. This is due to the fact that seaweed contains phycocolloids in the form of carrageenan, which promotes the binding process of processed foods. The primary source of carrageenan today is Eucheuma seaweed (Astuti & K.S, 2015). The protein content of seaweed is 2.60%, which is higher compared

to the protein content of tapioca starch, which is 1.1% (TKPI, 2017). In addition to high protein content, minerals contained in processed food ingredients are also critical factors due to their numerous benefits for the human body (Astuti & K.S, 2015).

Based on the numerous benefits of seaweed, researchers conducted research on the substitution of seaweed with tapioca flour to evaluate the effectiveness of tilapia nuggets. The production of tilapia pieces that are substituted with seaweed and tapioca flour has raised concerns about the appropriate level of seaweed required for producing tilapia pieces with a mixture of high-quality seaweed and consumer preference. Sensory tests employing senses such as appearance, smell, taste, and texture can be used to determine the level of consumer preference. The quality of the composition of tilapia pieces replaced with seaweed and tapioca flour can be seen from physical characteristics by measuring the hardness of the pieces. Furthermore, chemical testing involving moisture, ash, protein, and fat content was conducted to produce tilapia nuggets supplemented with *Eucheuma Cottonii* seaweed that meets the quality and safety requirements of SNI 7758 of 2013 for fish nuggets.

This study aimed to determine the best formulation for tilapia nuggets that meet SNI 7758 quality standards. By conducting sensory, physical, and chemical tests on the different formulations, the researchers were able to determine the best combination of ingredients that resulted in the production of high-quality tilapia nuggets that met the SNI 7758 standards. This study's findings could be valuable to fish processing industries in Indonesia that produce and market tilapia nuggets, as well as consumers who are concerned about the nutritional value and quality of the food they consume.

2. RESEARCH METHODS

The study was conducted at two different locations: the Laboratory of Science Education, FKIP, Lambung Mangkurat University, located at Jalan Brigadier General H. Hasan Basri, Prince, Kec. North Banjarmasin, Banjarmasin City, South Kalimantan Province and the MIPA Laboratory of the Faculty of Medicine, Lambung Mangkurat University, Banjarbaru, South Kalimantan. The research was carried out from March to May 2022. A total of 30 sensory testers from different age groups, genders, and social strata were selected as subjects for the study. Five people were selected as panelists for the effectiveness index test.

The research method employed in this study was the experimental method, while the research design used was a Completely Randomized Design (RAL) with five levels of treatment. The research instruments used included observations, literature studies, questionnaires, and experiments.

To determine the sensory test, the data analysis technique used was the Kruskal-Wallis test analysis, with a significant value of $p < 0.05$, followed by pairwise comparisons tests. For the physical value test, One-Way ANOVA was used, and if the significant value of $p < 0.05$ was obtained, it meant that there was a real influence, which was followed by the Tukey test to determine the differences that exist in each formulation. The data analysis technique for the chemical test was carried out using descriptive quantitative analysis, which was presented in the form of percentages and averages displayed in tables and graphs. After obtaining the average value of each formulation on each parameter, to determine the best formulation, a value that meets the quality standards

of SNI 7758 was found. Then, the data analysis technique to determine the best formulation was carried out using the effectiveness index method.

3. RESULTS AND DISCUSSION

A study was conducted to evaluate the characteristics of tilapia nuggets made with seaweed and tapioca flour substitution. The sensory evaluation included appearance, odor, taste, and texture, and the texture hardness was determined through physical tests. Chemical tests were performed to determine the water, ash, protein, and fat content of the nuggets. The average results for each parameter were obtained, and the best formulation was determined. Table 1 presents the formulation for making tilapia nuggets with substitutions of seaweed and tapioca flour.

Table 1. Formulation of substitution of seaweed and tapioca flour in tilapia nuggets

Ingredient	N0	N1	N2	N3	N4
Nile tilapia fish (g)	300	300	300	300	300
Tapioca flour (g)	43	32.25	21.5	10.75	0
Seaweed (g)	0	10.75	21.5	32.25	43
Garlic (g)	14.4	14.4	14.4	14.4	14.4
Salt (g)	3	3	3	3	3
Pepper (g)	3	3	3	3	3
Sugar (g)	3	3	3	3	3
Flavor enhancer	3	3	3	3	3
Ice water (g)	26.4	26.4	26.4	26.4	26.4
Eggs (9)	18	18	18	18	18
Coating Ingredients					
Water (ml)	50	50	50	50	50
Wheat flour (g)	50	50	50	50	50
Bread crumbs (g)	50	50	50	50	50
Salt (g)	3	3	3	3	3
Pepper (g)	3	3	3	3	3
Sugar (g)	3	3	3	3	3

1. Sensory test

The sensory test results which include appearance, odor, taste and texture from the Kruskal-Wallis test analysis can be seen in table 2 below.

Table 2. Sensory data from the Kruskal-Wallis test analysis results

Parameter	Average ± Standard deviation					Sig.	SNI quality requirements (Min. 7)
	N_0	N_1	N_2	N_3	N_4		
Appearance	7,20± 1,424	7,73± 1,230	7,20± 1,690	8,13± 1,358	7,79± 1,258	0,035*	Meet the requirement
Odor	8,20± 1,126	7,40± 0,814	7,20± 0, 961	7,53± 0,900	7,40± 1,102	0,001*	Meet the requirement
Taste	8,40± 0,932	7,73± 1,112	7,67± 1,093	8,13± 1,137	7,73± 1,230	0,041*	Meet the requirement
Texture	8,27± 1,112	7,33± 1,493	7,20± 1,518	7,73± 1,230	8,00± 1,259	0,017*	Meet the requirement

Description: Significant values followed by a sign (*) indicate a significant effect. Significant values not followed by a sign (*) indicate an insignificant effect.

After analyzing Table 2, it can be observed that all sensory test parameters, which include appearance, odor, taste, and texture, have a significant value of $p < 0.05$, thus allowing for further analysis through pairwise comparisons test. Table 3 displays the results of the pairwise comparisons test and is shown below.

Table 3. Results of pairwise comparisons

Parameter	Comparison of Tilapia Fish Nugget Formulation	Sig.
Appearance	$N_0 - N_2$	1,000
	$N_0 - N_1$	1,000
	$N_0 - N_4$	0,484
	$N_0 - N_3$	0,075
	$N_2 - N_1$	1,000
	$N_2 - N_4$	0,818
	$N_2 - N_3$	0,146
	$N_1 - N_4$	1,000
	$N_1 - N_4$	1,000
	$N_4 - N_3$	1,000
Odor	$N_2 - N_1$	1,000
	$N_2 - N_4$	1,000
	$N_2 - N_3$	1,000
	$N_2 - N_0$	0,001*
	$N_1 - N_4$	1,000
	$N_1 - N_3$	1,000
	$N_1 - N_0$	0,014*
	$N_4 - N_3$	1,000
	$N_4 - N_0$	0,023*
	$N_3 - N_0$	0,074
Taste	$N_2 - N_1$	1,000
	$N_2 - N_4$	1,000
	$N_2 - N_3$	0,864

Parameter	Comparison of Tilapia Fish Nugget Formulation	Sig.
	$N_2 - N_0$	0,100
	$N_1 - N_4$	1,000
	$N_1 - N_3$	1,000
	$N_1 - N_0$	0,197
	$N_4 - N_3$	1,000
	$N_4 - N_0$	0,269
	$N_3 - N_0$	1,000
Texture	$N_2 - N_1$	1,000
	$N_2 - N_3$	1,000
	$N_2 - N_4$	0,310
	$N_2 - N_0$	0,033*
	$N_1 - N_3$	1,000
	$N_1 - N_4$	0,699
	$N_1 - N_0$	0,096
	$N_3 - N_4$	1,000
	$N_3 - N_0$	1,000
	$N_4 - N_0$	1,000

Notes: Significant values followed by a sign (*) indicate significant differences. Significant values not followed by a sign (*) indicate insignificant differences.

a. Appearance

The results of the Kruskal-Wallis test indicated that the addition of different seaweed types to tilapia nuggets had a significant effect on the appearance of the nuggets at the 0.05 significance level, with an Asymp sig value of 0.035. Therefore, the null hypothesis (H0) was rejected, and the alternative hypothesis (H1) was accepted, indicating that the substitution of seaweed with tapioca flour affects the appearance of tilapia nuggets. However, the pairwise comparisons test using the Tukey test did not reveal any significant differences between samples. Thus, it can be concluded that increasing the amount of seaweed used in the nuggets will reduce the panelists' liking of the appearance parameter. This is likely due to the browning reaction that occurs when seaweed is heated, resulting in non-enzymatic browning reactions (Maillard reaction) between reducing sugars and amino acids. As a result, the use of seaweed affects the appearance of the product (Anam, Andarini, Prima, & Amanto, 2020). External factors that can impact the appearance of the nuggets after frying include the use of cooking oil as a heat-conducting medium, which can add saltiness and nutritional value to the brownish-yellow pieces when fried. All five treatments produced similar colors, with a layer of brown-yellow dry breadcrumbs (Winarno F., Food Chemistry and Nutrition, 2008).

According to the quality and safety requirements for fish nuggets specified in SNI 7758 of 2013, the minimum value in the sensory test is 7. Based on these parameters, all samples in various treatments that involved the addition of seaweed with different formulations met the quality standards of SNI 7758 of 2013 in terms of appearance.

b. Odor

The results of the Kruskal-Wallis test showed that the addition of different seaweed types to tilapia nuggets had a significant effect on their appearance at a 0.05 significance level, with an Asymp sig value of 0.001. Thus, H0 was rejected, and H1 was accepted,

indicating that there was an influence of seaweed substitution with tapioca flour on the odor of tilapia nuggets. However, further testing using the Tukey test revealed that the significant difference was only observed between N2 (Tilapia Fish Nuggets with 50% Tapioca Flour Formulation: 50% Seaweed) and N0 (Tilapia Fish Nuggets with 100% Tapioca Flour Formulation: 0% Seaweed).

The addition of seaweed in each treatment resulted in a reduction of fish aroma in the nuggets produced. This effect was consistent with previous studies, such as Mulian (2022), who reported that increased seaweed use led to a decrease in fish aroma and a slight seaweed smell. However, Anam, Andarini, Prima, & Amanto (2020) argued that seaweed has a distinctive fishy aroma due to the presence of ammonia, which is a compound consisting of nitrogen and hydrogen elements with a distinctive odor. Nonetheless, since the amount of seaweed used in the study was relatively small, the sense of smell could still tolerate the odor, with the lowest average being above 7, which indicates neutrality.

According to the quality and safety requirements of fish nuggets stipulated by SNI 7758 of 2013, the minimum value in the sensory test is 7. Based on this standard, all samples from various treatments of seaweed addition with different formulations met the quality standards of SNI 7758 of 2013 in terms of odor.

c. Taste

The results of the Kruskal-Wallis test showed that the addition of different seaweed types to tilapia nuggets had a significant effect on their appearance at a 0.05 significance level, with an Asymp sig value of 0.041. Thus, H0 was rejected, and H1 was accepted, indicating that there was an influence of seaweed substitution with tapioca flour on the taste of tilapia nuggets. However, further testing using the Tukey test revealed no significant difference between the other samples. Based on these data, it was concluded that the addition of seaweed caused a decrease in the specification of fish flavor in tilapia nuggets.

Good taste in food is typically attributed to chemical reactions on amino acids in fat and protein content. The decrease in taste value after the addition of seaweed could be due to the amino acid content in seaweed, such as lysine, phenylalanine, methionine, leucine, and valine, which give a bitter taste (Anam, Andarini, Prima, & Amanto, 2020). However, the addition of seaweed in small amounts may still be tolerable, and the bitter taste can be covered by other ingredients, such as spices. Therefore, the lowest taste value achieved was still in the range above 7, which means neutral and can still be considered palatable.

According to the quality and safety requirements of fish nuggets stipulated by SNI 7758 of 2013, the minimum value in the sensory test is 7. Based on this standard, all samples from various treatments of seaweed addition with different formulations met the quality standards of SNI 7758 of 2013 in terms of taste.

d. Texture

The results of the Kruskall-Wallis test showed that the addition of different seaweed in tilapia nuggets had a significant effect on the appearance of nuggets at the 0.05 test level, with an Asymp sig value of 0.017. Based on this, H0 was rejected, and H1 was accepted, indicating that there was an influence between the substitution of seaweed with tapioca flour on the texture of tilapia nuggets. However, after further testing using the Tukey test, it was found that the significant difference was only observed between N2

(Tilapia Fish Nuggets with 50% Tapioca Flour Formulation: 50% Seaweed) and N0 (Tilapia Fish Nuggets with 100% Tapioca Flour Formulation: 0% Seaweed).

The texture value varied from sample to sample, which was attributed to the binder or tapioca flour used in making nuggets in this study. Flour is often used as a binder because of its starch content, which forms an amylose fraction when exposed to hot water. The amylose fraction plays a crucial role in gel stability due to the hydration properties of amylose in starch, which can bind water molecules and then form an elastic mass. However, amylose gel stability is lost if too much water is added (Winarno F. G., 1997), which may have caused the formulation of tilapia nuggets without the addition of seaweed to be very hard.

The addition of seaweed to tilapia nuggets with various percentages caused a significant influence on the texture of the product, resulting in a variety of values. This is because the hardness of a product is influenced by the binding power of water. According to Kusnandar (2010) in Aditomo, Nopianti, & Widiastuti (2017), the higher the amount of water binding ability, the better the texture of the food produced and vice versa. In addition, heating is a factor that affects water retention, the higher the temperature, the lower the amount of bound water and the lower the particle roughness.

The results of this study are in line with the research proposed by Mulian (2022) that seaweed can affect texture. This is due to the ability of seaweed to absorb a lot of water and contain carrageenan, so the more seaweed used in processing, the softer the resulting texture. The texture of pieces that are too hard due to the use of abundant tapioca flour can be managed well after the addition of seaweed, as seen from the texture value of 8.27 without seaweed substitution, while the lowest value is obtained with seaweed substitution. The value of 7.20 indicates that the substitution of seaweed can reduce the hardness of the ball structure caused by tapioca flour, resulting in a slightly hard and slightly compact ball structure that is easier to consume.

According to the parameters of the quality and safety requirements of fish nuggets in accordance with the provisions of SNI 7758 of 2013, the minimum value in the sensory test is 7. Based on these parameters, all samples in various treatments of adding seaweed with different formulations can be said to have met the quality standards of SNI 7758 of 2013 in terms of texture.

2. Physical test

In the physical properties test, the nuggets were tested 5 times. The physical properties of the nuggets were analyzed using a One-Way ANOVA test. Table 4 shows the results of the physical properties test of tilapia nugget products with the addition of seaweed (*Eucheuma Cottonii*).

Table 4. Results of data analysis in One-way ANOVA test

Average ± Standard deviation					Sig.
N_0	N_1	N_2	N_3	N_4	
856±4,183	666± 4,183	650± 6,124	711± 7,416	756± 4,183	0,00*

Note: Significant values followed by a sign (*) indicate a significant effect. Significant values not followed by a sign (*) indicate an insignificant effect.

According to the results presented in Table 4, there is a significant difference ($p < 0.05$) in the average physical properties test values for the texture hardness of tilapia nuggets across all data groups. Therefore, further analysis was conducted using the Tukey test to determine the average difference between the formulations of tilapia nuggets with seaweed and tapioca flour substitutions. The results of this analysis are presented in Table 5, which provides the data related to the physical properties test for the texture hardness of tilapia nuggets obtained from the Tukey test.

Table 5. Results of Tukey test analysis

Formulation	Comparison	Sig
N0	N1	.000
	N2	.000
	N3	.000
	N4	.000
N1	N0	.000
	N2	.001
	N3	.000
	N4	.000
N2	N0	.000
	N1	.001
	N3	.000
	N4	.000
N3	N0	.000
	N1	.000
	N2	.000
N4	N4	.000
	N0	.000
	N1	.000
	N2	.000

Notes: Significant values followed by a sign (*) indicate significant differences. Significant values not followed by a sign (*) indicate insignificant differences.

The results of the physical properties test show that there are differences in the average test values for tilapia nuggets with substitutions of seaweed and tapioca flour. The formulation with the highest ratio of tapioca flour content (N0) obtained the highest value of 856 grams. This indicates that increasing the weight used to press the nuggets results in a harder texture. The addition of tapioca flour to the fish pieces causes the formation of amylose and fat complexes in tapioca granules, which expand upon heating and absorb more water to form a gel when cooling, resulting in a harder texture. In contrast, the use of seaweed as a binder can significantly reduce the level of hardness in the texture of tilapia nuggets. The One-Way ANOVA test confirmed that each formulation of tilapia nuggets was significantly different ($p < 0.05$) in terms of hardness. Seaweed, with its high phycocolloid content, can help in the binding process in processed food production, acting as gelling agents, stabilizers, emulsifiers, and dispersants.

The phycocolloid compounds found in seaweed can reduce the texture hardness of tilapia nuggets. However, after the Tukey test (see Table 5), the differences between the samples were not significant, indicating that the seaweed substitution only influenced the hardness of the nugget texture without significant differences between the formulations.

3. Chemical Test

Chemical tests were conducted at the MIPA Laboratory, Faculty of Medicine, Lambung Mangkurat University, Banjarbaru, South Kalimantan. The results of the chemical tests are presented in Table 6.

Table 6. Chemical test results

No	Sample code	Water content (%)	Ash content (%)	Protein content (%)	Fat content (%)
1	N_0	62,36	2,14	11.54	0,02
2	N_1	59,95	2,31	13,94	0,76
3	N_2	53,66	2,29	14,86	0,79
4	N_3	63,82	2,27	14,26	0,85
5	N_4	64,95	2,69	14,21	0,85

Chemical tests are objective measurements of product quality based on the chemical content present in the product (Hanum, 2019). In this study, chemical tests were conducted on tilapia nuggets with the addition of seaweed. The results of these tests are discussed below.

a. Water content

Analysis of water content in food is very important both in dry food and fresh food. In dry food, water content is often related to the stability index, especially during storage. From the test results using the gravimetric method, the value of each treatment ranged from 53.66% - 64.95%. The lowest water content value was obtained in sample N2 (Tilapia Fish Nugget with 50% Tapioca Flour Formulation: 50% Seaweed). While the highest texture value was obtained in treatment N4 (Tilapia Fish Nuggets with 0% Tapioca Starch Formulation: 100% Seaweed). Based on this it can be concluded that H0 is rejected while H1 is accepted, which means that there is an influence between the substitution of seaweed with tapioca flour on the water content of tilapia fish nuggets. The addition of seaweed to the processing of tilapia pieces creates a three-dimensional network that is built to absorb water, and besides that seaweed is a polysaccharide compound that easily binds water with the presence of reversible sulfate groups in its molecule chain that the replacement of seaweed and tapioca flour will affect the water content. Water in tilapia nuggets.

According to SNI 7758 of 2013 the maximum water content of fish nuggets is 60%. Thus, tilapia nuggets with the addition of seaweed that meet quality standards are found in treatments N1 (Tilapia Fish Nuggets with 75% Tapioca Starch Formulation: 25% Seaweed) and N2 (Tilapia Fish Nuggets with 50% Tapioca Starch Formulation: 50% Seaweed). Meanwhile, the other treatments, namely N0, N3, and N4, did not meet the quality standards of SNI 7758 of 2013.

b. Ash content

According to Khalishi (2011) cited in Aditomo, Nopianti, & Widiastuti (2017), the ash content of a food product indicates its mineral content. The amount of non-

combustible minerals relative to volatile substances reflects the quantity of minerals the food contains. Based on the test results using the gravimetric method, the value of each treatment ranged from 2.14% to 2.69%. The lowest ash content value was obtained in sample N0 (Tilapia Fish Nugget with 100% Tapioca Flour Formulation: 0% Seaweed), while the highest value was obtained in treatment N4 (Tilapia Fish Nuggets with 0% Tapioca Starch Formulation: 100% Seaweed).

Therefore, it can be concluded that H0 is rejected, and H1 is accepted, indicating that there is an influence between the substitution of seaweed with tapioca flour on the ash content of tilapia fish nuggets. *Eucheuma Cottonii* seaweed has an ash content of 3.40, while the ash content in tapioca flour is 0.5% according to Puspitasari (2008). All commercial starches sourced from cereals and tubers contain small amounts of inorganic salts that also come from the material itself (Sudarmadji, 1996). Hence, the addition of more *Eucheuma Cottonii* seaweed in the tilapia nuggets increased the ash content compared to the treatment without seaweed. Ash content is a mixture of inorganic or mineral components contained in a foodstuff, such as seaweed.

Seaweed's mineral content is incomparable to vegetables from land. Seaweed contains many nutrients, including minerals such as phosphorus, calcium, selenium, iron, iodine, magnesium, and sodium. Seaweeds absorb these minerals from their habitat, the sea, which contains many minerals derived from natural salinity and dead and decaying marine life (Yaska, Yusa, & Yusasrini, 2017).

The substitution of seaweed and tapioca flour in tilapia nuggets can optimize the important role of minerals in maintaining body functions at the cellular, tissue, and whole body levels. Mardalena and Suryani (2016) classified mineral requirements into two groups: macrominerals (macroelements) and microminerals (microelements). Adequate mineral intake during the COVID-19 outbreak can help the immune system remain strong, enabling the body to remain healthy and avoid outbreaks in the new normal era (Lomboan, Malonda, & Sekeon, 2020).

Despite its many mineral benefits, the maximum ash content in fish nuggets is limited to 2.5% according to SNI 7758 of 2013. As such, tilapia nuggets with the addition of seaweed that meet quality standards are found in treatments N0 (Tilapia Fish Nuggets with 100% Tapioca Flour Formulation: 0% Seaweed), N1 (Tilapia Fish Nuggets with 75% Tapioca Starch Formulation: 25% Seaweed), N2 (Tilapia Fish Nuggets with 50% Tapioca Starch Formulation: 50% Seaweed), and N3 (Tilapia Fish Nuggets with 25% Tapioca Starch Formulation: 75% Seaweed). However, treatment N4 (Tilapia Fish Nuggets with 0% Tapioca Starch Formulation: 100% Seaweed) did not meet the quality standards set by SNI 7758 of 2013.

c. Protein content

The analysis shows that the lowest protein content is found in N0 (Tilapia Fish Nuggets with 100% Tapioca Flour Formulation: 0% Seaweed), while the highest protein content is in N2 (Tilapia Fish Nuggets with 50% Tapioca Starch Formulation: 50% Seaweed). Based on this, it can be concluded that H0 is rejected and H1 is accepted, which suggests that there is an influence between the substitution of seaweed with tapioca flour on the protein content of tilapia fish nuggets. The protein content tends to increase with the reduction of tapioca and the addition of *Eucheuma Cottonii* seaweed. This increase is mainly due to the different formulations of tapioca and *Eucheuma Cottonii* seaweed used.

Aslan L (1998) argues that seaweed contains a high protein content of 2.60%, while Puspitasari (2008) states that the protein content of tapioca flour is 0.5%.

Seaweed is able to bind water and retain water-soluble proteins during the boiling process, which causes the protein content in tilapia nuggets to increase with the increase in seaweed meal content. However, high and low measured protein values can be influenced by the amount of water lost from the ingredients (dehydration). The measured protein value is higher if the amount of water lost is higher. The measured protein content also depends on the amount of added ingredients and is strongly influenced by the water content. The reaction of seaweed carrageenan with proteins, as amino acids have negatively charged sulfate ester groups with positively charged carboxyl groups, also contributes to the increase in protein content. Additionally, the negatively charged hydroxyl group of carrageenan binds to the amino group on the protein.

After being adjusted to meet SNI 7758 of 2013 concerning the quality requirements of fish nuggets, the acceptable protein content in fish nuggets should be at least 5%. According to the results of the protein content analysis, all treatments meet the standards set by the Indonesian national standard.

d. Fat content

After conducting the Soxhlet method, the results for each treatment range from 0.02% to 0.85%. The sample with the lowest fat content is N0 (Tilapia Fish Nugget with 100% Tapioca Flour Formulation: 0% Seaweed), while the highest fat values are obtained from treatments N3 (Tilapia Fish Nuggets with 25% Tapioca Starch Formulation: 75% Seaweed) and N4 (Tilapia Fish Nuggets with 0% Tapioca Starch Formulation: 100% Seaweed).

From the results, it can be concluded that H0 is rejected and H1 is accepted, indicating that there is an influence of seaweed substitution with tapioca flour on the fat content of tilapia fish nuggets. According to Aslan, L (1991), *Eucheuma Cottonii* seaweed contains 0.40% fat, while Puspitasari (2008) argues that tapioca flour contains 0.5% fat.

Previous research by Yaska, Yusa, & Yusasrini (2017) has shown that the addition of *Eucheuma Cottonii* seaweed can increase emulsion stability. As a processed meat product, nugget is essentially a fat emulsion. With the role of agar in *Eucheuma Cottonii* seaweed, the fat emulsion can be stabilized by lowering surface tension and forming a protective layer that covers the dispersed sphere, leading to more dispersed and stable insoluble compounds in the emulsion. The stability of the fat emulsion helps to prevent the release of fat from fish tissue during cooking, which can cause an increase in fat content when seaweed is added.

Based on the results, the fat content in all tilapia nuggets with the addition of seaweed meets the quality standards of SNI 7758 in 2013, which is below 15%.

4. The best formulation determination test

De Garmo (1984) concluded that the effectiveness index method can be used to determine the best formulation, as shown by the results in Table 7 below.

Table 7. Effectiveness Index Method Calculation Results

Parameter	Weight	N_1		N_2	
		NE (Effectiveness Value)	NH (Outcome Value)	NE (Effectiveness Value)	NH (Outcome Value)
Appearance	10,8	1	10,8	0	0
Odor	8,2	1	8,2	0	0
Taste	5,4	1	5,4	0	0
Texture	13,2	1	13,2	0	0
Hardness	11,3	1	11,3	0	0
Water content	9,9	1	9,9	0	0
Ash content	18,3	1	18,3	0	0
Protein content	6,4	0	0	1	6,4
Fat content	7,9	0	0	1	7,9
Total	91,4	7	77,1	2	14,3

The best formulation for tilapia nuggets with substituted seaweed and tapioca flour is determined through the effectiveness index method. The effectiveness index is calculated by summing the Outcome Value (NH) of all parameters in each treatment group, and the treatment group with the highest NH value is considered the best.

Based on the calculations, it was found that N1 is the best formulation with an NH value of 77.1, compared to N2 with an NH value of only 14.3. This is because N1 has higher values for several parameters, such as appearance, odor, taste, texture, texture hardness, moisture content, and ash content. As a result, N1 is considered superior to N2.

4. CONCLUSION

The research conducted led to four main conclusions as follows:

1) The substitution of *Eucheuma Cottonii* seaweed with tapioca flour as a binder for tilapia nugget products has a significant influence. All formulations met the sensory test quality standards according to SNI 7758 of 2013.
2) The formulation of tilapia nuggets had a significant effect, as proven by the One-Way ANOVA test, which showed that the substitution of seaweed and tapioca flour had a significant impact on the physical test value, specifically on the hardness of the texture of tilapia nuggets.
3) The substitution of *Eucheuma Cottonii* seaweed with tapioca flour as a binder for tilapia nugget products influenced the results of the chemical tests. Only two formulations met the chemical test criteria outlined in the SNI 7758 quality standard of 2013, namely tilapia nuggets with sample formulations N1 and N2.
4) According to the effectiveness index method, the best formulation was N1, which obtained a higher value of 77.1.

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