Characterization of functional properties catfish protein isolates (Clarias sp.)

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Abstract. Production of catfish protein isolates can be an alternative to provide added value to this commodity, which is expected to be a potential source of quality protein and promote human health. This study was aimed to characterize the chemical and functional properties of large-size catfish protein isolates and its functional properties. The stages of this study were to produce catfish protein isolates by using alkaline (pH 11) and isoelectric point (pH 5.5) methods and characterize the chemical and functional properties of catfish protein isolates produced. The result showed that catfish protein isolates contained 9 essential amino acids, protein content of 86.74% (wb) or 90.46% in dry basis (dB) and fat content of 0.54% (wb) or 0.56% (dB). Functionally, the catfish protein isolates produced have the ability in gelling forming a concentration of 5%, 4.08 g/mL oil absorption, 3.38 g/mL water absorption, emulsion capacity and stability of 1.52 mL/mL and stable over 90 minutes, 0.89 mL/mL foam capacity, and 0.64 g/mL density of bulky.

Keywords: catfish, characterization, functional properties, protein isolates

1. Introduction

Fish protein isolate is one of food ingredients in the form of powder with high protein content (minimum 90% dry basis (dB)). This powder form provides several advantages including practical application, stable during storage, and does not require special storage conditions. Studies focusing on food protein isolates, the benefits, and their application have been reported by (Yoon et al 2019, Kobayashi et al 2017a, Tahergorabi et al 2010). The application of pH-shifting method in producing protein isolate can effectively recover protein from fish meat including myofibril and sarcoplasmic proteins (Kobayashi et al 2017b).

Several studies had utilized some fish species to produce protein isolate and characterize its functional properties, e.g. saithe (Shaviklo et al 2012), tilapia (Foh et al 2012), bigeye snapper (Panpinat et al 2016), eggs of yellowfin tuna fish (Lee et al 2016), carp (Tian et al 2016), and catfish (Yarnpakdee et al 2014). The principle of producing catfish protein isolates is to solubilize meat protein at high pH
condition in order to separate soluble proteins from the skin, bone, connective tissue, and cell membrane by centrifugation and to precipitate proteins at its isoelectric point. The method of producing catfish protein isolates in this study refers to Yarnpakdee et al (2014) which involves solubilizing protein under the alkaline condition and isoelectric precipitation to produce catfish protein isolates with functional properties and can be used for potential nutritional sources.

Study on large-sized catfish-derived protein isolate including its functional and chemical characterization is still limited. In addition, the production of catfish protein isolates is one effort to diverse fish-based products utilization as a potential source of nutrition. Its food application such as emulsifiers, gelling agents or as nutritional supplements. Moreover, the catfish protein isolate can be a potential protein source and may contribute to the increased added value of large-sized catfish. This study was aimed to evaluate the physical and chemical properties of fresh catfish as raw material, and catfish protein isolates characteristic including proximate composition, amino acid profile, and its functional properties.

2. Materials and methods

2.1. Materials

The material used in this study was large-size hybrid catfish (Clarias sp.) (size ≤ 5/kg). It was obtained from fish farmers at Bogor, West Java, Indonesia.

2.2. Methods

2.2.1. Preparation of raw materials for catfish protein isolates. Catfish were transported to the laboratory in living conditions. The preparation of fish white flesh is started from termination of fish by breaking the bone between the head and dorsal area, removal of viscera, and separation of white flesh by removing the red flesh part. The resulting white flesh cut into cubes with size of 0.5 x 0.5 x 0.5 cm, then weighed and stored at -20°C until the protein extraction process carried out.

2.2.2. Catfish protein isolates. Production of fish protein isolates refers to the method of Yarnpakdee et al (2014) with a slight modification. The minced white flesh was added by cold distilled water (2°C - 4°C) with a ratio of fish: water at 1:5. The mixture was crushed by blender and then homogenized at 11,000 rpm rotational speed for 1 minute. Mixture pH is adjusted by adding NaOH 2M gradually while stirring using a magnetic stirrer until the pH reached 11. This process was conducted in chilled condition. The mixture was centrifuged at a speed of 5,000 xg for 10 minutes at a temperature of about 4°C -10°C to separate the supernatant from precipitate. The precipitate was solubilized using HCl 2N through gradual addition and stirred to yield a mixture pH of 5.5. The solution was undergone centrifugation at 10,000 xg for 20 minutes at a temperature of 4°C-10°C. The obtained precipitate was dried by freeze dryer to get catfish protein isolates in the powder form. Catfish protein isolates was prepared in proper packaging (plastic and aluminum foil) and stored in refrigerator at a temperature of -4°C until subsequent step.

2.2.3. Chemical analysis of catfish and catfish protein isolates. Chemical analysis of catfish and catfish protein isolates included amino acid analysis based on the UPLC method and proximate.

2.2.4. Solubility analysis (Fajri et al 2016). Catfish protein isolate was weighed as much as 0.5 g and placed into 10 mL centrifuge tube. Distilled water was added to reach a volume of 10 mL, then the mixture was manually homogenized. The centrifuge tube containing the sample was heated at 60°C in a water bath for 30 minutes. After heating, the tube was cooled at room temperature then centrifuged at 3,000 rpm for 20 minutes. The supernatant was poured into a petri dish and dried in an oven with a temperature of 105°C. Finally, the obtained residue was weighed. The percentage (%) of solubility was calculated by the following equation (1):
Solubility (%) = \frac{\text{weight of residual}}{\text{sample weight}} \times 100 \quad (1)

2.2.5. Gel formation analysis (Huda et al 2001). Catfish protein isolates with different weight (2.5, 5, 7.5, 10, 12.5, 15) g were added by 10 mL of distilled water respectively. The mixture was stirred and the pH solution was adjusted to be 8 by adding NaOH 2M. A volume of 2 mL solution was placed into a test tube with a lid and heated at 100°C for 15 minutes in a water bath. The test tube containing the sample was cooled with running water and stored in the refrigerator for 2 hours. Gel formation ability is determined by selecting the lowest protein isolate concentration which made the formed gel in the test tube to be still retained after outpouring.

2.2.6. Water absorption analysis (Khattab and Arnfield 2009). One gram catfish protein isolate was placed into centrifuge tubes and added by 10 mL of distilled water. The sample was homogenized by vortex for 2 minutes. The mixture was left for 20 minutes then centrifuged at 3,000 rpm for 25 minutes. The precipitate was separated from the supernatant and dried in an oven at 45°C. During drying process, the centrifuge tube containing sample was placed in upside-down position for 30 minutes, then sample was weighed. Calculation of water absorption capacity was referred to the following formula (2):

\text{Water absorption (g water/g)} = \frac{\text{weight of absorbed water}}{\text{sample weight}} \quad (2)

2.2.7. Oil absorption analysis (Khattab and Arnfield 2009). A 0.5 g of fish protein isolate was placed in the centrifuge tube and added by 3 mL of corn oil. The mixture was vortexed for 2 minutes and centrifuged at 3000 rpm for 25 minutes. The formed supernatant was measured in volume as unabsorbed oil. The absorbed oil was calculated by the difference between the initial oil volume and the volume of oil remained in the measuring cup. The calculation formula for oil absorption is (3):

\text{Oil absorption (mL oil/g)} = \frac{\text{volume of oil absorbed}}{\text{sample weight}} \quad (3)

2.2.8. Emulsion capacity and emulsion stability analysis (Ghavidel and Prakash 2006). A 0.75 g of protein isolate was added by 37.5 mL distilled water and the pH solution was adjusted to 8 using NaOH 2 N. The sample mixture was homogenized by a magnetic stirrer for 5 minutes. A volume of 37.5 mL corn oil was added to the mixture and blended for 1 minute. The emulsion formed is put into a 100 mL measuring cup. The stability of the emulsion was observed for 90 minutes with an observation interval every 15 minutes. Calculation of percent emulsion capacity is referred to the following equation (4):

\text{Emulsion capacity (mL emulsified/mL)} = \frac{\text{emulsified volume}}{\text{mixed total volume}} \quad (4)

2.2.9. Foaming capacity and foaming stability analysis (Pires et al 2012). Samples of catfish protein isolate 3% (30 g.L\(^{-1}\)) was prepared by addition of distilled water. The mixture pH was set to 8 using NaOH 2 N. The mixture was homogenized with a blender for 1 minute and poured into a 100 mL measuring cup. The foam capacity (FC) was calculated by a percentage of the increased volume of the mixture immediately after being homogenized. Foaming stability (FS) was described as the percentage volume of remained foam after 60 minutes.

2.2.10. Water holding capacity (WHC) analysis (Geirsdottir et al 2011). A mixture of 3 g protein isolate, 100 g catfish meat, and 20 g aquades was prepared through homogenizing by blender. The mixture was left for 30 minutes in the refrigerator. About 2 g of sample mixture was wrapped in cloth and placed in a centrifuge tube which previously filled by plastic granules as a barrier. The sample was
centrifuged at a speed of 3,000 rpm for 5 minutes (10°C). WHC was calculated by comparing the weight before and after centrifugation.

2.2.11. Bulk Density analysis (Astawan et al 2016). Bulk density was calculated by comparing the sample weight with the volume of container used (g/mL). Fish protein isolates were placed into a 10 mL measuring cup and the measuring cup was taped no more than 30 times. Isolate was added into measuring cup again to reach a volume of 10 mL, then the total placed protein isolate was weighed (5).

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\text{Bulk density} = \frac{\text{sample weight}}{\text{the volume of measuring cup}} \quad (5)
\]

3. Results and discussion

3.1. Physical and chemical characteristics of catfish raw materials

3.1.1. Characteristics of catfish (Clarias sp.). The raw material in this research was hybrid catfish (Clarias sp.). The observed catfish had total lengths between 390-520 mm and total weight between 457-807 g/individual. Based on these characteristics, catfish in this study were categorized as large-sized catfish. They are usually intended for specific aim such as filling the fishing ponds.

Catfish is divided into four body parts, namely meat, head, bones, skin, gills, and entrails. The percentage of body parts of catfish in this study is shown in table 1. The catfish meat was the largest part reaching 44.66%. The proportion of red flesh and white flesh part was 1:6. Head and bone yield was 37.66%. This part included the head, backbone, and abdominal spines. The head of the catfish had the heaviest weight than the rest parts (backbone and abdominal spines). The percentage of edible meat part of this study was different from snakehead fish (Channa striata) which was range between 36.2%-42.1% in lengths of 232-471 mm (Asikin et al 2017).

Table 1. The average percentage of catfish body parts

| No. | Catfish body parts (g) | Weight (g) | Percentage (%) |
|-----|------------------------|------------|----------------|
| 1.  | Meat catfish:          |            |                |
| a.  | White flesh            | 2,231      | 38.45          |
| b.  | Red flesh              | 360        | 6.20           |
| 2.  | Head and backbones     | 2,185      | 37.66          |
| 3.  | Skin                   | 347        | 5.98           |
| 4.  | Gills and entrails     | 679        | 11.70          |
|     | Total                  | 5,802      | 100            |

3.1.2. Chemical characteristics of catfish raw materials. The proximate content of white flesh and red flesh part of fresh catfish are displayed in table 2. Table 2 described that the ash content of white and red flesh of catfish were 1.25% (wb) and 1.11% (wb) respectively. The ash content of fish meat was low because the bone and head part as a source of mineral had been separated. The ash content catfish meat is an inorganic component in the form of minerals that are not burned out during the combustion process.

Protein is the second most abundant chemical component found in both white flesh and red flesh with values of 18.24% (wb) and 14.63% (wb), respectively. These conditions indicate that catfish has good nutritional potential as a food source. Protein has an important role, including the formation of new
tissues in the body. In addition, it can be used as an energy source, as an enzyme and forming body antibodies. The white flesh part had a higher protein value than red flesh one.

**Table 2. Proximate content of white and red flesh of catfish**

| Component          | White flesh (%wb) | Red flesh (%wb) |
|--------------------|-------------------|-----------------|
| Moisture content   | 75.94±0.02        | 71.51±0.39      |
| Ash content        | 1.25±0.05         | 1.11±0.05       |
| Protein content    | 18.24±0.09        | 14.63±0.08      |
| Fat content        | 4.16±0.01         | 10.32±0.02      |
| Carbohydrates by difference | 0.42±0.01 | 2.43±0.24 |

Fat content in white flesh was lower 4.16% (wb) than the red flesh 10.32% (wb). The high fat component in red meat can cause a decreasing in quality in the form of rancidity due to the oxidation process and affect the color of the final product produced. Carbohydrate in fish meat has the lowest proportion with a value of 0.42% (wb) (white flesh) and 2.43% (wb) (red flesh). The carbohydrate content in each part of the meat is relatively low. The form of carbohydrates commonly found in animal-based foods is a small amount of glycogen.

Overall, the results of this study are different from the results of the study of (Taiwo et al 2014; Adeosun et al 2014) about the dumbo catfish showing water content at 75.58% (wb), ash content at 1.20% (wb), protein content at 19.33% (wb), and a fat content at 4.39% (wb), respectively. Catfish in this study have higher protein content and lower fat content than common carp (Tian et al 2017). Differences in species and habitat affect the amount and composition of fish fat. Different chemical compositions in fish are influenced by biological factors such as species, level of gonadal maturity, feed, season, and spawning conditions. The protein and fat content in the fish meat can affect the final product characterization, therefore the raw material used in this study for protein isolate production was the white flesh.

### 3.2. Catfish protein isolate

#### 3.2.1. Processing of catfish protein isolates

The raw material used in catfish protein isolate production was white flesh of fresh catfish. The catfish protein isolate produced in this study was then used for producing protein hydrolysate. The selection of white flesh is important because of its higher protein content and lower fat content than red flesh so that the cutting of peptide bonds during the hydrolysis process can run effectively. Figure 1 is a 60 mesh catfish protein isolate flour which has bright colors and yellowish-white. In producing isolates, there are 2 main stages, namely the process of protein solubility at the alkaline condition and the precipitation process occurring in isoelectric pH. The protein at isoelectric pH has the same number of positive and negative charges so that the protein solubility is minimum and finally precipitation occurs. The solution has pH above isoelectric point, the positively charged protein will move to the cathode and the negatively charged protein will move to the anode.

**Figure 1. Isolate of catfish protein.**
The yield value is a quite important parameter to determine the effectiveness and economic value of a product. The yield of catfish protein isolate was gravimetrically obtained. The average yield of catfish protein isolate was 9.03% (based on white flesh weight). The yield value of catfish protein isolates was similar to yield of sea cucumber protein isolates (Karnila 2012). Catfish protein isolate in this study had high protein and low-fat content, which were 86.74% (wb) or 90.46% in dry basis (db) and 0.54% (wb) or 0.56% (db), respectively. The result of this study coincides with the characteristics of tilapia protein isolates (Pires et al 2012). The protein content of catfish protein isolates fulfills the criteria of FAO standard for protein isolates with a minimum protein content of 90% (db) and 0.5% (db) fat. The results of the proximate analysis of catfish protein isolates are shown in table 3.

| Parameter             | Catfish Protein Isolate (%wb) |
|-----------------------|-------------------------------|
| Moisture              | 4.12±0.48                     |
| Ash                   | 1.05±0.16                     |
| Protein               | 86.74±1.99                    |
| Fat                   | 0.54±0.02                     |
| Carbohydrates by difference | 7.56±1.66             |

wb = wet basis

This catfish protein isolate has higher protein content than tuna fish protein isolates (70.33% wb) (Kelana 2013). Protein contents which vary on several protein isolates are affected by several factors such as the type of fish, type of extraction, solvent, water-soluble sarcoplasmic concentration, extraction time, centrifugation conditions, and drying method.

3.2.2 Amino acid profile

The amino acid profile analysis was conducted on both fresh catfish white flesh as raw material and its protein isolate. The most abundant amino acid of the catfish white flesh glutamic acid (137.35 mg/g protein wb). Amino acid profile of catfish meat and catfish protein isolates is presented in table 4. Fresh catfish meat has a quite complete essential amino acid, hence it can be claimed as a good source of protein. Fresh meat also contained some amino acids contributing to antioxidant activity, such as aromatic amino acid groups (Phe, His, Trp, Tyr) and hydrophobic amino acids (Phe, Met, Ala, Leu, Ile, Trp, Tyr). Najafian and Babji (2014) reported that amino acids having antioxidant contributions are acidic amino acids (Asp), hydrophobic amino acids (Val), and hydrophilic amino acids (His and Pro). Essential aromatic amino acids (Tyr, Phe) are able to donate electrons to radical species and make it become stable (Sarmadi and Ismail 2010).

Based on table 4, total amino acid of catfish protein isolate reached 92.92%, consisting of hydrophobic amino acids at 40.83% and hydrophilic amino acids at 13.20%. The higher value of hydrophobic amino acid content indicates that catfish protein isolates can provide good functional properties. Glutamic acid was the most abundant amino acid in the catfish protein isolate. Glutamic acid has a hydrogen group that can be substituted with sodium to form monosodium glutamate (MSG). This salt has a strong intensity of savory flavor, so it can be used as an enhancer of flavor in food (Kusnandar 2011). Glutamate is abundant in high-protein food sources and it is included with non-essential amino acids

Fresh meat and catfish protein isolates in this study contained complete essential amino acids indicating the good quality of protein source. The quality of catfish protein isolates meets the standards of essential amino acid requirements for adults and infants based on Berck (1992). The result of this study is similar to the amino acid profile of common carp protein isolate (Tian et al 2017) and tuna eggs protein isolate.
Catfish protein isolates can be utilized as the potential sources of animal protein in contributing daily protein intake with a more practical form and as potential food ingredients.

### Table 4. Profile of amino acids catfish protein isolates (mg/g protein).

| Amino acid         | Composition (mg/g wb protein) | FAO / WHO (2007) (mg/g protein) | AAE Chemistry Score |
|--------------------|-------------------------------|---------------------------------|---------------------|
|                    | Raw material | Isolates | Raw material | Isolates | Raw material | Isolates |
| Cystine (Cys)      | 2.80          | 4.46     |              |           | 100          | 100      |
| Methionine (Met)   | 26.94         | 40.02    |              |           | 100          | 100      |
| (Sulfur amino acid)| 28.74         | 44.48    | 25           | 100       | 100          | 100      |
| Lisin (Lys)        | 76.12         | 86.71    | 58           | 100       | 100          | 100      |
| Leusin (Leu)       | 78.58         | 88.97    | 66           | 100       | 100          | 100      |
| Isoleusin (Ile)    | 46.30         | 51.12    | 28           | 100       | 100          | 100      |
| Valine (Val)       | 48.82         | 52.18    | 35           | 100       | 100          | 100      |
| Threonine (Thr)    | 49.30         | 57.13    | 34           | 100       | 100          | 100      |
| Triptopan (Trp)    | 11.45         | 10.40    | 11           | 100       | 94.53        |          |
| Histidine (His)    | 25.84         | 31.67    | 19           | 100       | 100          | 100      |
| Phenylalanine (Phe)| 50.24         | 63.96    |              |           |              |          |
| Tyrosine (Tyr)     | 38.52         | 56.15    |              |           |              |          |
| Arginine (Arg)     | 69.04         | 90.62    |              |           |              |          |
| Aspartic Acid (Asp)| 84.82         | 98.35    |              |           |              |          |
| Serin (Ser)        | 40.72         | 47.31    |              |           |              |          |
| Glutamic Acid (Glu)| 137.35        | 167.89   |              |           |              |          |
| Proline (Pro)      | 30.05         | 32.52    |              |           |              |          |
| Glycine (Gly)      | 47.41         | 39.30    |              |           |              |          |
| Alanine (Ala)      | 50.81         | 52.43    |              |           |              |          |
| ARM                | 60.75         | 67.53    |              |           |              |          |
| AAE                | 413.59        | 482.16   |              |           |              |          |
| AAHb               | 370.26        | 437.36   |              |           |              |          |
| AAHf               | 122.87        | 141.43   |              |           |              |          |

AAE (Essential Amino Acid): Phe, Met, His, Lys, Ile, Leu, Thr, Trp, Val
ARM (Aromatic Amino Acid): Phe, His, Trp, Tyr
AAS (Amino Acid Sulfur): Met, Cys
AAH b (Hydrophobic Amino Acid): Phe, Pro, Met, Ala, Leu, Ile, Tyr, Val
AAH f (Hydrophilic Amino Acid): Ser, Cys, Thr, Pro

Amino acids concentration of catfish protein isolate is relatively higher than the raw material or fresh catfish meat. This is because cold chain is always maintained during treatment so that damage due to processing can be minimized. Fresh catfish meat and catfish protein solution in this study contained 9 essential amino acids which included Phe, Met, His, Lys, Ile, Leu, Thr, Trp, and Val. Based on the chemical score of essential amino acids, both catfish and isolates were included in high-quality food ingredients. This is indicated by the high score of essential amino acids (the chemical score of AAE is close to 100) for all types of essential amino acids. The tryptophan amino acid in fresh white flesh decreased slightly after isolation process.
3.2.3. Gel formation. The protein in charge of forming the gel is the myofibril protein, especially the myosin fraction. When associated with the type of isolates production, the isolation of catfish protein in this study is also categorized as myofibril protein extraction. Catfish protein isolates have the ability to form gels at concentrations of 5% (w/v). The gel strength is formed because of the interaction between protein and protein or a protein and water through disulfide bonds and hydrogen bond against hydrophilic amino acid groups. Hydrophobic interaction in the protein network is responsible for gel formation. Disulfide bonds have a big contribution to gel formation. The formation of sulfhydryl bonds can cause the water around it to be trapped. The more water trapped in the gel, the bigger the gel.

3.2.4. Solubility. The solubility of the catfish protein isolate in this study was 2.51% which was classified as low. The low solubility value of catfish protein isolates is due to the nature of the myofibril protein which does not dissolve into the water but dissolves into the salt solution. Fish protein isolates generally contain myofibril proteins that do not dissolve into water. According to Huda et al (1998) showed that yellow stripe scad fish protein isolate had the lowest solubility.

3.2.5. Water absorption. The most important characteristic of protein is water absorption capacity. Water absorption capacity is the ability of food to hold water during food processing. The interaction of food protein with water will determine the nature of hydration, solubility, viscosity, gelation and product development. The results showed that water absorption capacity of catfish protein isolates was 3.8g/g as illustrated in table 5. This catfish protein isolate had a quite high water absorption capacity. The high water absorption capacity indicates high porosity of the isolate so that water is trapped in the spaces among particles. Water absorption of catfish protein isolates was higher than ronggeng fish and lanyam (2.98 g/g or 296%). The ability of binding water by catfish protein isolates is due to the presence of polar amino acids that are able to bind water molecules.

Water absorption is a manifestation of the interaction between protein and water occurring on the side of polar amino acids. Some polar amino acids such as proline, serine, cysteine, alanine, threonine, alanine, glycine, and tyrosine were found in the inner and outer globular proteins. Hydrophilic amino acids such as aspartic acid, glutamic acid, glutamine, asparagine, lysine, histidine, and arginine are present on the outer surface of globular proteins (Hutton and Campbell 198). Water absorption capacity is also influenced by the protein content of the food. Protein levels of catfish protein isolates, which was amounted to 90.46% were higher than the protein content of ronggeng and lanyam protein isolate (87.5%) (Astawan 1990).

| Parameter                  | Value     |
|----------------------------|-----------|
| Solubility (%)             | 2.51±0.31 |
| Water Absorption (g/mL)    | 3.38±0.03 |
| Oil Absorption (g/g)       | 4.08±0.14 |
| Emulsion Capacity (mL/mL)  | 1.52±0.01 |
| Foaming Capacity (mL/mL)   | 0.89±0.11 |
| WHC (%)                    | 79.03±0.15|
| Bulk Density (g/mL)        | 0.64±0.01 |

3.2.6. Oil absorption. Protein-fat interactions are properties that greatly affect fat absorption. The results showed that the fat absorption of catfish protein isolates was 4.8 g/mL. This is greater when compared to the oil absorption capacity of skipjack eggs protein concentrates (1.82 g/mL). According to Astawan (1990) showed that the oil absorption capacity of ronggeng fish protein and lanyam were about 169%
and 178%. This is not really different from the study of Pires et al (2012) exhibiting the oil absorption capacity of protein hydrolysate of hake fish protein was 4.67 g/mL.

The catfish protein isolate in this study has the ability to absorb a big amount of fats. This high oil absorption capacity can be related to the application of high pH (11) in isolating protein. The alkaline condition will cause protein denaturation. Globular proteins can be opened due to denaturation process, so that hydrophobic amino acids contained in proteins such as leucine, isoleucine, phenylalanine, methionine, tryptophan, and valine can easily bind to fat. The ability to absorb oil is important, especially for food ingredient usually used in making dough, making cakes, sausages, salad sauces, and mayonnaise (Lehninger 1984).

3.2.7. Emulsion capacity and emulsion stability. The balance of food in absorbing water and oil can affect the ability to form food emulsions. Protein emulsion capacity depends on the balance of hydrophilic and lipophilic bonds in food matrix. The emulsion capacity of catfish protein isolates was 152.11% (1.52 g/mL), higher than the emulsion capacity of skipjack egg protein concentrate (81.65%).

Emulsion capacity of catfish protein isolates was also higher than yellow stripe scad protein (10.83%), albumin (72.92%), and casein 90.73% (Huda et al 1998). Optimal emulsion capacity is formed because there is a balance between the hydrophobic group and the hydrophilic group. The hydrophobic group tends to have strong affinity for lipid-soluble molecule, while the hydrophilic group had an affinity for water. In the formation of emulsion properties, there is an interaction of hydrophobic amino acids that bind to fat, and hydrophilic amino acids which form a matrix network of protein molecules trapping water, thus forming surface molecules with low tension.

3.2.8. Foaming capacity and foaming stability. Foam is a dispersion structure containing colloidal fluid, which consists of a dispersing medium (protein solution) and dispersed phase (gas or air). Factors that influence foam formation are the viscosity, surface tension, and the nature of the film formed on the surface of the liquid. The foaming capacity of catfish protein isolates was 88.83% (0.89 mL/mL), which was higher than the ronggeng fish protein and lanyam (Astawan 1990).

In contrast to the emulsion stability, the foam formed by fish protein isolates was only stable for 15-60 minutes, then it decreased with the length of time of observation. The foaming capacity of this study was lower than the protein concentrate of skipjack tuna eggs (1.90 mL/mL) and the foam stability at 10^6 minutes was 0.22 (Reuwipassa et al 2014). If the foam capacity of the sample is higher, the stability of the formed foam will decrease. The foam will be relatively stable at high viscosity and low surface tension. The ability of proteins in trapping gas is the main factor determining the characteristics of protein foam. According to Chamalaiah et al (2011) stated that foam capacity depends on the flexibility of the molecule and the physicochemical properties of the protein.

3.2.9. Water holding capacity (WHC). The WHC properties of fish meat are due to the interaction between water and protein through a group of hydrophilic amino acids tending to bind water. The WHC value of catfish protein isolates was 79.03% (0.79 mL/g). The result of this study was higher than the WHC value of red snapper by-product isolates, i.e. 0.50-0.59 mL/g (Pramono et al 2017). The utilization of the acid and base in the fish protein production isolates may influence the WHC value of fish protein isolates. In production of fish protein isolates, the use of acid-base can reduce sarcoplasmic protein and extract more maximally the myofibril protein which is responsible for maintaining water in gel formation. The increase in the value of WHC is in line with the increase in pH value, maximum pH with the value of WHC which is at pH 8-9 (Liu et al 2010).

3.2.10. Bulk density. Bulk density is the ratio between the weight of the material and the volume of space occupied and expressed in units of g/ml. The smaller the density of the sample, the bulkier the
material is. The value of the bulk density of protein catfish isolates in this study was 0.64 g/mL, which was smaller than the bulk density of the protein concentrate of mrigala fish egg (Cirrhinus mrigala) (0.77 g/mL) (Chamalaiah et al 2011) and higher than the bulk density of the skipjack eggs protein concentrates (0.51 g/mL) (Reuwipassa et al 2014) and cape hake fish isolates (0.34 g/mL) (Pires et al 2012). The functional characteristics of catfish protein isolates in this study describe their ability as ingredients, emulsifiers, substitutes, binders and gelling agents in various applications of high protein-based products.

4. Conclusion

The white meat of catfish used for protein isolate production had a protein value of 18.24% (wb) and fat of 4.16% (wb). The catfish protein isolate had a protein content of 86.74% (wb) or 90.46% in dry basic db) and fat 0.54% (wb) or 0.56% (db). The resulting catfish protein isolates had the ability to form gel at a concentration of 5%, the oil absorption capacity at 4.08 g/mL, the water absorption capacity at 3.38 g/mL, the emulsion capacity at 1.52 mL/mL and this emulsion was stable for more than 90 minutes, the foam capacity at 0.89 mL/mL, and the bulk density at 0.64 g/mL. Both fresh catfish meat and produced catfish protein isolate contained 9 essential amino acids including Phe, Met, His, Lys, Ile, Leu, Thr, Trp, and Val. Both of them owned high protein quality as indicated by the high chemical score of essential amino acids for all types of essential amino acids.

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