Characterization of physical and chemical properties of swanggi fish meatballs with edamame paste substitution

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Abstract. Swanggi fish is characterized by high protein content, firm texture, and white flesh. This fish is well-suited for developing value-added products such as meatballs. The quality of Swanggi fish meatball products depends significantly on the type and formulation of raw materials used. This research aims to assess the impact of substituting swanggi and surimi fish meat with edamame paste on the physical and chemical properties of fish meatballs. The research method used a randomized block factorial design, consisting of 2 factors with 2 repetitions. Factor A is surimi and fish meat, while Factor B is the substitution of edamame for fish meat and surimi. Parameters measured in the fish ball products included water-holding capacity, elasticity, texture, protein content, and moisture content. Results show that surimi, as a raw material, yields superior physical and chemical properties compared to fish meat. The optimal formulation consisted of 70% surimi and 30% edamame paste, producing meatballs with a water-holding capacity of 30.59%, elasticity of 5.00, texture of 15.86 N, protein content of 26.79%, and moisture content of 70.70%. These findings demonstrate the potential of edamame-enriched surimi formulations to improve the quality of Swanggi fish meatballs.

1 Introduction

Fish meatballs are made from fish meat that is shaped into balls and mixed with spices, flour, and other additives to produce a chewy texture and delicious taste. Meatballs should be made from white fish meat, which is high in protein and low in fat. One type of fish that is good for making meatballs is swanggi fish. Swanggi fish (Priacanthus macracanthus) is a marine fish that has thick, white meat, contains 83.4% protein, and is low in fat [ ]. This type of fish is also widely caught by fishermen in the Situbondo district, so it is inexpensive. The East Java Provincial Statistics Agency reported that the production of swanggi fish reached 12,681 tons in 2020 [2]. For these reasons, swanggi fish is very suitable for producing

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meatballs. The production of swanggi fish meatballs is expected to increase economic value and diversify fishery products.

Fish meatballs are protein-based processed products with characteristic properties, namely a chewy, compact, elastic, juicy, and savory texture that is widely enjoyed. These distinctive properties of fish meatballs are contributed by the formation of myofibrillar protein gels that form a three-dimensional network during heating (Park, 2014; Lanier, 1992). Fish meatballs made from swanggi fish meat produce a soft texture. The formation of a high-quality gel in fish ball production is very important, where WHC greatly affects texture and cooking stability (Yin et al., 2023). The quality of swanggi fish balls is greatly influenced by the type and characteristics of the raw materials used. To improve the gel strength of swanggi fish ball dough, surimi can be used. Surimi is a processed fish intermediate obtained through repeated washing with water { }. This process will produce myofibril protein extract which has high gel strength, thus forming a chewy meatball texture.

Surimi or partial surimi incorporation is often used to improve gel strength, elasticity, and WHC in fish products due to its concentrated myofibrillar protein matrix (Park, 2014). However, current food innovation trends encourage the integration of plant-based ingredients to improve nutrition, reduce formulation costs, and increase functionality. One type of binder that can be used is edamame.

Edamame (Glycine max L. Merrill) is a green soybean vegetable originating from Japan. Edamame: 100 g of peas contains 582 kcal, 11.4 grams of protein, 7.4 grams of carbohydrates, 6.6 grams of fat, 100 mg of vitamin A, 0.27 mg of B1, 0.14 mg of B2, 1 mg of B3, and 27 mg of vitamin C. Edamame paste, which is rich in protein, fat, and natural polysaccharides, allows it to function as an effective water-binding and retaining agent. It has been proven that the addition of edamame paste in making chicken sausages has a positive influence on the texture and water-holding capacity [4]. Studies on soy-based binders show improvements in juiciness, texture, and nutritional value in ground meat systems (Nugroho, 2025; Xu et al., 2005). Edamame also has a less unpleasant taste than old soybeans, so it is more suitable to mix with fish meat.

The use of edamame as a binder has been widely practiced. However, research on the interaction between fish myofibrillar protein and, in particular, formulation combinations with Swanggi fish or surimi for meatball products is still limited. Therefore, it is necessary to study the mechanism of edamame paste substitution for fish myofibrillar protein, which affects texture, WHC, color, and chemical composition, as this is very important for optimizing gel formation and designing fish meatballs combined with natural vegetable binders that are rich in nutrients and high in protein.

This study aims to determine the effect of using surimi and fish meat, as well as substituting edamame paste as a binding agent, on the physical and chemical properties of swanggi fish meatballs. Determine the optimal formulation of fish meat or surimi, as well as the percentage of edamame paste substitution as a binding agent, to produce fish meatballs that exhibit good physical and chemical properties. This study is expected to support the development of knowledge about the formulation of edamame paste combinations based on fish-based food ingredients that produce highly nutritious functional foods.

2 Materials and Methods

2.1 Materials

The materials for making meatballs include fresh swanggi fish, measuring 20.7 cm and weighing around 110.5 grams, is obtained from Besuki Market in Situbondo Regency. The swanggi fish, measuring 20.7 cm and weighing approximately 110.5 grams, was obtained from Besuki Market in Situbondo Regency. The fish was sent to Jember in a styrofoam box filled with ice cubes. Frozen edamame beans are sourced from PT Mitratani 27, Jember. The additional ingredients, namely Daun brand salt, Ladaku brand ground pepper, Desaku brand garlic powder, Pak Tani brand tapioca flour, and isolate soy protein flour, were purchased online through the Shopee app; sugar, salt, monosodium glutamate, egg whites, and ice cubes were purchased at the market in Tanjung, Jember Chemicals for analysis are H_2SO_4, boric acid, methyl red indicator, HCL solution, NaOH, cupric sulfate, and distilled water purchased at a chemical store, Jember.

2.2 Equipments

The equipment used in making fish meatballs is digital scales, food processor (Signora), chopper SJ-18 (Getra) o,ven (Venticell), desiccator, stove, centrifuge Model H1-16K (Benchtop), freezer (sharp), Kjeldahl flask (Buchi), Vapodest (Gerhardt), color reader (Konika Minolta, Japan) and texture analyzer (LLOYD, UK).

2.3 Methodology

The research method used a factorial randomized block design, consisting of two factors with with 2 replications. Factor A, namely surimi (A2) and fish meat (A1). While factor B, namely variations in substitution of fish meat with edamame paste as follows: B1 (100:0), B2 (90:10), B3 (80:20), B4 (70:30), B5 (60:40), and B6 (50:50). Data processing used statistical analysis, namely analysis of variance (ANOVA) with a significance level of 5% and average difference testing using the Tukey test or Honest Significant Difference (HSD) test. Statistical data processed using *Microsoft Excel 2019.*

2.4 Production of edamame Substituted Fish Meatballs

This research was conducted in three stages: 1) production of frozen surimi, 2) production of frozen paste, and 3) production of fish balls substituted with edamame paste.

2.4.1 Production of frozen surimi

The stages of the surimi production process are trimming, leaching, filtering, mixing, packaging, and freezing. The trimming process involves cutting off the head, guts, skin, bones, and tail. Then, the fish body is filleted with a knife, and the fish meat is removed using a spoon. The leaching process is carried out by adding cold water, stirring for 10 minutes, then filtering with a filter cloth and pressing. The leaching process is repeated 3 times. Next, it is mixed with 0.3% tripolyphosphate and 2% salt until homogeneous. The surimi is packaged in plastic and frozen in a freezer at -30°C for 24 hours to obtain frozen surimi [}.

2.4.2 Production of Edamame Paste

Edamame pasta production stages include thawing, peeling, grinding, packaging, and storage. The thawing process was carried out at room temperature for 3 hours. Peeling the edamame skin is done manually. Grind the edamame seeds using a chopper on speed 2 for 10 minutes until they form a smooth paste. Next, it is packaged in plastic and frozen in a freezer at -30°C for 24 hours.

2.4.3 Production of Fish meatballs

There are several production processes for swanggi fish meatballs, which are substituted with edamame paste, namely weighing the ingredients, mixing, grinding, molding, cooking, draining, cooling, packaging, and freezing. [(Modifikasi Nuraini et al, 2011)]. The production process of swanggi fish meatballs, which are substituted with edamame paste, can be seen in Figure 1.

The fish ball formulation produced consists of 200 grams of surimi, swanggi fish meat, and edamame; 50 grams of tapioca; 46.5 grams of egg white; 2 grams of pepper powder; 20 grams of powdered garlic; 5 grams of sugar; 2 grams of sodium glutamate; 50 grams of soy protein isolate flour; and 60 grams of ice cubes.

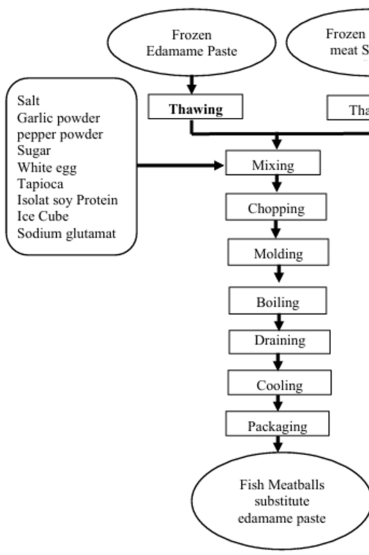

Fig . 1. Flowchart of Making Fish Meatball [Modifikasi Nuraini et al, 2011]

2.5 Parameter

The parameters examined in the fish meatballs made from surimi and swanggi fish meat, using edamame paste as a substitute binder, focused on their physical and chemical properties. The physical properties assessed included water holding capacity (WHC) using Centrifuge Methode [**Rawdkuen],** the folding test [**Park, J.W. (2014).**], and texture with texture analyzer (IOPbu yanti) , while the chemical properties evaluated comprised protein content using Kjeldahl method [(SNI 01-2891-1992) and moisture content Moisture content analysis was conducted using gravimetric method [AOAC)].

3 Results And Discussions

3.1 Physical properties

The physical properties of fish meatballs are characteristics that can be measured without changing their composition. The physical properties of fish meatballs can change during processing and storage [5]. Testing the physical properties of fish meatballs substituted with edamame aims to determine product quality and consumer acceptance. Apart from that, it can also be used to determine that the product meets the 2014 SNI 3818 standard. The physical property parameters of the fish meatballs tested are texture, elasticity, tenderness, and color [4]. The results of the analysis of the physical properties of swanggi fish meatballs, in which fish meat is treated with surimi substituted with edamame paste, are presented in Table 1.

Table 1. Physical Properties of Fish Meatballs Made from Surimi and Swanggi Fish Meat, Substituted with Edamame Paste as a Binding Agent.

Treatmens	Physical Properties		
	Water Holding Capacity (%)	Folding Test (Score)	Texture (N)
A1B1	24.14 ± 0.06^{b}	4.00 ± 0,00^{ab}	10.76 ± 2.33^{ab}
A1B2	24.41 ± 1.54^{b}	4.00 ± 0,71^{ab}	10.73 ± 0.95^{b}
A1B3	25.22 ± 1.29^{ab}	3.50 ± 0.00^{b}	11.54 ± 0.14^{ab}
A1B4	28.23 ± 0.52^{ab}	4.00 ± 0.71^{ab}	11.64 ± 0.97^{ab}
A1B5	27.64 ± 3.92^{ab}	3.50 ± 0.00^{b}	11.26 ± 0.07^{ab}
A1B6	27.18 ± 0.91^{ab}	3.00 ± 0.00^{b}	6.27 ± 0.83^{b}
A2B1	25.48 ± 2.89^{ab}	5.00 ± 0.00^{a}	12.51 ± 2.88^{ab}
A2B2	27.86 ± 0.58^{ab}	5.00 ± 0.00^{a}	14.54 ± 0.25^{ab}
A2B3	24.59 ± 0.83^{b}	5.00 ± 0.00^{a}	14.37 ± 1.07^{ab}
A2B4	30.59 ± 0.87^{a}	5.00 ± 0.00^{a}	15.86 ± 0.21^{a}
A2B5	28.45 ± 0.38^{ab}	5.00 ± 0.71^{ab}	9.23 ± 0.86^{b}
A2B6	24.54 ± 1.29^{b}	4.50 ± 0.00^{a}	9.41 ± 1.89^{b}

Description:
A1B1 (100%, 0% edamame), A1B2 (90% fish meat, 10% edamame), A1B3 (80% fish meat, 20% edamame), A1B4 (70% fish meat, 30% edamame), A1B5 (60% fish meat, 40% edamame), A1B6 (50% fish meat, edamame 50%), A2B1 (surimi 100%, edamame 0%), A2B2 (surimi 90%, edamame 10%), A2B3 (surimi 80%, edamame 20%), A2B4 (surimi 70%, edamame 30%), A2B5 (surimi 60%, edamame 40%), A2B6 (surimi 50%, edamame 50%).

3.1.1 Water Holding Capacity / WHC (%)

WHC of fish meatballs shows the ability of the protein structure of meatballs to bind water [6]. A high WHC value produces a chewy, elastic, and juicy meatball texture. This shows that fluid loss during meatball processing is very low [7]. Apart from that, the WHC value is also related to low cooking loss values, so that fish meatballs contain high nutrition[4]. The WHC value of fish meatballs prepared with fish meat and surimi and the edamame paste substitution treatment ranged between 24.14 % and 30.59%. The results of statistical analysis in Table 1 showed that the interaction of surimi and fish meat swanggi with the substitution of edamame pasta has a significant effect ($P>0.05$) on the water-holding capacity. The results of the 5% BNJ test showed that fish balls treated with a combination of 70% surimi and 30% edamame paste produced a higher WHC value of 30.59 %, compared to fish meat treated without edamame paste, which had a WHC value of 24.14%.

These results indicate that surimi containing myofibrillar protein can improve the gel of fish meatball dough to bind water [8]. During heating, this protein will form a three-dimensional gel network structure that can trap more water, resulting in higher WHC compared to products made from minced fish meat that still contain lipids and non-protein impurities that can interfere with gel formation. Meanwhile, edamame paste acts as a plant-based binding agent containing soluble fiber, starch, and plant protein that can absorb water from fish balls. Edamame paste is trapped in the surimi protein network through hydrogen bonds. On the other hand, in non-surimi formulations, the weaker gel structure limits the ability of edamame components to increase WHC, resulting in relatively lower values

3.1.2 Elasticity (Score)

The folding parameter aims to determine the texture and elasticity of fish meatballs. The folding test is conducted organoleptically by assessing the occurrence of cracks in 3-5 mm thick fish ball slices when folded manually [9]. A high score indicates that the fish meatballs have a dense, elastic texture and are crack-free.

The scores in the folding test of fish meatballs made from surimi and swanggi fish meat substituted with edamame paste as a binding agent ranged from 3.00 to 5.00. The statistical analysis results in Table 1 show that the interaction between surimi and fish meat swanggi with edamame paste substitution has a significant effect ($P>0.05$) on the elasticity. The results of the 5% BNJ test showed that fish balls from the treatment of 50% non-surimi swanggi fish meat with 50% edamame paste produced the lowest elasticity of fish balls with a score of 3. Meanwhile, the treatment of 60% surimi with 40% edamame paste was very elastic with a score of 5.

The interaction of surimi with swanggi fish meat and edamame paste has a significant effect on the elasticity of fish balls. Surimi-based fish ball formulations consistently produced high elasticity values compared to non-surimi treatments. This indicates that myofibrillar protein is responsible for determining the functional performance of gel-based fish products. This is in line with previous studies that noted that surimi contains myosin, which forms a strong gel (Lanier, 1992; Park, 2014). The elasticity of surimi gel is formed during the heating process of myofibrillar protein with other ingredients, thereby forming an elastic, non-cracked, and chewy meatball structure [10].

Meanwhile, the formulation of 60% surimi and 40% edamame paste produced elastic fish balls (score 5). This indicates a synergistic interaction between the functional components of surimi and edamame. At this ratio, myofibrillar proteins are able to form a strong elastic gel network, and the starch and soluble fiber components of edamame paste increase water absorption and fill the microstructure voids, contributing to a smoother cohesive matrix. A similar event was also found in the interaction between animal protein and plant polysaccharides, which increased the homogeneity and stability of meatball gels (Zhang et al., 2021).

3.1.3 Texture (N)

The texture of food products is related to the sensory or organoleptic value of solid materials, namely the impression in the mouth after the process of chewing and tasting food [12]. Texture is an important physical property of food and can affect consumer acceptance. The texture of fish meatballs is chewy, elastic, and not clayey, and has a compact consistency and is not mushy or too hard [6]. The texture of meatballs is influenced by the content and type of fish protein and additional ingredients as a binder[13].

The texture values of fish meatballs made with edamame paste as a binding agent ranged from 6.41 N to 15.86 N. The statistical analysis results in Table 1. show that the interaction between surimi and fish meat swanggi with edamame paste substitution has a significant effect (P>0.05) on the texture. The results of the 5% BNJ test demonstrated that the interaction treatment of 70% surimi with 30% edamame paste yielded the optimal fish meatball texture value of 15.86 N. Conversely, the treatment of surimi and swanggi fish meat with 40% to 50% edamame paste substitution with surimi and swanggi fish meat resulted in low texture values, namely 6.27 N, 9.23 N, and 9.41 N.

The use of edamame paste as a binding agent can enhance the gel strength of meatballs. However, adding high levels of edamame paste may weaken the structure and texture [14]. For example, tests on fish meatballs with more than 30% edamame paste showed significantly lower texture values. Edamame is high in fiber, which can interfere with the emulsification process of fish protein gel in the meatball dough. A poor emulsion in the dough leads to a meatball texture that is soft and inelastic [11].

Combining surimi with a 20% substitution of edamame paste significantly enhances gel strength and yields an optimal fish ball texture, which ranges from 9.23 ± 0.86 N to 14.34 ± 0.25 N. In contrast, using fish meat with edamame paste substitution results in a lower fish.

3.2 Chemical Properties

These include water content, carbohydrates, proteins, fats, vitamins, and minerals. Acidity and alkaline properties help determine nutritional value. Chemical properties also include intrinsic changes that occur during processing and affect the nature of the material. These changes can alter the flavor and texture of processed food products [15]. The difference in water and protein content in fish meatballs will affect their physical properties. Meanwhile, the water and protein content of fish meatballs depends on the type of fish used as raw material and the formulation of other additives. Table 2 shows the chemical properties of fish meatballs from Surimi and Swanggi Fish Meat, Substituted with Edamame Paste as a Binding Agent.

Table 2. Chemical Properties of Fish Meatballs Made from Surimi and Swanggi Fish Meat, Substituted with Edamame Paste as a Binding Agent.

Treatmens	**Chemical Properties**	
	***Moisture Content* (%)**	**Protein content (%)**
A1B1	69.96 ± 0.08^{a}	26.16 ± 0.03^{b}
A1B2	69.60 ± 0.57^{a}	26.60 ± 0.02^{f}
A1B3	69.75 ± 1.06^{a}	26.60 ± 0.04^{f}
A1B4	69.56 ± 0.50^{a}	27.17 ± 0.03^{c}
A1B5	70.26 ± 0.98^{a}	26.95 ± 0.01^{d}
A1B6	69.74 ± 0.98^{a}	27.28 ± 0.06^{bc}
A2B1	74.35 ± 1.05^{a}	26.40 ± 0.03^{g}
A2B2	71.90 ± 0.19^{a}	26.40 ± 0.03^{g}
A2B3	70.78 ± 1.24^{a}	26.60 ± 0.04^{f}
A2B4	70.70 ± 0.42^{a}	26.79 ± 0.01^{e}
A2B5	71.05 ± 1.06^{a}	27.41 ± 0.04^{b}
A2B6	70.90 ± 0.99^{a}	27.63 ± 0.01^{a}

Description:
A1B1 (100%, 0% edamame), A1B2 (90% fish meat, 10% edamame), A1B3 (80% fish meat, 20% edamame), A1B4 (70% fish meat, 30% edamame), A1B5 (60% fish meat, 40% edamame), A1B6 (50% fish meat, edamame 50%), A2B1 (surimi 100%, edamame 0%), A2B2 (surimi 90%, edamame 10%), A2B3 (surimi 80%, edamame 20%), A2B4 (surimi 70%, edamame 30%), A2B5 (surimi 60%, edamame 40%), A2B6 (surimi 50%, edamame 50%).

3.2.1 Moisture Content (%).

The moisture content of food ingredients can determine quality, durability, and physical and sensory properties, including texture, appearance, and flavor [16]. The moisture content of fish meatballs is affected by the types and formulations of ingredients, as well as the processing techniques used. Table 2 presents the moisture content values of fish meatballs made with fish meat and surimi, along with the substitution of edamame paste.

These values range from 69.56% to 74.35%, with an average of 70.79%. Statistical analysis using ANOVA ($p<0.05$) indicated that the treatment involving fish meat and surimi (A) had a significant effect on moisture content. In contrast, the addition of edamame paste (B) and its interaction did not show a significant effect.

The water content of fish meatballs processed with surimi and edamame paste substitution was 71.78%, higher than that of fish meatballs without surimi, which was 69.81%. Surimi is a processed fish meat product that is washed repeatedly. The washing process removes water-soluble sarcoplasm, thereby increasing the concentration of myofibrillar protein. Myofibrillar protein contains actin and myosin, which have high emulsifying capacity. The treatment of surimi will increase due to the stronger activity of myofibrillar protein in binding water. Myofibrillar protein has a water-binding capacity of around 97% [14]. The washing process will increase the hydrophilic properties of surimi, so that it has a high water-holding capacity.

3.2.2 Protein Content (%)

WHC Protein compounds indicate the nutritional value of food ingredients. Protein content can indirectly affect the physical properties of fish meatballs, such as cohesion, structure, and texture. The protein content of fish meatballs in the treatments of fish meat and surimi with edamame paste substitution ranged from 26.16% to 27.63%, with an average of 26.83% (Table 2). Data analysis using ANOVA ($p < 0.05$) showed that treatment factor A, namely fish meat and surimi (A); factor B, namely substitution of edamame paste as a binding agent (B); and the interaction between the two had a significant effect on the protein content of swanggi fish meatballs.

Fish meatballs made with surimi contain 26.8% protein, which is slightly higher than the protein content of meatballs made with fish meat, which is 26.79%. Surimi is created by extracting fish protein through a process of repeated washing, which removes water-soluble protein compounds such as sarcoplasmic proteins, blood, and enzymes [16]. The extraction focuses on myofibrillar proteins, which serve as a dough emulsifier. These proteins bind together fat, water, and other ingredients, forming a meatball dough emulsion. This emulsion is crucial for achieving the compact structure and texture of the meatballs [14].

The treatments that included 40% and 50% edamame substitution (designated as B5 and B6) resulted in higher protein levels compared to the other treatments, yielding protein content of 27.45% and 27.18%, respectively. Edamame, a type of soybean harvested while the pods are still young and green, contains approximately 11% protein[14]. Therefore, incorporating edamame paste into the fish meatballs will positively impact their overall protein content.

The treatment of surimi with edamame paste resulted in a protein content of approximately 26.16% to 27.63% in the fish meatballs. Fish meatballs made with edamame paste have a significantly higher protein content than the Indonesian National Standard (SNI) for fish ball quality, which is set at 9%. This increase in protein is attributed to the specific formulation of ingredients used. The combination of edamame paste and surimi provides a high protein content.

4 Conclusion

The use of surimi and fish meat, as well as the substitution of edamame paste as a binding agent, had a significant effect on physical properties, namely WHC, fold test, and texture, as well as chemical properties, namely water and protein content of fish meatballs. The use of surimi resulted in higher texture, fold test, and WHC values compared to fish meat. Substituting edamame paste above a concentration of 30% caused a decrease in texture, WHC, and fold test (elasticity) values. However, it improved chemical properties, namely water and protein content. The formulation of 70% surimi and 30% edamame paste produces meatballs that have good physical and chemical properties. The water holding capacity (WHC) was measured at 30.59%, with a fold strength of 5.00, indicating elasticity. The texture was recorded at 6.41 N, the protein content was 27.63%, and the water content was 70.78%. This property meets SNI 01-3818-2014 standards.

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