Fisheries Journal, 15 (5), 2710-2724 (2025)
http://doi.org/10.29303/jp.v15i5.1803

COMBINATION OF TAPIOCA STARCH WITH NANOCITOSAN IN *EDIBLE FILM* ON SHELF LIFE AND ORGANOLEPTIC VALUE OF FISH SIOMAY DURING ROOM TEMPERATURE STORAGE

Kombinasi Tepung Tapioka dengan Nanokitosan dalam *Edible Film* Terhadap Umur Simpan dan Nilai Organoleptik Siomay Ikan Selama Penyimpanan Suhu Ruang

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(Received August 21th 2025; Accepted October 25th 2025)

ABSTRACT

Fish siomay are susceptible to bacterial contamination, have a high moisture content, and the lack of cold storage facilities in traditional shops can shorten the shelf life of siomay products. The solution to overcome these problems is to close and limit the interaction between the product and the environment by using *edible film*s that are environmentally friendly, biodegradable, and antibacterial. *Edible film* is made from a combination of tapioca starch and fish scale nanokitosan. This study aims to determine the effect of the combination of tapioca starch with fish scale nanocitosan on *edible film* on the shelf life and organoleptic value of fish siomay during storage at room temperature. This study used a completely randomized design (CRD) with 5 treatments and 4 repetitions. The treatments used were PO (2.1% Tapioca Starch: 0% Nanocitosan), P1 (1.95% Tapioca Starch: 0.15% Nanocitosan), P2 (1.8% Tapioca Starch: 0.3% Nanocitosan), P3 (1.65% Tapioca Starch: 0.45% Nanocitosan), P4 (1.5% Tapioca Starch: 0.6% Nanocitosan). Data on thickness, Water Vapor Transmission Rate (WVTR), tensile strength, elongation, elastic modulus, moisture content, pH, Total Plate Count (TPC) were analyzed using ANOVA and DMRT while organoleptic tests used Krustal Wallis and Mann-Whitney. The results showed that the combination of different concentrations of tapioca starch and fish scale nanokitosan in the preparation of *edible film* affects the shelf life and organoleptic value of fish during storage at room temperature.

Keywords: Edible film, Fish Siomay, Nanocitosan, Shelf Life, Tapioca Starch

ABSTRAK

Siomay ikan rentan terhadap kontaminasi bakteri, memiliki kadar air yang tinggi, dan kurangnya fasilitas penyimpanan dingin di toko-toko tradisional sehingga dapat memperpendek umur simpan produk siomay. Solusi untuk mengatasi masalah tersebut adalah dengan menutup dan membatasi interaksi antara produk dengan lingkungan dengan menggunakan *edible film* yang ramah lingkungan, mudah terurai, dan antibakteri. *Edible film* dibuat dari kombinasi tepung tapioka dan nanokitosan sisik ikan. Penelitian ini bertujuan untuk mengetahui pengaruh kombinasi tepung tapioka dengan nanokitosan sisik ikan pada *edible film* terhadap daya simpan dan nilai organoleptik siomay ikan selama penyimpanan pada suhu ruang. Penelitian ini menggunakan Rancangan Acak Lengkap (RAL) dengan 5 perlakuan dan 4 kali pengulangan. Perlakuan yang digunakan adalah PO (2,1% Tepung Tapioka : 0% Nanokitosan), P1 (1,95% Tepung Tapioka : 0,15% Nanokitosan), P2 (1,8% Tepung Tapioka : 0,3% Nanokitosan), P3 (1,65% Tepung Tapioka : 0,45% Nanokitosan), P4 (1,5% Tepung Tapioka : 0,6% Nanokitosan). Data uji ketebalan, Water Vapor Transmission Rate (WVTR), kuat tarik, elongasi, modulus elastik, kadar air, pH, Total Plate Count (TPC) dianalisis menggunakan ANOVA dan DMRT sedangkan uji organoleptik menggunakan Krustal Wallis dan Mann-Whitney. Hasil penelitian menunjukkan bahwa kombinasi konsentrasi tepung tapioka dan nanokitosan sisik ikan yang berbeda dalam pembuatan *edible film* berpengaruh nyata (P<0,05) terhadap umur simpan dan nilai organoleptik ikan selama penyimpanan pada suhu ruang.

Kata Kunci: Edible film, Nanokitosan, Siomay Ikan, Tepung Tapioka, Umur Simpan

INTRODUCTION

Indonesia has a potential fish resource wealth of up to 12 million tons per year, as stipulated in the Decree of the Minister of Maritime Affairs and Fisheries No. 19 of 2022. Fish is a perishable food ingredient, requiring special handling to maintain its quality by processing it into ready-to-eat or ready-to-consume frozen food. One popular frozen food is siomay (Rindiani and Purnasari, 2022).

Siomay is a food product in Indonesia that is susceptible to bacterial contamination and has a short shelf life. According to research by Maharani & Sari (2022), the siomay products tested contained pathogenic bacteria such as Escherichia coli and Salmonella, which can be harmful in large quantities. Furthermore, bacteria can multiply rapidly in conditions with high water content (Apriana *et al.,* 2023). According to the Indonesian National Standards Agency (2013), the maximum water content for siomay is 60% (w/w), making it highly perishable and having a short shelf life of approximately 1-2 days at room temperature (Santika & Batubara, 2024).

Siomay products sold in traditional stores still lack proper chain management due to the lack of cold storage facilities (Milasari, 2021). This situation poses significant challenges for traditional stores that lack access to cold storage facilities, preventing perishable products like siomay from having a long shelf life (Suhag *et al.,* 2020). Therefore, one approach is to cover and limit product interaction with the environment to provide antibacterial protection. One approach is to use edible film.

According to the Food and Drug Administration (FDA), edible film is an environmentally friendly food packaging alternative because it is made from safe and biodegradable materials, allowing it to be consumed directly with the food it covers (Stephani *et al.,* 2021). Edible films have the advantage of being carriers for additives such as antimicrobials and antioxidants, extending the shelf life of foods (Fitriana *et al.,* 2023). One innovation used in edible film production is based on nanochitosan and tapioca starch.

Nanochitosan has a particle size of 100–400 nm, while nanoparticles are particles measuring 1–100 nanometers. They exhibit higher antibacterial activity than conventional chitosan due to their ability to penetrate bacterial cell walls (Sektiaji *et al.,* 2022). Tapioca starch is a biodegradable, inexpensive ingredient for edible films, and has the ability to form clear, flexible films. However, tapioca starch-based edible films have drawbacks, including poor mechanical properties or easy tearing due to low water resistance, low resistance to humidity due to the hydrophilic nature of starch, and high water vapor transmission (Kustyawati *et al.,* 2021). Furthermore, the mechanical properties of starch films are also relatively weak due to their low elasticity (Chang *et al.,* 2024). Therefore, a combination of materials is needed to improve the functional characteristics of the edible film. Based on the description above, the purpose of this study was to determine the effect of the combination of tapioca flour and nanochitosan in edible film on the shelf life and organoleptic value of fish dumplings during room temperature storage.

RESEARCH METHODS

Place and Time

The research was conducted from December 1, 2024, to May 20, 2025, at the Faculty of Fisheries and Marine Sciences, Airlangga University. The manufacture of nanochitosan, edible film, water content test, pH test, and Water Vapor Transmission Rate (WVTR) were carried out at the Chemistry and Analysis Laboratory, Faculty of Fisheries and Marine Sciences, Airlangga University. The manufacture of siomay and organoleptic tests were carried out at the Food Laboratory, Faculty of Fisheries and Marine Sciences, Airlangga University. Room temperature storage of siomay was carried out at the Anatomy and Cultivation Laboratory, Faculty of Fisheries and Marine Sciences, Airlangga University. TPC (Total Plate Count) testing was carried out at the Microbiology Laboratory, Faculty of Fisheries and Marine Sciences, Airlangga University. Thickness, tensile strength, elongation, and elastic modulus testing were carried out at the Laboratory of the Faculty of Science and Technology, Airlangga University. Nanochitosan size testing was carried out at the Institute of Life Sciences, Engineering, and Technology (LIHTR), Airlangga University.

Tools and Materials

The tools used in this study were a hot plate stirrer (Thermo Scientific Cimarec), food dehydrator, watch glass, disposable petri dish, magnetic stirrer, 250 mL Erlenmeyer flask, 100 mL beaker glass, 50 mL measuring cup, 1000 µL micropipette, microtip, spatula, measuring pipette, desiccator and 210 g analytical balance (OHAUS), knife, basin, food chopper, spatula, spoon, measuring cup, steamer and gas stove, test tube, autoclave, Bunsen burner, petri dish, porcelain cup, incubator, digital pH meter, thermohygrometer, 100 mL beaker glass, moisture analyzer. The materials used in this study were chitosan fish scales, Sodium Tripolyphosphate (NaTTP), acetic acid, distilled water, tapioca flour, glycerol, tilapia fish, tapioca flour, dumpling skin, carrots, spring onions, shallots, garlic, eggs, pepper, sugar, salt and Monosodium Glutamate (MSG).

Research methods

This research is an experimental study using a Completely Randomized Design (CRD) with 5 treatments and 4 replications. The edible film formulation treatment refers to the research of Abdillah & Charles (2021) who used arrowroot starch and iota-carrageenan as the basic ingredients using 20 mL. In addition, this study also refers to the research of Izzi *et al.,* (2023) who used tapioca flour and whey protein concentrate (WPC) as the basic ingredients and then made modifications. The modification in this study lies in the main ingredients using tapioca flour and nanochitosan with a volume of 30 mL for one disposable petri dish. The treatment in this study:

P0 : Combination of edible film from 2.1% tapioca flour and 0% nanochitosan (control).
P1 : A combination of edible film made from 1.95% tapioca flour and 0.15% nanochitosan.
P2 : A combination of edible film made from 1.8% tapioca flour and 0.3% nanochitosan..
P3 : A combination of edible film made from 1.65% tapioca flour and 0.45% nanochitosan.

P4 : A combination of edible film made from 1.5% tapioca flour and 0.6% nanochitosan.

Nanochitosan Production

Nanochitosan was made referring to Hafizhah (2024), using an ionic gelation process. The first stage of making a chitosan solution was by dissolving 210 mg of chitosan in 70 mL of acetic acid solution (4.5 mg/mL), stirring using a magnetic stirrer. 29 mL of sodium tripolyphosphate (STPP) solution (1.2 mg/mL) was then added to the chitosan solution during stirring with the addition of the STPP solution carried out continuously at a rate of 1 mL/minute. The two solutions were mixed at a stirring speed of 1500 rpm for 1, 2, and 3 hours.

Making Edible Film

Edible film was made based on research conducted by Abdillah and Charles (2021) and Izzi *et al.,* (2023) with slight modifications. Edible film production begins with the preparation of tools and materials. The steps taken before making the edible film include weighing all ingredients, including tapioca flour and nanochitosan, with a concentration of 7%. The edible film formulation using a combination of tapioca flour and nanochitosan can be seen in Table 1.

Table 1. Edible Film Formulation Using a Combination of Tapioca Flour and Nanochitosan

		Bahan			
No.	**Treatment**	**Tapioca Flour (w/v) grams**	**Nanochitosan (v/v) %**	**Glycerol (30%) of Main Ingredients (mL)**	**Aquades (mL)**
1.	**P0**	2,1	0	0,63	27,27
2.	**P1**	1,95	0,15	0,63	27,27
3.	**P2**	1,8	0,3	0,63	27,27
4.	**P3**	1,65	0,45	0,63	27,27
5.	**P4**	1,5	0,6	0,63	27,27

In this study, the edible film formulation was carried out using a volume of 30 mL for each preparation. The process began by mixing 27.27 mL of distilled water into a 100 mL beaker covered with aluminum foil. The mixture was then heated on a hot plate at 5°C and stirred at 300 rpm for 1 minute. Next, the tapioca starch was dissolved at 120–140°C at 250–300 rpm for 20 minutes.

Nanochitosan was added gradually while stirring until homogeneous at 120°C at 250–300 rpm for 10 minutes. Subsequently, glycerol, representing 30% of the total ingredients (tapioca starch and nanochitosan), was added, and the solution was heated at 120°C with stirring at 300 rpm for 5 minutes. The processed edible film solution was then poured into 9 cm diameter disposable petri dishes. The edible film was dried in a food dehydrator at 50°C for 18 hours. Once dry, the edible film was removed from the disposable petri dish. The final product was stored in a sealed plastic container.

Data Analysis

The data from thickness test, Water Vapor Transmission Rate (WVTR), tensile strength, elongation, elastic modulus, water content test, pH and Total Plate Count (TPC) were analyzed using one-way ANOVA (Analysis of Variance) at α 5%. If there are significant test results, DMRT (Duncan Multiple Range Test) will be conducted at α = 5% to more clearly determine the differences between samples. The data from organoleptic test results were analyzed using the Kruskal-Wallis method to determine the ranking of each parameter and identify any significant differences between treatments. If differences are found, the analysis is continued with the Mann-Whitney test to determine the differences between treatments.

RESULT

This study consisted of two stages: the characteristics of edible film and the application of edible film to fish siomay at room temperature storage, which aimed to determine the shelf life of fish siomay products. Edible film made from a combination of tapioca flour and nanochitosan was then applied to fish siomay products, as can be seen in Figure 1.

Figure 1. Application of edible film on fish dumplings.

Edible film characterization

The characterization of edible films made from a combination of tapioca flour and nanochitosan showed that the average thickness of the edible film in this study ranged from 0.19 mm to 0.37 mm, the Water Vapor Transmission Rate (WVTR) of the edible film ranged from 19.91 grams/m2/day to 57.72 grams/m2/day, the tensile strength of the edible film ranged from 0.55 MPa to 1.05 MPa, the elongation of the edible film ranged from 76.96% to 136.28%, and the elastic modulus of the edible film ranged from 0.79 MPa to 5.48 MPa. The average characteristics of the edible film can be seen in Table 2.

Table 1. Edible Film Characteristics

Testing Parameters	Treatment				
	P0	P1	P2	P3	P4
Thickness Test (mm)	0,37±0,07^{a}	0,28±0,04^{b}	0,21±0,01^{b}	0,26±0,11^{b}	0,19±0,02^{b}
WVTR test (gram/m2/day)	39,81±14,53^{ab}	19,91±4,60^{c}	37,82±7,62^{bc}	57,72±15,07^{a}	43,79±13,79^{ab}
Tensile Strength Test (MPa)	0,9±0,18^{a}	0,55±0,10^{b}	0,58±0,13^{b}	1,05±0,34^{a}	0,57±0,13^{b}
Elongation Test (%)	76,96±2,43^{b}	80,72±9,77^{b}	95,74±15,00^{b}	85,01±6,23^{b}	136,28±55,96^{a}
Elastic Modulus Test (MPa)	4,74±0,83^{a}	3,05±0,94^{b}	1,81±0,70^{c}	5,48±0,57^{a}	0,79±0,34^{c}

Description: The average result of four repetitions ± standard deviation. Different superscript notations indicate significant differences in Duncan's further test ($P<0.05$).

Thickness Test

The results of the one-way ANOVA (*Analysis of Variance*) analysis showed that the different concentrations of tapioca flour and nanochitosan combinations had a significant difference ($P<0.05$) in the thickness of the edible film. The results of the DMRT (Duncan Multiple Range Test) further test showed that the edible film with the highest thickness was produced at P0 at 0.37 mm and the lowest thickness was produced at P4 at 0.19, which was not significantly different from P1, P2, P3.

Water Vapor Transmission Rate Test (WVTR)

The results of one-way ANOVA (Analysis of Variance) analysis showed that different concentrations of tapioca flour and nanochitosan combinations had significant differences ($P<0.05$) on the Water Vapor Transmission Rate (WVTR) of edible film. The results of the DMRT (Duncan Multiple Range Test) further test showed that the highest edible film WVTR was produced at P3 at 57.72 grams/m2/day which was significantly different from P0, P1, P2 and P4. The lowest WVTR was produced at P1 at 19.91 grams/m2/day which was significantly different from P0, P2, P3, P4.

Tensile Strength Test

The results of the one-way ANOVA (Analysis of Variance) analysis showed that different concentrations of tapioca flour and nanochitosan combinations had a significant difference ($P<0.05$) in the tensile strength of edible films. The results of the DMRT (Duncan Multiple Range Test) further test showed that the highest tensile strength of edible films was produced at P3 at 1.05 MPa and the lowest tensile strength was produced at P1 at 0.55 MPa, which was not significantly different from P2 and P4.

Elongation Test

The results of one-way ANOVA (Analysis of Variance) analysis showed that different concentrations of tapioca flour and nanochitosan combinations had significant differences ($P<0.05$) on the elongation of edible films. The results of the DMRT (Duncan Multiple Range Test) further test showed that the highest edible film elongation was produced at P4 at 136.28% and the lowest elongation was produced at P0 at 76.96%, which was not significantly different from P1, P2 and P3.

Elastic Modulus Test

The average value of the elastic modulus of edible films made from a combination of tapioca flour and nanochitosan in this study ranged from 0.79 to 5.48 MPa. The results of one-way ANOVA (Analysis of Variance) analysis showed that different concentrations of tapioca flour and nanochitosan combinations had significant differences ($P <0.05$) on the elastic modulus of edible films. The results of the DMRT (Duncan Multiple Range Test) further test showed that the highest elastic modulus of edible films was produced at P3 at 5.48 MPa and the lowest elastic modulus was produced at P4 at 0.79 MPa, which was not significantly different from P2.

Application of Edible Film on Fish Siomay During Storage

The application of edible film coating to fish dumplings stored at room temperature on days 0, 3, and 6 in this study resulted in an average moisture content ranging from 45.86% to 61.87%, a pH ranging from 6.34 to 7.05, and a TPC ranging from 0.64 to 11.50 log CFU/g. The test results are shown in Table 3.

Table 3. Test Data for Edible Film Application to Fish Dumplings

Testing Parameters	Treatment	H0	H3	H6
Water content (%)	P0	59,81±0,59^{b}	57,28±0,28^{c}	61,87±0,73^{a}
	P1	58,96±0,99^{b}	56,09±0,82^{cd}	60,23±0,82^{b}
	P2	56,07±0,61^{cd}	52,80±0,37^{ef}	57,41±0,99^{c}
	P3	53,20±0,62^{e}	50,79±1,18^{g}	54,75±1,02^{d}
	P4	49,06±1,00^{h}	45,86±1,79^{i}	51,54±0,96^{fg}
pH	P0	6,75±0,08^{c}	7,02±0,03^{a}	7,05±0,04^{a}
	P1	6,64±0,06^{d}	6,80±0,04^{bc}	6,87±0,06^{b}
	P2	6,57±0,03^{d}	6,73±0,02^{c}	6,81±0,02^{bc}
	P3	6,43±0,07^{ef}	6,44±0,06^{ef}	6,49±0,06^{e}
	P4	6,34±0,04^{g}	6,38±0,08^{fg}	6,48±0,03^{e}
TPC (Log CFU/g)	P0	1,03±0,03^{i}	4,89±0,35^{e}	11,50±0,34^{a}
	P1	0,96±0,06^{ij}	4,26±0,21^{f}	10,10±0,19^{b}
	P2	0,91±0,05^{ij}	4,08±0,10^{f}	9,71±0,10^{c}
	P3	0,73±0,09^{jk}	3,00±0,06^{g}	9,18±0,06^{d}
	P4	0,64±0,04^{k}	2,40±0,08^{h}	9,01±0,08^{d}

Description: The average result of four repetitions ± standard deviation. Different superscript notations indicate significant differences in Duncan's further test (P<0.05).

Water Content Test

The results of the One-way ANOVA analysis showed that the edible film treatment and storage time at room temperature provided a significant difference (P<0.05) in the water content of fish dumplings (Table 2). The results of the DMRT (Duncan Multiple Range Test) further test showed that the highest water content of the edible film was produced at P0 on the 6th day of storage at 61.87% and the lowest water content of the edible film was produced at P4 on the 3rd day of storage at 45.86%.

Hydrogen potential test (pH)

The results of the One-way ANOVA analysis showed that the edible film treatment and storage time at room temperature provided a significant difference (P<0.05) on the pH of fish dumplings (Table 2). The results of the DMRT (Duncan Multiple Range Test) further test showed that the highest edible film pH was produced at P0 on the 6th day of storage at 7.05, while the lowest edible film pH was produced at P4 on the 0th day of storage at 6.34.

Total Plate Count Test (TPC)

The results of the One-way ANOVA analysis showed that the edible film treatment and storage time at room temperature provided a significant difference (P<0.05) on the TPC of fish dumplings (Table 2). The results of the DMRT (Duncan Multiple Range Test) further test showed that the highest edible film TPC was produced at P0 on the 6th day of storage at 11.50 Log CFU/g while the lowest edible film TPC was produced at P4 on the 0th day of storage at 0.64 Log CFU/g.

Organoleptic Test

Organoleptic tests were used to assess the appearance, aroma, taste, and texture of the siomay by 30 panelists. The assessments were conducted on days 0, 3, and 6 with room temperature storage to determine the level of acceptance of fish siomay coated with edible film made from a combination of tapioca flour and nanochitosan.

Appearance

The appearance test was assessed using product-specific brightness, no slime (9), fairly bright, no slime (7), slightly dull, slightly slime (5), dull, slimy (3). The average appearance results can be seen in Table 4.

Table 4. Results of the Organoleptic Appearance Test of Fish Siomay

No.	Treatment	Average Appearance + SDV		
		Day 0	Day 3	Day 6
1	P0	7,9±0,90^{a}	7,7±0,83^{a}	5,4±1,08^{a}
2	P1	8,1±0,56^{a}	7,9±0,63^{a}	5,5±1,22^{a}
3	P2	8,2±0,71^{a}	8,1±0,83^{a}	5,6±1,47^{a}
4	P3	8,1±0,64^{a}	8,0±0,64^{a}	5,5±1,23^{a}
5	P4	8,0±0,64^{a}	7,9±0,73^{a}	5,5±1,25^{a}

Description: The average result of four repetitions ± standard deviation. Different superscript notations indicate significant differences between treatments (P<0.05).

The results of the Krustal Wallis test analysis showed that the appearance of fish dumplings coated with edible film using different concentrations of tapioca flour and nanochitosan combinations was not significantly different (P<0.05) with respect to the length of storage time at room temperature on days 0, 3, and 6. Based on the results of the average appearance of fish dumplings coated with edible film using a combination of tapioca flour and nanochitosan concentrations through organoleptic tests in (Table 3). The appearance value on day 0 of storage ranged between 7.9-8.0 and day 3 ranged between 7.7-8.1 and day 6 ranged between 5.4-5.6.

Odor

The odor test was assessed using the following aspects: product-specific strong (9), moderately strong, product-specific (7), neutral (5), and foul (3). The average odor results can be seen in Table 5.

Table 5. Results of the Organoleptic Test of Fish Siomay Odor

No.	Treatment	Average Odor + SDV		
		Day 0	Day 3	Day 6
1	P0	7,4±1,14^{a}	7,3±1,10^{a}	3,6±0,54^{a}
2	P1	7,5±1,29^{a}	7,5±1,25^{a}	3,7±0,50^{a}
3	P2	7,7±1,49^{a}	7,6±1,47^{a}	4,1±0,72^{b}
4	P3	7,6±1,29^{a}	7,5±1,26^{a}	4,0±0,57^{b}
5	P4	7,6±1,28^{a}	7,5±1,25^{a}	3,9±0,58^{b}

Description: The average result of four repetitions ± standard deviation. Different superscript notations indicate significant differences between treatments (P<0.05).

The results of the Krustal Wallis test analysis showed that the odor of fish dumplings coated with edible film using different concentrations of tapioca flour and nanochitosan combinations was not significantly different (P<0.05) with the length of storage time at room temperature on days 0 and 3 and significantly different (P<0.05) on day 6. The results of the Mann Whitney test on day 6 showed that it was significantly different (P<0.05) in treatments P0 with P2, P3, P4 and P1 with P2, P3, P4. While there was no significant difference (P<0.05) in treatments P0 with P1 and P2 with P3, P4. The highest odor value was produced in treatment P3 at 4.1 and the smallest odor was produced in treatment P0 at 3.6.

Taste

The taste test was assessed using product-specific strong (9), moderately strong, product-specific (7), slightly sour (5), and sour (3). The average taste results can be seen in Table 6.

Table 6. Results of the Organoleptic Taste Test of Fish Siomay.

No.	Treatment	Average Taste + SDV		
		Day 0	Day 3	Day 6
1	P0	7,7±0,72[a]	7,6±0,64[a]	3,8±0,58[a]
2	P1	8,0±0,64[a]	7,9±0,58[a]	3,9±0,58[a]
3	P2	8,1±0,98[a]	8,0±1,02[a]	4,1±0,74[a]
4	P3	7,9±0,71[a]	7,8±0,76[a]	4,0±0,60[a]
5	P4	7,8±0,89[a]	7,7±0,89[a]	4,0±0,47[a]

Description: The average result of four repetitions ± standard deviation. Different superscript notations indicate significant differences between treatments (P<0.05).

The results of the Krustal Wallis test analysis showed that the taste of fish dumplings coated with edible film using different concentrations of tapioca flour and nanochitosan combinations was not significantly different (P<0.05) with respect to the length of storage time at room temperature on days 0, 3, and 6. Based on the results of the average taste of fish dumplings coated with edible film using a combination of tapioca flour and nanochitosan concentrations through organoleptic tests in (Table 5). The taste value on day 0 of storage ranged between 7.7-8.1 and on day 3 ranged between 7.6-8.0 and on day 6 ranged between 3.8-4.1.

Texture

The texture test was assessed using the aspects of dense and compact (9), fairly dense and compact (7), slightly soft (5), and soft (3). The average texture results can be seen in Table 7.

Table 7. Results of the Organoleptic Test of Fish Siomay Texture

No.	Treatment	Average Texture + SDV		
		Day 0	Day 3	Day 6
1	P0	7,4±1,06[a]	7,1±1,02[a]	3,9±0,50[a]
2	P1	7,8±0,89[a]	7,7±0,97[bc]	4,0±0,56[a]
3	P2	7,9±1,07[a]	7,8±1,15[c]	4,2±0,66[a]
4	P3	7,6±1,08[a]	7,4±1,12[ab]	4,1±0,55[a]
5	P4	7,7±1,04[a]	7,6±0,98[b]	4,1±0,46[a]

Description: The average result of four repetitions ± standard deviation. Different superscript notations indicate significant differences between treatments (P<0.05).

The results of the Krustal Wallis test analysis showed that the texture of fish dumplings coated with edible film using different concentrations of tapioca flour and nanochitosan combinations was not significantly different (P<0.05) against the length of storage time at room temperature on days 0 and 6 and significantly different (P<0.05) on day 3. The results of the Mann Whitney test on day 3 showed that it was significantly different (P<0.05) at P0 with P1, P4 and P2 with P3. While there was no significant difference (P<0.05) in the treatments P0 with P3 and P1 with P2, P3, P4 and P2 with P4 and P3 with P4. The results of the largest texture value were in the P2 treatment, namely 7.8 and the smallest in the P0 treatment, namely 7.1.

DISCUSSION

The combination of different concentrations of tapioca starch and fish scale nanochitosan in the production of edible films affects the shelf life and organoleptic quality of fish during room temperature storage. Edible films can act as a barrier to oxygen and physical stress, protecting the product during storage (Abdillah and Charles, 2021). Tapioca starch acts as the main polymer, forming a film structure that exhibits gelatinization properties. This gelatinization process causes amylose molecules to come closer together through hydrogen bonds (Anisa, 2025). Nanochitosan can enhance the edible film's ability to inhibit water vapor permeability and enhance the film's physical and microbiological resistance. This is due to the nanoparticles' ability to spread more evenly and bond strongly with the tapioca starch matrix (Gumaran and Hutabarat, 2023). Furthermore, nanochitosan also has antimicrobial properties that can slow the rate of water vapor and oxygen transfer, thereby extending the shelf life of products coated with edible film (Park *et al.,* 2021). The combination of tapioca starch and nanochitosan forms a more effective edible film for fish dumplings, preserving the color, texture, and odor of the fish longer than edible films without nanochitosan.

Based on the research results, the characteristics of the resulting edible film showed discrepancies in certain treatments, such as thickness parameters with the P3 treatment. The film thickness, which should have been low, actually increased, while mechanical properties such as tensile strength, elongation, and elastic modulus showed opposite results. This is suspected to be influenced by the edible film's constituent materials, namely the concentration of tapioca starch and nanochitosan used, as the two materials have different functional properties. Tapioca starch acts as the primary component of the matrix, while nanochitosan acts as a filler to fill the voids between the polymer chains (Rahim and Musta, 2019). A certain concentration of tapioca starch can improve the quality of the edible film matrix because it acts as the primary component, forming a strong and compact polymer network. The combination with nanochitosan serves to fill the voids in the matrix, thereby increasing its structural density and mechanical properties (Shapi'i *et al.,* 2022).

At optimal concentrations, the combination of both can increase the matrix compactness so that the thickness, tensile strength, and elastic modulus increase significantly (Shapi'i *et al.,* 2022). However, the addition of excess nanochitosan can reduce the proportion of tapioca flour, causing the matrix to become less dense and the filler distribution is inhomogeneous due to particle agglomeration, so that the tensile strength and elongation decrease (Jati *et al.,* 2025). In addition, when tapioca flour is added in excess, the matrix becomes denser so that it is filled with nanochitosan, causing the thickness to increase. However, this condition can also make the film stiffer and less elastic due to reduced polymer chain mobility (Wang *et al.,* 2025). Conversely, at low amounts of tapioca flour, the matrix becomes more porous and many cavities are filled with nanochitosan, so that the thickness increases but the mechanical properties decrease because optimal intermolecular bonds are not formed. This is in line with the research of Ghani *et al.,* (2016) that the uneven distribution of nanochitosan will result in inconsistent mechanical properties, even though the thickness increases.

This discrepancy in mechanical properties can also be influenced by the mixing technique and the order in which ingredients are added. Inhomogeneous mixing can inhibit the formation of hydrogen bonds between the hydroxyl groups in tapioca and the amine groups in nanochitosan, reducing matrix cohesion. These factors cause discrepancies in some treatments (Shapi'i *et al.,* 2022; Hundekari & Swami, 2024). Therefore, selecting the optimal concentration of tapioca starch and nanochitosan and controlling the mixing process are crucial for obtaining edible films with appropriate physical and mechanical properties.

Thickness is an important physical parameter in edible film characterization because it affects the transmission rate of water vapor and oxygen, as well as resistance to physical damage and microbial contamination, thus contributing to the extension of the shelf life of packaged products (Zaidar, 2022). The results of the edible film thickness test in this study met the JIS standard for P2 at 0.21 mm and P4 at 0.19 mm, while P0, P1, and P3 did not meet the JIS standard limit, exceeding 0.25 mm. This is consistent with research by Rizki et al. (2022), which found that thickness increased due to increased total dissolved solids in edible films made from cassava starch and nanochitosan.

Water Vapor Transmission Rate (WVTR) is the rate of water vapor loss calculated based on the amount of water vapor lost per unit time relative to the surface area of the edible film (Hutabarat *et al.,* 2022). The WVTR test results for edible films in this study for all treatments did not meet the JIS standard limit, exceeding 7 g/m2/day. The high WVTR in starch-based edible films is due to a less dense polymer structure, allowing water vapor diffusion through the film's pores (Hutabarat *et al.,* 2022; Rizki *et al.,* 2022).

Tensile strength is a key mechanical property that reflects the edible film's ability to withstand tensile forces before breaking (Izzi *et al.,* 2023). The tensile strength test results for edible films in this study met the JIS standard, exceeding 0.3 MPa. This is in line with Anisa (2025), who stated that increasing the amylose content in tapioca can form a larger polymer network and strengthen hydrogen bonds between molecular chains, resulting in a film with a more compact and stronger structure.

Elongation is the percentage increase in the length of an edible film, measured from the initial length to the breaking point upon pulling (Hutabarat *et al.,* 2022). The results of the edible film elongation test in this study met JIS standards, exceeding 70%. The heating process during edible film production affects the elongation value because the longer the heating, the more water evaporates. This reduction in water content can cause the edible film to become stiffer and less elastic (Hutabarat *et al.,* 2022).

The elastic modulus of an edible film is the ratio of tensile strength to elongation at break (Hikmah, 2022). The results of the edible film elastic modulus test in this study met JIS standards, exceeding 0.35 MPa. Based on research conducted by Kholiq and Kusuma (2024), which produced a high elastic modulus of 3.16 MPa, it states that the elastic modulus value is influenced by the tensile strength value, and the greater the tensile strength value, the higher the elastic modulus value.

Moisture content is an important chemical parameter in determining the quality and shelf life of food products, including fish dumplings. The results of the fish dumplings moisture content test in this study were still in accordance with SNI 7756:2013, namely below 60% on days 0 and 3 of storage. However, on day 6 of storage, it exceeded the SNI maximum limit of more than 60%. High moisture content in ready-to-eat products such as dumplings can accelerate the growth of microorganisms and chemical reactions that cause damage, such as softening of the texture and rotting (Syahrum *et al.,* 2017). The edible film coating functions as a barrier to water vapor transmission, maintaining stable moisture content during storage at room temperature (Muflih, 2022). Research conducted by Bawinto *et al.,* (2015) confirms that the decrease in water content during storage can be caused by evaporation due to temperature and the environment.

The pH value is an important indicator in assessing the freshness and chemical stability of a food product. A neutral or slightly acidic pH can inhibit the growth of spoilage and pathogenic microorganisms, thus maintaining product quality during storage (Laksanawati *et al.,* 2024). The increase in pH during storage of foods such as fish dumplings is associated with protein degradation, which produces basic compounds, such as ammonia, due to enzymatic and microbial activity. This is supported by Mulyanto et al. (2017), who stated that protein decomposition produces compounds such as ammonia, carboxylic acids, and sulfide acids.

Total Plate Count (TPC) is the primary microbiological indicator for assessing the quality and safety of food products using the spread plate method and serves to detect the general number of microorganisms during storage (Damayanti *et al.,* 2020). The results of the TPC test for fish dumplings in this study showed that the TPC values on days 0 and 3 of storage were still within the Indonesian National Standard (SNI) limit, at below 5×104 Log CFU/g. However, on day 6 of storage, the fish dumplings exceeded the SNI limit, exceeding 5×104 Log CFU/g. Fish-based products such as dumplings have high water and protein content, making them susceptible to microbial growth if not properly protected (Santoso *et al.,* 2021). Nanochitosan has been shown to be effective in inhibiting microbial growth due to its antimicrobial properties (Ngo *et al.,* 2020). Meanwhile, tapioca flour, as the main matrix, plays a role in forming a dense and integrated film structure, thus inhibiting the diffusion of water and oxygen, which are factors supporting microbial growth (Laksanawati *et al.,* 2024).

The appearance of fish dumplings on days 0 to 3 still complied with SNI 7756:2013, characterized by bright color and no slime. A significant decrease occurred on day 6, marked by a dull color, the appearance of mucus, and white spots due to microbial activity (Handayani *et al.,* 2019).

The highest odor value was found in treatment P3 at 4.1, and the lowest odor value was found in treatment P0 at 3.6. On days 0 and 3, the siomay odor remained in accordance with Indonesian National Standards (SNI), while on day 6, the odor exhibited a foul odor that did not comply with SNI. Nanochitosan inhibits the growth of volatile-producing bacteria until day 3 (Santoso *et al.,* 2021).

The siomay flavor remained distinctive until day 3, with no off-flavors, indicating protection against fat oxidation and protein degradation. The decrease in flavor on day 6 was attributed to the formation of acidic compounds from protein decomposition by microorganisms (Handayani *et al.,* 2019).

The siomay texture remained dense and compact until day 3, maintaining internal moisture and preventing microbial contamination (Syahrum *et al.,* 2017). However, on the 6th day, the texture deteriorated to become soft due to bacterial activity which reduced the binding strength of the constituent materials (Handayani *et al.,* 2019).

CONCLUSION

Based on the results of the research that has been conducted, it can be concluded that the edible film with a combination of tapioca flour and nanochitosan produces an edible film that meets the Japanese Industrial Standard (JIS) standards in tensile strength, elongation, and elastic modulus, but exceeds the limits in thickness and WVTR. The best treatment for thickness and elongation was obtained at P4, while tensile strength and elastic modulus were at P3. This combination significantly affected the shelf life and organoleptic value of fish dumplings at room temperature storage, with the best treatment of water content, pH, and TPC at P4, and organoleptic at P2. Overall, this combination was able to maintain the quality of fish dumplings during storage until the 3rd day.

ACKNOWLEDGEMENT

The author would like to express his gratitude and appreciation to all parties who have made valuable contributions to this research.

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