Functional Properties and Chemical Composition of Dried Surimi Mackerel (Scomberomorus Sp) With Different Cryoprotectants and Drying Methods

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Abstract. Dried surimi is a form of surimi that has undergone drying process will be added to food as a food additive. Dried surimi must have a high nutritional content and a good functional properties. This research aims to analyze the functional properties and chemical composition of dried surimi with different cryoprotectants and drying method. This research consisted of sample preparation; making of wet and dried surimi then characterizing. Data analysis was performed descriptively. To determine the difference in significance between each treatment data were analyzed using ANOVA. The results of the analysis showed that the value of protein solubility ranged from 38.38 to 52.26%; water absorption 1.00 to 1.93%; kamba density 0.40 to 0.66%; viscosity 2.57 to 69.83 cP; water content 6.01 to 7.35% and protein content 85.35 to 85.57%. The results of ANOVA of dried surimi showed that the type of cryoprotectant has a very significant effect on protein solubility; drying method and cryoprotectant type have very significant effect on water absorption and water content and drying method has very significant effect on protein content. Dried Surimi is classified as fish protein concentrate type A, with yield ranges from 26.3 to 40.2%.

1. Introduction
Increased consumption of community fish has been carried out by introducing various processed products made from fish by fortifying fish protein into food products. The development of these products requires high quality fish raw materials. One of them is in the surimi form or known as Wet Concentrate Protein. Surimi is one of the processed products originating from Japan. According to Balange and Benjakul 2009; Lanier et al. 2014; Cando et al. 2015 [1], surimi is a concentrate of fish myofibril protein produced through several stages of the process including separation of meat from skin and bones, mincing, washing, adding salt, adding cryoprotectant, and continuing with freezing. Some of the benefits of using surimi include being able to be used directly for processing various fish-based preparations and for the fortification of various processed products; odorless; supply and price are relatively stable because they can be stored for a long time; easier handling; lower storage, distribution and transportation costs and less waste disposal problems.

One characteristic of this surimi is that it utilizes protein or fish protein concentrate properties. Assumption that if in the future, fish resources will be increasingly depleted, surimi can become a superior product that is able to answer the needs of community fish protein. One of the potential fish used as surimi raw material is Mackerel fish. Besides being sold in fresh form, Mackerel is processed into various products. The processing of mackerel fish as surimi raw material in Indonesia has been widely used, in addition to mackerel fish has white meat characteristics that are very well used for a variety of products, mackerel fish also has a high enough nutritional protein that is 21.4gr / 100gr fish [2]

For wider use, surimi can be converted into flour or dry form so that it is called dry protein or fish protein concentrate (FPC). In the form of flour, surimi has many advantages including being able to be stored at room temperature, easy to handle so that the distribution costs are cheaper, easy to transport and store, easy to apply in industry, and easy to mix in dry mix [3]. Research that has been carried out...
on the functional properties of dried surimi from three different types of fish such as: yellow selar fish; beloso fish, purple spotted big eye fish and fish cured [3] on protein and carbohydrate content; and research to find out the functional properties of curied fish surimi flour using the oven and freeze drying method [4] but are limited to functional trait tests.

The demand for fish protein ingredients including dried protein for the development of functional foods or ready-to-eat products in the world is gradually increasing. The use of dry surimi protein in the food industry is as a binder, dispersing agent, and emulsifier, besides it can also be used as a formulation and enrichment material in food. Use in food is also well known for its functional properties besides being a source of protein containing amino acids the body needs [5]. Dried surimi produced in addition to having high nutritional value must also have good functional properties. Characterization of the properties of this flour is very necessary to develop product formulations that are in accordance with the targeted quality so that it can be consumed by humans, functional properties and nutritional value of surimi flour include solubility test, water absorption, kamba density, viscosity, proximate and amino acid content.

The processing of dried surimi uses drying by evaporating a portion of the ingredient water or removing liquid from the material [6]. The main objective of drying technology developed in the food industry is to extend the shelf life of a food product. The use of oven drying method, is considered to have a low cost, but this drying process in addition can cause protein denaturation besides it can also reduce the functional properties of surimi flour protein considering the use of surimi flour in food formulations as ingredients of fish protein fortification must be ensured to have high nutritional standards so that it can make a good contribution to the fulfillment of human nutrition in addition to having good functional properties. Therefore, to prevent protein denaturation and to maintain the functional properties of surimi flour protein, one of them uses a drying method that is considered better even though it is considered to have an expensive cost of using the freeze drying method. The freeze drying process consists of freezing the product and subsequent drying in a vacuum chamber. The drying process is carried out in two phases: primary drying which removes frozen water through sublimation and secondary drying which removes bound water without freezing [7]. Freeze drying often presents stability problems due to the instability of the conformation of many proteins when subjected to freezing and dehydration pressure. Therefore, proteins must be stabilized against these two fundamentally different pressures. The use of cryoprotectants for surimi production is important to maintain gel stability during freezing and thawing. Cryoprotectants added to the manufacture of surimi are intended to prevent denaturation of proteins, namely myofibrillar proteins during freezing and storage by binding to water and protein and supporting the gel structure after melting by reducing protein aggregation between molecules [8]. Cryoprotectants used such as disaccharides, polysaccharides, polialaccharides, polyalcohols, acids, or polyphosphates [9].

The functional properties of surimi flour depend on the type of fish and the drying method used [10]. But whether the use of Cryoprotectant types and the treatment of different drying methods can affect the functional properties and nutritional value of dried surimi. Therefore a study was carried out to find out the functional properties as well as the chemical composition of protein content and water content of dried surimi Mackerel fish (Scomberomorus Sp) with different types of cryoprotectant and drying method.

2. Experimental

2.1. Material
The raw material to be used is Mackerel fish (Scomberomorus commerson) was obtained from the traditional market Ambon. Supporting materials to be used are ices, STPP (Sodium tri polyposphate), refined sugar (sucrose) and salt (NaCl). While the equipment used is an electric oven, Freeze Dryer, HPLC, electric meat grinder, blender, knife, draining container, basin, cutting board, nylon press / cotton cloth, aluminum pan, spoon, flour sieve, analytical balance, vacuum sealer, plastic packaging, as well as a set of instruments and other laboratory equipment for analysis.
2.2. Preparation of Sample
Weeding is the removal of the head and entrails of fish and then washed. Filleting namely the separation of meat from skin and bone.

2.3. Making of wet surimi
After preparation of sample, the meat is chopped and then washed with cold water five times with the ratio of fish and ice = 1: 3 and the addition of 0.1% salt in the last washing. After the leaching process, pressing is done with a press cloth. After pressing the meat, it is then milled until it becomes mashed and weighed. The final process was mixed with 0.3% cryoprotectant for each type: STPP, sucrose, salt and without adding of cryoprotectant.

2.4. Making of Dried Surimi
Surimi with 0.3% cryoprotectant type, divided into two parts. The first part of surimi is arranged thinly and evenly in an aluminum container then dried in an electric oven at 60°C for ± 7 hours until it is completely dry. The second part of the surimi that has been separated previously will go through a fast freezing process in the freezer at a temperature of ± 25°C for ± 30 hours. The frozen Surimi was then dried in a freeze dryer with a temperature of ± 49.9°C for 30 hours. After drying, the milling is carried out with a blender so that it is homogeneous and weighed to find out the yield. The final process of making surimi flour is sifting to produce homogeneous and refined surimi flour.

2.5. Analytical Procedure
Analytical methods performed on this surimi flour include: calculation of yield based on the ratio between the weight of the surimi produced and the initial weight of the fish; Analysis of functional properties (Protein solubility [11]; Water absorption gravimetric method [12]; Kamba density [13]; Viscosity brookfield method [14]; Moisture test oven method [15]; Protein content in the Kjeldahl method [16].

2.6. Data analysis
Data analysis was done descriptively. Research data are displayed in the form of histogram. To determine the difference in significance between each treatment data were analyzed using analysis of variance (ANOVA). The combination of research treatments as shown in Table 1

| Cryoprotectant Type | Drying Methods         |
|---------------------|------------------------|
|                     | Oven                  | Freeze drying |
| STPP                | STPPOV                | STPPFD        |
| Sukrose             | SukrOV                | SukrFD        |
| Salt                | SaltOV                | SaltFD        |
| No Cryoprotectant   | NCOV                  | NCFD          |

Where:
STPPOV = addition of 0.3% STPP cryoprotectant with oven drying
SukrOV = addition of 0.3% sucrose cryoprotectant with oven drying
SaltOV = addition of 0.3% salt cryoprotectant with oven drying
NCOV = without the addition of cryoprotectant with oven drying
STPPFD = addition of 0.3% STPP cryoprotectant with Freeze Drying
SukrFD = addition of 0.3% Sucrose cryoprotectant with Freeze Drying
SaltFD = addition of 0.3% Salt cryoprotectant with Freeze Drying
NCFD = without the addition of cryoprotectant with Freeze Drying
3. Results and Discussions

3.1 Yields

Yields of mackerel fish surimi flour by the oven method ranged from 26.3 to 29.5% while the freeze drying method ranged from 35 to 40.2%. The yield of surimi flour produced is classified as moderate due to several factors including the fact that the water content of the raw material of surimi is quite low, ranging from 67.88 to 68.51% so that the drying process takes place more quickly, in addition the processing of surimi during fish washing also affects the flour yield which causes the loss of sarcoplasmic protein and a portion of the myofibril protein carried by the water used when washing fish. Another factor affecting yield is the drying method used. However, the yield of surimi flour produced still meets the minimum standard of fish meal yield determined by the Ministry of Trade (1989), which is 26.3%.

3.2 Physical and functional characteristics of surimi flour

Food quality is determined not only by its chemical nature or nutrient content but also by its physical properties. The average value of the functional properties of dried surimi is shown in Fig. 1.

![Figure 1. The average value of the functional properties of dried surimi](image)

3.2.1. Protein Solubility. Figure 1 shows that the addition of cryoprotectant tends to reduce the solubility of the protein means that the protein that can be extracted is getting smaller or the protein is in a slightly soluble state. The addition of protein solubility salt is the smallest due to the influence of the ionic strength of the dissolved salt where the strength of the ions increases so that the water molecules bound by ions will be more and not enough to hydrate protein molecules. As a result, interactions between proteins are strong and their solubility decreases.

In the addition of neutral salts such as STPP, the protein solubility is greater than other cryoprotectants. This is due to increased ionic strength so that the solubility of the protein will be even greater. Protein can be precipitated from aqueous solution by adding neutral salts in high concentrations (salting-out), such as: magnesium salts, calcium sulfate, sodium sulfate, and phosphate salts (STPP) so that it will affect the strength of the ions in the solution. If ionic strength increases, protein solubility will be even greater. The effect of salt in increasing protein solubility is called the salting-in effect. At higher salt concentrations, protein solubility will decrease called the salting-out effect. At low ionic strength, ionized protein groups will be surrounded by opposing ions so that
interaction between proteins decreases and solubility increases. But if the strength of the ions increases, more water molecules are bound by ions so that it is not enough to hydrate protein molecules. As a result, interactions between proteins are stronger and their solubility decreases [17].

Protein solubility will be affected by the ionic strength of dissolved salts. The addition of cryoprotectant can reduce fat oxidation because fat oxidation products will damage the protein itself so that its solubility decreases. Other influential factors are the type of fish, the state of the fish meat, the duration of cooling or freezing, the low temperature and the speed of cooling or freezing. In general, the lower the temperature, the less protein is dissolved. Other factors that influence the solubility of proteins in a liquid are the type and composition of amino acids that make up proteins and the types of solvents. External factors such as water, fat, sugar, processing treatments such as salt addition, stirring and chemical / enzymatic modification also greatly affect the functional properties of proteins. The more protein that can be extracted, the greater the solubility of the protein and vice versa.

3.2. Water Absorption. Water absorption or hydration is the time required for a flour sample to absorb water. Water absorption or hydration is one of the important functional properties of proteins. Protein is the most important component influencing the absorption of water of a material [18]. Protein has the ability to bind water so that the higher the protein content of a food, the more water absorption. Besides that the binding of water can be strongly influenced by the addition of certain salts such as phosphate in this case STPP with a view to reducing water loss during heating [19].

The results showed that the absorption capacity of surimi flour ranged from 1.00 to 1.93%. The histogram of surimi flour water absorption shows that drying by the oven method with high temperature tends to reduce the ability to absorb water. This results in the reduction of the hyophilic group and the increase in the hydrophobic protein group due to heating. The opposite occurs when using the Freeze Drying method, the increased ability to absorb water is due to the increase in hyophilic groups and the reduction of hydrophobic protein groups. Apart from the influence of protein, the use of cryoprotectant also affects the water absorption. That is because cryoprotectant can cause binding of the transverse bond between actin and myosin, thus causing water trapping in protein tissues [20].

Fig.1 shows that the addition of cryoprotectant tends to increase the absorption of water except in the addition of salt by the oven method. Water absorption of surimi flour ranged from 1.00 to 1.93% where the highest in surimi flour with the addition of sugar. So the ability of surimi flour to absorb water with the addition of sugar is greater than STPP, salt and without addition. This is because sugar can cause water in surimi to become bound thus reducing water activity. The addition of cryoprotectant tends to increase water absorption because cryoprotectant can cause binding of the transverse bond between actin and myosin in fish meat, thus causing water trapping in protein tissue [20]. Water absorption is inseparable from protein involvement. Interactions between proteins and water such as water binding capacity, solubility, emulsion power, viscosity, gel power and syneresis determine the functional properties of these proteins in food. The greater the amount of water bound, the better the quality of the texture and mouthfeel of the food produced. Therefore, the quality of surimi flour produced is determined by its dispersion power, water absorption capacity, solubility, emulsion power, viscosity, gel power and syneresis density. The greater the amount of water bound, the better the quality of the texture and mouthfeel of the food produced. Therefore, the quality of surimi flour produced is determined by its dispersion power, water absorption capacity, solubility, emulsion power, viscosity, gel power and syneresis density. The greater the amount of water bound, the better the quality of the texture and mouthfeel of the food produced. Therefore, the quality of surimi flour produced is determined by its dispersion power, water absorption capacity, solubility, emulsion power, viscosity, gel power and syneresis density. The greater the amount of water bound, the better the quality of the texture and mouthfeel of the food produced. Therefore, the quality of surimi flour produced is determined by its dispersion power, water absorption capacity, solubility, emulsion power, viscosity, gel power and syneresis density. The greater the amount of water bound, the better the quality of the texture and mouthfeel of the food produced. Therefore, the quality of surimi flour produced is determined by its dispersion power, water absorption capacity, solubility, emulsion power, viscosity, gel power and syneresis density.
The results showed that the density of surimi flour cages ranged from 0.40 to 0.66\%. When compared with commercial fish meal around 0.77\%, the surimi flour produced has a smaller kamba density. Fig. 1 shows that the addition of cryoprotectant does not affect the density of the resulting surimi flour. The density of surimi flour is influenced by the water content of the material [22]. Low flour water content in the oven method is due to the large volume of water that evaporates when drying. As a result of the low water content of the flour, the volume of flour granules gets smaller so that the greater the density of the resulting surimi flour kamba.

The value of the density of dried surimi with the oven drying method ranged from 0.62 to 0.66\%, which tends to be greater than that of the freeze drying method, which ranges from 0.40 to 0.45\%. Foods with low kamba (voluminous) density will cause children to get full quickly before their energy needs are fulfilled [23]. Large density of kamba is very good in the process of storing flour, because the place used to store flour with the same weight will be smaller [24].

3.2.4. Viscosity. Measurement of viscosity using spindle Viscometer no.1 with a rotating speed of 60 rpm. The value of viscosity of dried surimi varies, ranging from 2.57 to 69.83 cP. Based on the Picture 1 shows that the addition of cryoprotectant STPP and sugar has the highest viscosity value, followed by treatment without the addition of cryoprotectant and the lowest viscosity value is the addition of salt cryoprotectant. So the substances that are dissolved in the addition of STPP and sugar are more than in the addition of salt and without the addition of cryoprotectant, so that the solution gets thicker which causes the resulting higher viscosity value.

The viscosity value of dried surimi by the oven method is lower than the viscosity value of the Freeze Drying method. This shows that the substance dissolved in the oven method is less than in the Freeze Drying method. The treatment of drying with a hot temperature (oven) can reduce the viscosity of the gel due to damage to the Hydrogen bond, breakage of the structure of the swelling of the granules because the granules are fragile and cannot stand the heating process. But on the contrary in drying with lower temperatures (Freeze Drying), the resulting viscosity is higher because of interactions including the formation of hydrogen bonds at low temperatures or exothermic processes [25].

3.3 Analysis of surimi flour variety analysis
Recapitulation of data from the analysis of variance with ANOVA is shown in Table 2.

| Parameters          | Drying Methods | Cryoprotectant Type | Interaction of Drying Methods and Cryoprotectant Type |
|---------------------|----------------|---------------------|-------------------------------------------------------|
| Protein solubility  | **             | **                  | *                                                     |
| Water absorption    | **             | **                  | *                                                     |
| Density kamba       | *              | *                   | *                                                     |
| Viscosity           | *              | *                   | -                                                     |
| Water content       | **             | **                  | **                                                   |
| Protein content     | **             | *                   | (-)                                                   |

Note:
* = significant effect
** = very real effect
(-) = No significant

The thickness of the ingredients is determined by the pH and sugar content. The process of drying surimi into dried surimi in general can result in random termination of α-1.4 bonds in the middle
(polysacharide chains) so that amylose and amylopectin fragments are produced which are lower than the original. More and more amylose and amylopectin fractions in the product can reduce the viscosity of the resulting paste and can also increase the likelihood of retrogradation [26].

Based on recapitulation of data from the analysis of variance in Table 2 shows that the drying method and type of cryoprotectant treatment have a very significant effect on the solubility of surimi flour protein, each of which is very significant at the level of 1% (α = 0.01) and the level of 5% (α = 0.05). The results showed that the solubility of dried surimi protein ranged from 38.38 to 52.26%. The dissolved protein in the oven treatment method is smaller than that of the Freeze Drying method, which shows that less protein can be extracted than the freeze drying method. This is because heating with an oven causes the protein contained in flour to develop or trap water particles around it so that the protein solubility is lower. Protein denatured due to heating treatment, thus reducing its solubility. The inner molecular layer (globula) which is hydrophobic (dislikes water) will come out while the hydrophilic part (likes water) will be folded inward. Multiplication or pembakikan will occur when the protein approaches the isoelectric pH, where the solubility in water is generally the smallest at pH 4.8 – 6.3 and then the protein will clot and settle [27]. The amount of protein solubility loss can generally be expressed as the amount of extractable protein, which mostly contains actomiosin, myosin, sarcoplasmic proteins, including other components of nitrogen [28].

Based on Table 2 shows that the drying method and the type of cryoprotectant have a very significant effect on the absorption capacity of the dried surimi water produced and the drying method, type of cryoprotectant and the interaction between the two treatments significantly affected the density of dried surimi cages.

3.4 Chemical analysis of water content and protein content of surimi flour

The results of the analysis of water content and protein content of dried surimi are shown Figure 2. The water content of dried surimi ranged from 6.01 to 16.77%. While protein content ranges from 79.28 to 85.57%. When compared with the quality standard of fish meal set by FAO (1972)[29], mackerel fish flour produced has met the criteria for the quality standard of Type A and Type B fish meal except the freeze drying method. Fish meal types A and type B include fish meal for human consumption [23]. The chemical composition of surimi flour has met the standards of fish meal [30]. The results of water content and protein content of dried surimi is shown in Fig. 2.

![The Average Water and Protein Contents of Dried Surimi](image)

Figure 2. The average water and protein contents of dried surimi
3.4.1. Water content. Figure 2 shows that the water content of mackerel fish dried surimi with variations in drying treatment and cryoprotectant types ranged from 6.01 to 16.77%. Oven method fish flour meets the fish flour standard according to FAO type A which is 10% [29], while the surimi flour Freeze drying method does not meet the fish flour standard according to FAO but in the Freeze drying method of sucrose with a water content of 11.96% still meets the standard for flour content in general which is 12%, the drying material is hygroscopic than the original material, so during storage the material is always placed in a dry and non-humid space. Water is an important component because it can affect the appearance, texture and taste of food [23]

Water content is very influential on the quality of food ingredients because in general the durability of food is closely related to the water content they contain. The lower the water content, the slower the growth of microbes so that food can last longer.

There is a close relationship between water content in food and its durability. Reducing water either by drying or adding water vaporizers aims to preserve food so that it can withstand microbiological and chemical damage [14]. Meanwhile, the water content in food ingredients affects the food resistance to microbial attacks stated in Aw. Various microorganisms have a minimum Aw so that they can grow well, for example Aw bacteria = 0.90; Aw yeast = 0.80 to 0.90 and Aw mold = 0.60 to 0.80 [31]

3.4.2. Protein content. The results of the analysis of dried surimi protein levels in this study have high protein levels, where the surimi flour protein content of the oven method ranges from 85.35 to 85.57% while the freeze drying surimi protein content method ranges from 79.28 to 79.72%. This result exceeds the fish meal standard according to the World Food Agency (FAO) category A which is at least 67.5% [29,30]. Protein content by the oven method is higher than protein content by the method Freeze drying but still exceeds the quality standard of good quality fish meal as suggested by [32,30] which is 60 to 75%, protein content of more than 50% even exceeds the protein content of mackerel fish flour as stated in the fish nutrition value database (2010)

The mean water content and protein content of Mackerel fish meal based on the method of drying compared with fish meal according to FAO [28,31] shown in Table 3.

Table 3. Average water and protein content of mackerel fish flour research results based on drying method and fish flour according to fao [28,31]

| Chemical Composition | Fish flour Mackerel (Oven Method) | Fish flour Mackerel (Freeze Drying Method) | Fish flour<sup>a</sup> | Fish flour<sup>b</sup> |
|----------------------|----------------------------------|---------------------------------------------|------------------------|------------------------|
|                      | Max 10                           | Max 10                                      | Max 10                 | Max 10                 |
|                      | Min 65                           | Min 65                                      | Min 66                 | Min 60                 |
| Water content (%)    | 6.85                             | 14.87                                       | 67.5                   | 60 - 10                |
| Protein content (%)  | 85.46                            | 79.46                                       |                        |                        |

Note: <sup>a</sup> FAO [29]<br> <sup>b</sup> Moeljanto [13]

4. Conclusion

Functional properties and chemical composition of dried surimi with the addition of 0.3% cryoprotectant type with the use of oven drying and freeze drying methods still provide good values for protein solubility, water absorption, kamba density, and viscosity. The results of the analysis of the functional properties of dry surimi showed that the solubility value of the protein ranged from 38.38 to 52.26%; water absorption 1.00 to 1.93%; kamba density 0.40 to 0.66%; viscosity 2.57 to 69.83 cP; chemical composition of water content of 6.01 to 7.35% and protein content of 85.35 to 85.57%.
Analysis of differences in the significance of each treatment showed that the type of cryoprotectant had a very significant effect on protein solubility; drying method and type of cryoprotectant have a very significant effect on water absorption; The drying method and type of cryoprotectant have a very significant effect on the water content of dried surimi and the drying method has a very significant effect on the protein content of the dried surimi so that it is classified as fish protein concentrate type A, with yield ranges from 26.3 to 40.2%.

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