Characteristics of surimi gelfrom Oreochromis mossambicus in different aquaculture areas

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Abstract. Gelling properties of surimi can be influenced by quality of tilapia meat. Meanwhile, the quality of meat can be influenced by aquaculture conditions and aquaculture areas. Hence, the objective of this research was to examine the quality of surimi with tilapia as raw materials cultivated in different areas. Tilapia cultivated in Sentani Lake, Rawa Pening Lake, and Wadas lintang Reservoir will be used for producing surimi in this study. The results showed that tilapia cultivated in Rawa Pening Lake can produce surimi with the highest gel strength and the lowest expressible moisture content than others (p<0.05). Rawa Pening Lake tilapia surimi has characteristics including gel strength of 842.68 ± 118.11 g.cm, whiteness 76.10 ± 0.83, expressible moisture content 13.96 ± 3.18%, hardness 0.31 ± 0.09 kgf, and springiness 6.62 ± 0.41 mm. Based on the observation of microstructure by using SEM, it showed that Rawa Pening Lake tilapia surimi produces a denser and finer gel network. Therefore, Rawa Pening Lake tilapia could be used as the alternative raw material for surimi.

1. Introduction

Based on statistics data from the Ministry of Marine Affairs and Fisheries Republic of Indonesia [1], the value of tilapia production each year increased by 21.41% in the period of 2010 to 2014. In 2014, the value of tilapia production was 999,695 tons. Most tilapia in Indonesia are freshwater aquaculture production, which is cultivated in ponds and other public waters, such as reservoir, lakes, and rivers. However, the processed tilapia products are still limited because of its off odour (muddy and fishy) [2]. Surimi products are one solution to increase consumption of tilapia.

Surimi is minced meat fish that has been leached, mixed with cryoprotectant, and stored frozen to maintain its quality. Gelling properties of surimi are used as the main determinant of grade surimi and myofibril-based products, such as meatballs, nuggets, and imitation crab meat [3][4]. Tilapia is expected to also be an alternative raw material of surimi to replace lean seawater fish which is insufficient to meet demand due to overexploitation. Thus, it can support sustainability of surimi plants.

Gel forming ability of surimi is influenced by fish species [5]. Meanwhile, several studies also show that salinity [6], feed [7], and water temperature which are influenced by habitat and seasons [8-11] can affect the nutrition of fish that are cultivated. Research on the chemical composition of wild freshwater fish in the lake [10] and surimi from tilapia [2][12][13] has been carried out. But there is no information about the comparative quality of tilapia surimi cultivated in different aquaculture areas in Indonesia.
Tilapia that is cultivated in Papua Province (Indonesia) is preferred to taste and texture by consumers than those cultivated in the Central Java (Indonesia). Nevertheless, tilapia production in Central Java Province is higher than tilapia production in Papua Province. In 2014 [1], tilapia aquaculture production in Central Java reached 501,809 tons, while in Papua reached 65,525 tons. Hence, the objective of this research was to examine the quality of surimi with tilapia as raw materials cultivated in different areas.

2. Methods

2.1. Materials
Tilapia (*Oreochromis mossambicus*), with weight of 274±17.93 g, were taken from a fish cultivation in Sentani Lake (Jayapura, Papua Province, Indonesia), Rawa Pening Lake (Salatiga, Central Java Province, Indonesia) and Wadaslintang Reservoir (Banjarnegara, Central Java Province, Indonesia). The fish were packed in a cool box and was kept on ice at 4 °C then transported to the Processing Laboratory of Fish Product Technology Department, Universitas Diponegoro (Semarang, Indonesia) where they were stored in freezer (-18 °C) until processed. Salt (NaCl) and wheat flour were used as ingredients for producing gels.

2.2. Production of surimi
Production of surimi was based on modification the research of Rawdkuen et al. [2]. Tilapia were gutted and washed after thawing. To get mince, skin and bones of fish were removed with meat bone separator. Then it was leached in cold water (4 °C) as much as three times the weight of fish minced with stirring for 5 min. The leached mince was squeezed using nylon screen. The leaching was repeated three times.

2.3. Gel preparation
Tilapia surimi, 3% (w/w) of NaCl, and 5% (w/w) of wheat flour were homogenized for 10 min at 4 °C. During homogenization, cold water was added to adjust the moisture content of the mixture (80%). Then, the sol was packed with the plastic casings (d: 2.5 cm) and the casing is tightened from both ends. To obtain kamaboko gel, the sol was incubated in water for 30 min at 40 °C, then boiled for 20 min at 90 °C in a water bath (Wisd WB-11 Daihan, Gangwon-do, Korea). The kamaboko gel were cold shocked in iced for 30 min, then stored at 4 °C before analysis. This method was based on the research by Arfat and Benjakul [14] with modifications.

2.4. Puncture test
Prior to puncture test, the kamaboko gel was cut into cylinders (h: 2.5 cm). Texture analyser (TA Plus Ametek Lloyd Instruments Ltd, Hampshire, UK) with a stainless-steel spherical probe (d: 1.27 cm) was used to determine gel strength and deformation. In this test using depression speed of 100 mm/min and trigger force 0.005 g.f at ambient temperature (26 to 29 °C).

2.5. Texture profile analysis (TPA)
TPA parameters like hardness, cohesiveness, springiness, and gumminess were of kamaboko gel was measured using a texture analyser (TA Plus Ametek Lloyd Instruments Ltd, Hampshire, UK) with a stainless-steel cylindrical probe of 1.27 cm diameter. The gel of 2.5 cm height, then compressed with trigger force 0.1 kg.f and depression speed of 1 mm/s at room temperature (26 to 29 °C).

2.6. Whiteness
Whiteness [15] was determined according to the equations (1). To find out the value of *L* *, a*, and b*, chromameter (Minolta CR-200, Osaka, Japan) was used.

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whiteness = 100 - [(100 - L^*)^2 + (a^*)^2 + (b^*)^2]^{1/2}
\] (1)
2.7. Expressible moisture content
Samples (3 ± 0.10 g) were put between two Whatman papers No. 1, then centrifuged (Universal 320R type 1406 Hettich, Tuttingen, Germany) for 20 min at 5000 g, 15 °C. Expressible moisture content was calculated as percentage difference between the sample weight before and after centrifuged and the weight of sample before centrifuged [12].

2.8. Microstructure of gels
Scanning electron microscopy (SEM) was used to observation the microstructure of kamaboko gel at voltage of 15 kV and magnification 50x. Before visualized with SEM (Jeol JSM 6510LA, Japan), gel samples (thickness: 2 mm) were dried first by using a freeze-dryer (Heto Power dry LL 1500, Tokyo, Japan) at temperature of -100 °C for 24 h. Then, dried sample is coated with platinum. The method was carried out by Hosseini-Shekarabi et al. [16] with modification.

2.9. Statistical Analysis
The design of this study used a completely randomised design. The data were carried out by one-way analysis of variance (ANOVA), then using Tukey’s test to comparison of means by using SPSS version 17.0 for windows (SPSS Inc., Chicago, USA).

3. Results and discussion

3.1. Puncture test
Gel strength and deformation of surimi gels with various tilapia aquaculture areas are shown in Table 1. Gel strength is one of the factors to determine the grade of surimi. Different aquaculture areas had significant difference (p < 0.05) on gel strength. Tilapia from Rawa Pening Lake produces surimi with the highest gel strength. It is can be explained that differences in aquaculture areas and aquaculture system affect the chemical composition of fish, such as proximate content, amino acid, fatty acid, and other chemical compounds [17]. This is closely related to natural feed, temperature, and other water quality. The amount of gel strength can be caused by the cross-linking of myosin disrupted by proteinase and lipid exposed to heat during gelation [18]. This is influenced by denatured protein content and lipid content of raw material [19] [20]. Endogenous transglutaminase (TGase) also was able to be contributed to gel strength. Endogenous TGase is an enzyme catalysing covalent bonding between ε-amino group of lysyl residues and the γ-carboxamid group of glutaminyl residues of adjacent protein molecules, so that it can induce cross linking of myosin heavy chains (MHC) during gelation process [12] [21].

Table 1. Effect of different aquaculture areas on puncture test, whiteness, and expressible moisture content of the gels.

| Sample                | Gel Strength (g.cm) | Deformation (mm) | Whiteness   | Expressible Moisture Content (%) |
|-----------------------|---------------------|------------------|-------------|----------------------------------|
| Sentani Lake          | 551.88 ± 141.60ab   | 13.83 ± 2.90a    | 73.87 ± 0.52a | 22.91 ± 2.66a                    |
| Rawa Pening Lake      | 842.68 ± 118.11a    | 13.46 ± 0.72a    | 76.10 ± 0.83b | 13.96 ± 3.18b                    |
| Wadaslintang Reservoir| 457.57 ± 106.27b    | 14.40 ± 0.43a    | 78.83 ± 0.76c | 23.19 ± 1.60a                    |

Note: The data is based on the average of triplication ± standard deviation with different superscript on the same column shows significantly different (p < 0.05).

No significant difference in deformation were found in surimi gels prepared with tilapia from difference aquaculture areas (p > 0.05) (Table 1). Deformation of kamaboko gels is shown elasticity. The lower deformation correlated the lower elasticity. Different results are shown by Arfat and Benjakul [14], that the decreased kamaboko gel deformation along with the increase in gel strength. The hard and
rigid gel is affected by the strength of the gel network. In general, the stronger gel network, the kamaboko gel will lose its elasticity. An increased of protein-protein interaction decrease protein-water interaction which results in a decrease in deformation. The kamobo gel from tilapia showed the higher deformation (13.46 to 14.40 mm) than kamaboko gel from other fish including black mouth croaker fish (10.73 mm) [16], frigate mackerel and Indian mackerel (6 to 10 mm) [22], and red tilapia (6.10 to 9.20 mm) [15]. In this study, kamaboko gel with tilapia as raw material had similar deformation value with the result study of Seighalani et al. [12], namely red tilapia surimi using TGase from microbial. The lower deformation shows that kamaboko gel had the strongest and rigid gel network structure.

3.2. Texture profile analysis (TPA)

TPA of the kamaboko gel are shown in Table 2 where is the difference aquaculture areas has no significantly different (p > 0.05) in hardness-1 value, but significantly different (p < 0.05) in hardness-2 value. Dey and Dora [23] states that hardness-2 value was always lower than hardness-1 value due to strong texture of compressed kamaboko gel. In this study, the kamaboko gel from Rawa Pening Lake of tilapia had the highest hardness 2 value. The highest hardness of kamaboko gel positively correlated with gel strength and breaking force [16]. When compared with the hardness value of kamaboko gel from black mouth croaker (Atrobucca nibe) (3.9 kg.f) [16], all samples in this study have a lower hardness value. The hardness is shown as the force needed to achieve deformation of kamaboko gel [24].

Cohesiveness and springiness are indicative of damage on gel structure from the first compression [15]. Cohesiveness covers both cohesive and adhesive strength as well as elasticity and viscosity of kamaboko gel [25]. In this study, cohesiveness value was not influenced by different aquaculture area of tilapia (p > 0.05). Cohesiveness values in all samples (0.08 to 0.19) are much lower than kamaboko gel from black mouth croaker surimi (0.7 to 0.8). The lower cohesiveness of kamaboko gel in this research indicate that the lower ability of the gel to return its initial shape after first compressing [16]. When the cohesiveness value approaches 1, the integrity of kamaboko gel is high after the first compression [26].

Springiness of kamaboko gel with different aquaculture areas of tilapia ranged from 2.13 to 6.62 mm, and the kamaboko gel from Rawa Pening Lake tilapia surimi had the highest springiness (p < 0.05). The results of this study showed that the quality of raw material can affect springiness [27]. Similar results with hardness 1 and cohesiveness were observed for gumminess, where is different aquaculture areas had no affected (p > 0.05). Gumminess is related to the amount of energy used to breakdown a semi solid food [28]. Some research results show that the higher hardness, cohesiveness, springiness, and gumminess correlated with a increase of gel strength and elasticity [16] [29], while the opposite result was shown others study [30].

Table 2. Texture profile analysis of surimi gels.

| Sample                  | Hardness-1 (kg.f) | Hardness-2 (kg.f) | Cohesiveness | Springiness (mm) | Gummines (kg.f) |
|-------------------------|-------------------|-------------------|--------------|-----------------|-----------------|
| Sentani Lake            | 0.24±0.01a        | 0.19±0.03ab       | 0.12±0.08a   | 4.23±2.44ab     | 0.03±0.03a      |
| Rawa Pening Lake        | 0.42±0.13a        | 0.31±0.09a        | 0.19±0.11a   | 6.62±0.41a      | 0.08±0.04a      |
| Wadaslintang Reservoir  | 0.24±0.11a        | 0.09±0.08b        | 0.13±0.10a   | 2.13±1.86b      | 0.03±0.03a      |

Note: The data is based on the average of triplication ± standard deviation with different superscript on the same column shows significantly different (p < 0.05)

3.3. Whiteness

Whiteness is also one of the factors that determine the grade of surimi. The results showed that tilapia with different aquaculture areas could affect the whiteness of surimi, where is the highest whiteness was obtained in Wadaslintang Reservoir tilapia surimi and the lowest whiteness was obtained in Sentani Lake tilapia surimi (p < 0.05) (Table 1). The whiteness of kamaboko gel from fish muscle is dependent
on raw material, amount of food additives added, and other compounds contained in surimi [28] [31] [32]. Surimi is made by leaching fish minced with water to remove myoglobin, lipid, and other impurities for increasing lightness and decreasing redness and yellowness. Therefore, the lowest whiteness may be caused by the strong bond of oxidized haem pigments that cannot be removed when the leaching process or may be caused by denaturation of the pigment due to heat and then causes turbidity [15]. In this research, all samples had lower whiteness value (73 to 78) than red tilapia surimi (76 to 80) [12].

3.4. Expressible moisture content
The ability of kamaboko gel to holding its water content is closely related to expressible moisture content. There is a connection between expressible moisture content and gel properties of kamaboko gel. The lowest expressible moisture content is shown on kamaboko gel made from Rawa Pening Lake tilapia surimi (p < 0.05) (Table 1). The lower expressible moisture content shows a higher ability of kamaboko gel to hold its water [22]. The expressible moisture content related to protein-water bonds and gelation [33]. In this study, kamaboko gel had higher expressible moisture content (13.96 to 23.19 %) than kamaboko gel from red tilapia surimi (10.50 to 11.75 %) [12]. This shows that kamaboko gel produced in this study release more water because the gel network cannot hold water. This is probably caused by free water content in meat. The free water is lost followed by losing internal pressure and shrinkage of cellular tissue which indicated the texture softening [24].

3.5. Microstructure of gels
Figure 1 show the SEM image of kamaboko gel with different aquaculture areas of tilapia. Microstructure of kamaboko gel with Wadaslintang Reservoir tilapia surimi (Figure 1c) showed a sponge like structure with larger and more cavities, compared to other kamaboko gels. This correlates with the low of gel strength and the high of expressible moisture content. Gel network of kamaboko gel with Rawa Pening Lake tilapia surimi appears more finer and denser (Figure 1b). The similar results have been reported in other studies that the large pores seen in the gel network microstructure correlated with breaking force and the expressible moisture content on kamaboko gel [24] [28].

![Figure 1. Microstructure of gels with a.) Sentani Lake, b.) Rawa Pening Lake, and c.) Wadaslintang Reservoir of tilapia aquaculture areas.](image-url)
4. Conclusions
Gelling properties of tilapia surimi were significantly different by the different aquaculture areas of tilapia as raw material. Kamaboko gel with tilapia from Rawa Pening Lake exhibited the highest gel strength and the lowest expressible moisture content (p < 0.05). Rawa Pening Lake tilapia surimi produces a denser and finer gel network. Therefore, Rawa Pening Lake tilapia could be used as the alternative of raw material surimi.

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