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Characteristics of the Sailfin Catfish (*Pterygoplichthys pardalis*) Fishball Based on the Ratio of Meat to Tapioca Flour

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ABSTRACT

This study evaluated the physicochemical characteristics of fishballs made with sailfin catfish (*Pterygoplichthys pardalis*) meat and tapioca flour as the main ingredients. Sailfin catfish samples were collected from Tempe Lake, South Sulawesi, Indonesia at a site in the Tanasitolo District, Wajo Regency where many fishermen catch fish. The fishballs were made with four ratios (% by weight) of white catfish meat and tapioca flour: 40:60; 50:50; 60:40 and 70:30. Based on Likert scale preference tests, the best formulation with the highest preference was the 60:40 meat/flour ratio. Fishball characteristics were determined through organoleptic tests, proximate composition, and heavy metal (Hg, Pb, and Cd) content analyses in addition to microbiological tests (total plate count, *Escherichia coli*, *Salmonella*, *Vibrio cholerae*, *V. parahaemolyticus*, and *Staphylococcus aureus*). The organoleptic score for these fishballs was 7; water, ash, protein, and fat content were 63.87, 0.93, 22.47, and 2.44%, respectively. Heavy metal content and microbiological test parameters were all below the relevant food quality standard thresholds. Therefore, the sailfin catfish meatballs, with a meat to tapioca flour ratio of 60:40 meet the nutritional content requirements under Indonesian national standard SNI 7266: 2017. They are safe and fit for human consumption and organoleptically acceptable.

INTRODUCTION

Alien invasive species are becoming increasingly common in freshwater ecosystems, including the island of Sulawesi **(Hilgers *et al*., 2018; Serdiati *et al*., 2020; Yanuarita *et al*., 2020)**. The sailfin catfish from South America, particularly the members of the genus *Pterygoplichthys*, are bottom-dwelling fishes that have proven capable of adapting to a wide range of conditions, including ponds and lakes as well as irrigation and wastewater canals with relatively high levels of pollution and limited food availability, whereas most other fishes struggle or fail to survive **(Rao & Sunchu, 2017)**.

One reason sailfin catfish can survive and reproduce in polluted environments is their ability to absorb and accumulate heavy metals.

Sailfin catfish have caused significant damage to aquatic habitats and native species in many countries, viz. Serbia **(Simonović *et al*., 2010)**, Thailand **(Chaichana & Jongphadungkiet, 2012)**, Bangladesh **(Hossain *et al*., 2018)**, India **(Kiruba-Sankar *et al.*, 2018)** and Indonesia **(Elfidasari *et al.*, 2019)**. It is worthy to mention that, the sailfin catfish *Pterygoplichthys pardalis*, in particular, has become dominant in Tempe Lake, South Sulawesi, Indonesia where it disrupts the lake's ecosystem, damages the nets, reduces the catch of local fishers and threatens the survival of endemic and other native fishes in the lake **(Amir *et al*., 2020; Hasrianti *et al*., 2020)**. Despite the abundance of this species, the sailfin catfish in Tempe Lake have not been exploited for human consumption because of their unappetizing appearance, strong and unpleasant fishy smell, adding to the small amount of meat (21-26%) on the carcass **(Kasmiati *et al*., 2022)**. As the sailfin catfish are not targeted and not retained by fishermen, the population of this invasive species has increased over time. In a recent study, fishermen reported that, around 70% of their catches were often sailfin catfish, which they removed from the net and then released them back to the lake. Studies of **Amir *et al.* (2020)** and **Kasmiati *et al*. (2022)** elucidated that, the heavy metal content in sailfin catfish caught in Tempe Lake, specifically in Tanasitolo District, Wajo Regency, was below the maximum levels stipulated in Indonesian national standard SNI 7387:2009 and the relevant food safety regulation **(BPOM RI, 2018)**. This indicates that sailfin catfish caught in this area should be safe for human consumption, either as fresh fish or in the form of processed fish products.

Sailfin catfish have been exploited in other countries and other regions of Indonesia in various ways. These include using sailfin catfish as ingredients in various processed fish products such as *empek-empek*, a kind of fish dumpling **(Trisnawati, 2007)** and fish crisps **(Nurilmala *et al*., 2011)**; they were also used as a source of collagen and gelatine **(Hermanto *et al*., 2014; Ebenstein *et al*., 2015; Dilhani *et al*., 2019; Nurubasha *et al*., 2019; Ismail *et al.*, 2021)** and utilized in waste management **(Nugroho *et al*., 2014)**. Furthermore, sailfin catfish were used as a feed supplement **(Panase *et al*., 2018; Srinual *et al*., 2020)** and a source of essential fatty acids in high protein foods **(Elfidasari *et al*., 2019)**.

In general, the diversification of fish-based products aims to increase added value and produce processed products that can provide animal protein to fulfil the nutritional needs of the human population **(Agustini & Swastawati, 2003)**. In addition, these diversified products often have the added advantage of having a longer shelf life than unprocessed fish. Meatballs or fishball, called *bakso*, are popular across all segments of Indonesian society. According to the Indonesian National Standard SNI 7266: 2017, fishballs are processed fish product that uses at least 40% minced fish meat or surimi mixed with other ingredients as necessary and is cooked before sale. Many fishes can be used as the primary ingredient in fishball, including narrow-barred Spanish mackerel **(Riyadi & Atmaka, 2010)**, sailfishes **(Poernomo *et al*., 2013)**, mackerel tuna **(Ardianti *et al*., 2014)**, milkfish, African catfishes, mackerel **(Muttaqin *et al*., 2016)** and tuna **(Farilanda *et al*., 2018)**.

There is a need to identify products that can be made from the sailfin catfish in Tempe Lake that will be readily accepted by consumers, such as the *bakso* (meatballs or fishball) which are so popular in both rural and urban societies. This research used the meat from Tempe Lake sailfin catfish as an ingredient to make fishball. It is hoped that the introduction of sailfin catfish in the form of fishball could be part of the solution to the socio-economic and ecological crises caused by this invasive fish, controlling the sailfin catfish population in the lake and providing an economic opportunity for the fishing communities around Tempe Lake.

MATERIALS AND METHODS

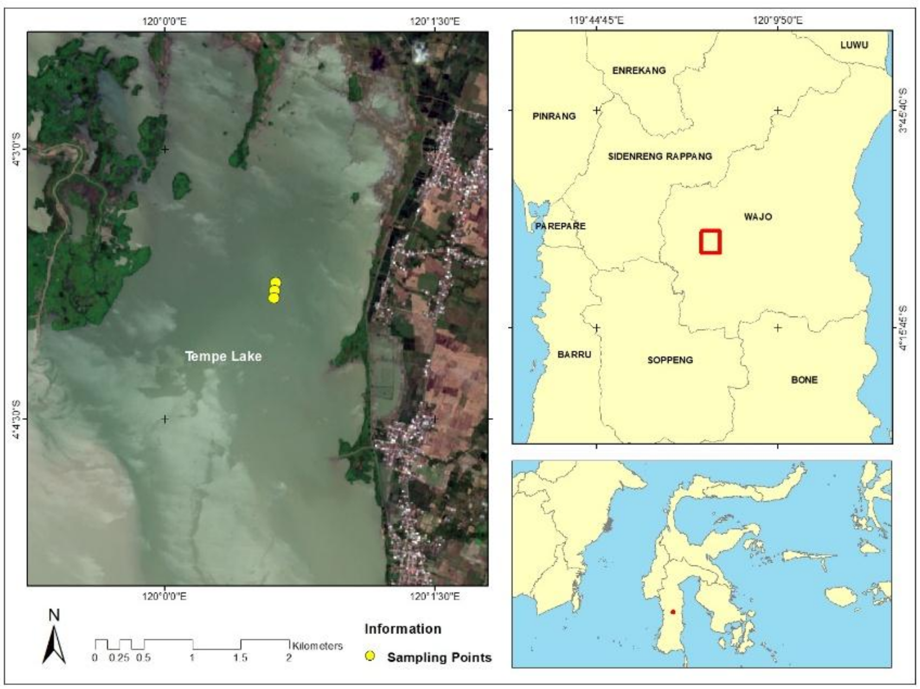

Fig. 1. Map showing the sailfin catfish sampling sites in Barutancung Village, Tanasitolo District, Wajo Regency, South Sulawesi Province, Indonesia

Sailfin catfish samples were collected using purposive sampling to obtain representative data **(Sugiyono, 2010)**. The fish used were at least 30cm long with a minimum weight of 250g. The number of samples used was 11 sailfin catfish. The fish selected were cleaned in the lake to remove any dirt such as sand and mud, and were placed in a styrofoam box with ice as a cooling medium to keep the fish fresh. The fishball ingredients were sailfin catfish meat, ice, tapioca flour, eggs, garlic, shallots, salt, ground pepper and Ajinomoto flavor enhancer monosodium glutamat (MSG).

1. Sailfin catfish preparation

Sailfin catfish were washed under running water while using a brush to remove dirt trapped between the scales. After removing the head and the tail, the abdomen was cut open to remove the internal organs. The body was then filleted by making a dorsal incision along the spine to give left and right sides, with the spine attached to the right-hand side. The spine was removed by carefully separating and lifting the flesh with a knife. Any meat remaining on the bones or the skin was scraped off. The white meat was separated from the red meat, washed and dried and then weighed. The white meat was placed in plastic containers with 250g in each container and stored in a freezer until used to make fishball.

2. Fishball formulations

The sailfin catfish fishballs were made following four formulations, each of which had a different ratio of sailfin catfish meat to tapioca flour, by weight. The ratios were: 40:60; 50:50; 60:40, and 70:30. The total amount of sailfin catfish meat used to make these four fishball variants was 550g.

These four sailfin catfish fishball formulations were subjected to a preference test using the Likert scale **(Sugiyono, 2010)** with 35 panellists. The parameters evaluated were appearance, odour, taste and texture, based on the Indonesian standard SNI 7266: 2017. The sailfin catfish fishball formulation with the highest score was then analyzed to determine physical and chemical characteristics.

3. Sailfin catfish fishball quality testing

The sailfin catfish fishball formulation with the highest preference score was subjected to an organoleptic test by six qualified panellists following the Indonesian standard SNI 2946: 2015. The parameters evaluated were appearance, odor, taste and texture. Organoleptic testing is a way to use human senses as the main tool for evaluating the quality of processed fisheries products (SNI 2346: 2011). Proximate composition analysis was then conducted to determine the proportions of water and ash (gravimetric methods), protein (Kjeldhal method) and lipids (Soxhlet method). The safety of the fishball for human consumption was evaluated by measuring heavy metal content (Hg, Pb and Cd) through atomic absorption spectrophotometry as well as microbiological methods including total plate number (SNI 2332.3: 2015) and assays for *Escherichia coli* (SNI 2332.3: 2015), *Salmonella* (SNI 01-2332.2-2006), *Vibrio cholerae* (SNI 01.2332.4: 2006), *V. parahaemolyticus* (SNI 01-2332.5-2006) and *Staphylococcus aureus* (SNI 2332.9: 2015).

DATA ANALYSIS

The preference test data were determined using one-way analysis of variance (ANOVA) throughout SPSS 22 statistical software. Significant difference was specified at 95% level of probability (α = 0.05) to assess the most preferred ration of sailfin catfish meat and tapioca flour. The normality test indicated a non-normal data distribution; therefore, non-parametric Kruskal Wallis and Mann Whitney tests were used. The results of the organoleptic, proximate composition and heavy metal (Hg, Pb, and Cd) concentrations were presented as the average of three replicates. Data on the microbiology assay are presented in Table (3) and analyzed descriptively.

RESULTS AND DISCUSSION

The Kruskal Wallis and Mann Whitney tests applied to the Likert scale preference data from the 35 panellists based on appearance, odor, taste and texture showed that the fishball with 60% sailfin catfish meant and 40% tapioca flour had the highest mean score. This most preferred formulation was used in the following tests.

1. Organoleptic parameters

The organoleptic scores for the fishball with sailfin catfish and tapioca flour at a ratio of 60:40 were 7 for all four parameters, meeting the provisions of the Indonesian standard SNI 7266: 2017 on fishball quality. These values correspond to fishball with a slightly rough and uneven surface, and somewhat dull appearance; the product-specific smell and taste was considered somewhat lacking, while the texture was dense, compact and slightly chewy.

2. Proximate composition analysis

The proximate composition analysis of the sailfin catfish fishball (Table 1) met the requirements of the relevant Indonesian national standard (SNI 7266: 2017). The protein content (22.5%) was three times over the minimum requirement (7%). The fishball can therefore be considered as a high quality product which not only meets but substantially exceeds the statutory nutritional requirements.

Table 1. Proximate composition analysis of sailfin catfish fishball

Component	Proportion (%)*	Standard (SNI 7266: 2017)
Water	63.87± 2.14	Maximum 70%
Ash	0.93± 0.37	Maximum 2. 5%
Protein	22.47± 0.23	Minimum 7%
Lipid	2.44± 0.12	-

* Values are mean ± standard deviation of triplicate determination (*n=3*).

The sailfin catfish fishball produced in this study had a higher protein content than the African catfish fishball produced in the study of **Prasaja *et al*. (2019)**. While, other ingredients may have some effects, this is most likely due to the higher protein content in sailfin catfish meat compared to African catfish meat, as revealed by proximate analysis **(Bimantara, 2018)**. Additionally, the sailfin catfish fishball had a relatively high lipid content compared to fishball from some other freshwater fishes such as the giant snakehead *Channa micropeltes* **(Restu, 2012)**, the African catfish *Clarias gariepinus* **(Prasaja *et al.*, 2019)** and the striped snakehead *C. striata* **(Rurukan *et al.*, 2019)**.

3. Heavy metal content

The level of mercury (Hg), lead (Pb) and cadmium (Cd) in the sailfin catfish fishball based on the measurement by using the atomic absorption spectrophotometer is shown in Table (2). For each of the three heavy metals, the content was below the threshold in the Indonesian quality standard SNI 7266: 2017, and the fishball can therefore be considered safe for human consumption as far as heavy metal content is concerned.

Table 2. Heavy metal content of the sailfin catfish fishball

Heavy metal	Content (mg/kg) *	Quality standard (SNI 7266: 2017)
Mercury (Hg)	0.0376±0.003	Maximum 0.5 mg/kg
Lead (Pb)	0.0226±0.001	Maximum 0.3 mg/kg
Cadmium (Cd)	0.0497±0.001	Maximum 0.1 mg/kg

* Values are mean ± standard deviation of triplicate determination (*n=3*)

The heavy metal content of the sailfin catfish fishball was lower than that reported in several other processed fisheries' products. For example, in fish jerky (*abon*) made from rays, the lead content ranged from 0.2615 to 0.3385mg/ kg, while **Sinambella *et al*. (2020)** detected 0.18mg/ kg lead and 0.10 mg/kg mercury in swordfish jerky. The low level of heavy metal contamination in the sailfin catfish fishball indicates that the ingredients used were safe, and in particular the sailfin catfish from the study site can be considered safe with high quality based on this criterion. This is consonant with the findings of **Kasmiati *et al*. (2022)** who investigated the heavy metal content in various body parts of sailfin catfish from Tempe Lake. The heavy metal content in the white flesh of the sailfin catfish, the body part used to make the fishball in this study, contained 0.0470mg/ kg mercury, 0.0356mg/ kg lead and 0.0221mg/ kg cadmium **(Kasmiati *et al.*, 2022)**. These values are below the maximum thresholds of both the Indonesian standard SNI 7387:2009 and the Indonesian Food and Drugs Administration standard **(BPOM RI, 2018)**.

Microbiological assays

The assay results for total plate number, *E. coli*, *Salmonella*, *V. cholera*e, *V. parahaemolyticus* and *S. aureus* in sailfin catfish fishball (Table 3) were all below the maximum values allowed under the relevant standard (SNI 7266:2017). Therefore, the sailfin catfish fishball can be considered safe for human consumption from a microbiological standpoint.

Microbial contamination could occur during the fishball production processes. Potential sources of microbial contamination include the equipment (tables, mixer and other tools) and the ingredients used, including both the fish meat and the other ingredients (flour, flavourings, etc.), as well as poor hygiene during the various processing stages. If the food product being produced comes into contact with previously contaminated surfaces, pathogenic bacteria can settle and multiply on and in the fishball. There is also a risk of contamination during storage, and the multiplication of any pathogenic microorganisms will be influenced by ambient temperature; thus, temperature control (e.g. maintaining a cold chain) is important in order to reduce the speed at which microbes reproduce **(Ismail *et al*., 2016)**. An excessive abundance of microorganisms can change the organoleptic characteristics and the nutritional quality of the product, eventually causing the product to become unfit for human consumption; if pathogenic microbes are present, the product can become unsafe, presenting a health risk to consumers **(BPOM RI, 2008)**.

Table 3. Microbiological assay results for the sailfin catfish fishball

Parameter	Result	Quality standard
Total plate number (colonies/g)	4.2×10^3	1.0×10^5
E. coli (MPN/g)	<3	<3
Salmonella (per 25 g)	Negative	Negative
V. cholerae (per 25 g)	Negative	Negative
V. parahaemolyticus (MPN/g)	<3	<3
S. aureus (colonies/g)	<10	1.0×10^5

CONCLUSION

Sailfin catfish fishball with a meat to tapioca flour ratio of 60:40 was the most preferred among the four formulations tested. These fishballs had a somewhat coarse, dull and uneven surface. While, the product-specific taste and smell still need to be optimised; the texture was dense, compact and slightly chewy. The heavy metal content (Hg, Pb, and Cd) and microbial assay results met the Indonesian quality standard SNI 7266:2017 for fishball.

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REFERENCES

Agustini, T.W. and Swastawati, F. (2003). Utilization of fishery products as value-added products in the program of food diversification. Journal of Food Industry

Technology (Pemanfaatan hasil perikanan sebagai produk bernilai tambah (*value-added*) dalam upaya penganekargaman pangan. Jurnal Teknologi Industri pangan), 14(1): 74-81.

Amir, N.; Syahrul and Djamaluddin, N. (2020). Suckermouth Catfish (*Pterygoplichthys pardalis*) In Wajo Regency, South Sulawesi Province: The Heavy Metal Content of Lead (Pb), Mercury (Hg) and Arsenic (As). Journal of Fisheries Agribusiness, 13(2): 168-174. https://doi.org/10.29239/j.agrikan.13.2.168-174

Ardianti, Y.; Widyastuti, S.; Rosmilawati, W.; Saptono and Handito, D. (2014). The effect of carrageenan addition on the physical and organoleptic properties of *Euthynnus affinis* fishball (Pengaruh penambahan karagenan terhadap sifat fisik dan organoleptik bakso ikan tongkol (*Euthynnus affinis*). Agroteksos, 24(3): 159-166.

Bimantara, A. (2018). Proximate composition of cultivated catfish with difference in water and feed quality management. Journal of Fisheries and Maritime Science (Uji proksimat ikan lele yang dibudidayakan dengan perbedaan manajemen kualitas air dan pakan. Jurnal Ilmiah Perikanan dan Kelautan), 10(1): 40-45. https://doi.org/10.20473/jipk.v10i1.8541

BPOM RI. (2008). Testing of Food Microbiology (Pengujian Mikrobiologi Pangan). Info POM, 9 (2): 1-11

BPOM RI. (2018). Maximum limit of heavy metal contamination in processed food. (Batas maksimum cemaran logam berat dalam pangan olahan). BPOM No. 5, 2018. Food and Drug Control Agency (Badan Pengawas Obat dan Makanan), Indonesia

Chaichana, R. and Jongphadungkiet, S. 2012. Assessment of the invasive catfish *Pterygoplichthys pardalis* (Castelneu, 1855) in Thailand: Ecological impacts and biological control alternatives. Tropical Zoology, 25(4): 173-182. https://doi.org/10.1080/03946975.2012.738494

Dilhani, E.H.P.U.; Dissanayake, K.S.M.; Alakolanga, A.G.A.W. and Abeyrathne, E.D.N.S. (2019). Extraction of crude collagen from *Pterygoplichthys pardalis* skin and determination of functional properties of its hydrolysates. Journal of Agriculture and Addition, 2(1): 1-20. https://doi.org/10.1007/s10068-019-00601-z

Ebenstein, D.; Calderon, C.; Troncoso, O.P. and Torres, F.G. (2015). Characterization of dermal plates from armoured catfish *Pterygoplichthys pardalis* reveals sandwich-like nanocomposite structure. J. Mech. Behav. Biomed. Mater, 45:175–182. https://doi.org/10.1016/j.jmbbm.2015.02.002

Elfidasari, D.; Shabira, A.P.; Sugoro, I. and Ismi, L.N. (2019). The nutrient content of *Plecostomus* (*Pterygoplichthys pardalis*) flesh from Ciliwung River Jakarta, Indonesia. Nusantara Bioscience, 11(1): 30-34. https://doi.org/10.13057/nusbiosci/n110106

Farilanda; Yusuf, S. and Riani, I. (2018). Analysis of added value and profit of tuna fishball business in West Kendari District (Case Study in Cahaya Nur Group). Journal of Social Economics of Fisheries, Halouleo University, Indonesia

(Analisis nilai tambah dan keuntungan usaha fishballs tuna di Kecamatan Kendari Barat (Studi Kasus Kelompok Cahaya Nur. Jurnal Sosial Ekonomi Perikanan, Universitas Halouleo, Indonesia), 3(3): 184-195.

Hasrianti; Surianti; Putri, R.S.; Damis; Rahmat; M.R. and Arif, S.H. (2020). The effect of sailfin catfish (*Pterygoplichthys* sp) population explosions on the production of gill net catches in Lake Sidenreng water. EnviroScienteae, 16(3): 382–388. https://doi.org/ 10.20527/es.v16i3.9680

Hermanto, S.; Hudzaifah, M.R. and Muawanah, A. (2014). Physicochemical characteristics of gelatin from the skin of Hyposarcus pardalis extracted using acid. Journal of Valence Chemistry (Karakteristik fisikokimia gelatin kulit ikan sapu-sapu (*Hyposarcus pardalis)* hasil ekstraksi asam. Jurnal Kimia Valensi), 4(2): 109-120. https://doi.org/10.15408/jkv.v0i0.3608

Hilgers, L.; Herder, F.; Hadiaty, R.K. and Pfaender, J. (2018). Alien attack: Trophic interactions of flowerhorn cichlids with endemics of ancient Lake Matano (Sulawesi, Indonesia). Evolutionary Ecology Research, 19 (5): 575–90.

Hossain; Mohammad, Y.; Robert, L.V.; Ramon Ruiz-Carus and Shams, M.G. (2018). Amazon sailfin catfish *Pterygoplichthys pardalis* (Loricariidae) in Bangladesh: a critical review of its invasive threat to native and endemic aquatic species. Fishes, 3 (1): 14. https://doi.org/10.3390/fishes3010014.

Indonesian National Standard (Standar Nasional Indonesia, SNI). (1992). How to Test Food and Drinks (Cara Uji Makanan dan Minuman). SNI 01-2891-1992. National Standardization Agency (Badan Standardisasi Nasional), Jakarta

Indonesian National Standard (Standar Nasional Indonesia, SNI). (2006). Method of chemical test – Part 2: Determination of moisture content in fishery products (Cara uji kimia – Bagian 2: Penentuan kadar air pada produk perikanan). SNI 01-2354.2-2006. National Standardization Agency (Badan Standarisasi Nasional), Jakarta.

Indonesian National Standard (Standar Nasional Indonesia, SNI). (2006). Method of chemical test – Part 4: Determination of protein content by the total nitrogen method in fishery products (Cara uji kimia – Bagian 4: Penentuan kadar protein dengan metode total nitrogen pada produk perikanan). SNI 01-2354.4-2006. National Standardization Agency (Badan Standardisasi Nasional), Jakarta.

Indonesian National Standard (Standar Nasional Indonesia, SNI). (2009). Maximum limit of heavy metal contamination in food (Batas maksimum cemaran logam berat dalam pangan). SNI 7387: 2009. National Standardization Agency (Badan Standardisasi Nasional), Jakarta.

Indonesian National Standard (Standar Nasional Indonesia, SNI). (2010). Method of chemical test – Part 4: Determination of ash content and acid insoluble ash in fishery products (Cara uji kimia – Bagian 4: Penentuan kadar abu dan abu tak larut dalam asam pada produk perikanan). SNI 01-2354.1:2010. National Standardization Agency (Badan Standardisasi Nasional), Jakarta.

Indonesian National Standard (Standar Nasional Indonesia, SNI). (2011). Method of chemical test – Part 5: Determination of levels of heavy metals lead (Pb) and Cadmium (Cd) in fishery products (Cara uji kimia – Bagian 5: Penentuan kadar kadar logam berat timbal (Pb) dan Cadmium (Cd) pada produk perikanan). SNI 01-2354.5-2011. National Standardization Agency (Badan Standardisasi Nasional), Jakarta.

Indonesian National Standard (Standar Nasional Indonesia, SNI). (2011). Instructions for organoleptic or sensory testing of fishery products (Petunjuk pengujian organoleptik atau sensori pada produk perikanan). SNI 2346:2011. National Standardization Agency (Badan Standardisasi Nasional), Jakarta.

Indonesian National Standard (Standar Nasional Indonesia, SNI). (2016). Method of chemical test – Part 6: Determination of levels of heavy metal mercury (Hg) in fishery products (Cara uji kimia – Bagian 6: Penentuan kadar logam berat mercuri (Hg) pada produk perikanan). SNI 01-2354.6-2016. National Standardization Agency (Badan Standardisasi Nasional), Jakarta.

Indonesian National Standard (Standar Nasional Indonesia, SNI). (2017). Fishball (Bakso Ikan). SNI 7266-2017. National Standardization Agency (Badan Standardisasi Nasional), Jakarta.

Ismail, M.; Kasmiati and Metusalach. (2021). Physicochemical characteristics of Amazon sailfin catfish (*Pterygoplichthys pardalis*) skin gelatin. AACL Bioflux, 14(4): 2071-2085.

Ismail, M.R.; Kautsar, P.; Sembada, S.; Aslimah and Arief, I.I. (2016). Physical and microbiological quality of beef meatballs at different storage temperatures. Journal of Production and Technology of Livestock Products science (Kualitas Fisik dan mikrobiologis bakso daging sapi pada penyimpanan suhu yang berbeda. Jurnal Ilmu Produksi dan Teknologi Hasil Peternakan), 4 (3): 372-374.

Kasmiati; Nursakinah, L.; Andi, A.P.; Rahmatul, K.; Nurfaidah; Fahrul and Syahrul. (2022). Species determination and heavy metal content of sailfin catfish (*Pterygoplichthys pardalis*) from Tempe Lake, South Sulawesi, Indonesia. Biodiversitas. 23(9), 4409-4417. https://doi.org/10.13057/biodiv/d230905.

Kiruba-Sankar, R.; Raj, J.P.; Saravanan, K.; Kumar, K.L.; Angel, J.R.J.; Velmurugan, A. and Roy, S.D. (2018). Invasive Species in Freshwater Ecosystems – Threats to Ecosystem Services. In: “Biodiversity and Climate Change Adaptation in Tropical Islands.” Sivaperuman C.; Velmurugan A.; Singh A. K. and Jaisankar, I. (Eds). Elsevier Inc., pp. 257–296. http://doi.org/10.1016/B978-0-12-813064-3/00009

Muttaqin, B.; Surti, T. and Wijayanti, I. (2016). The Effect of Egg White Powder (EWP) Concentration on the Quality of different Fishballs made from Catfish (Clarias batrachus), Milkfish, and Chub Mackerel. Journal of Processing and Biotechnology of Fishery Products (Pengaruh konsentrasi egg white powder (EWP) terhadap kualitas bakso dari ikan lele, bandeng, dan kembung. Jurnal Pengolahan dan Bioteknologi Hasil Perikanan), 5(3): 9-16.

Nugroho, A.A.; Rudiyanti, S. and Haeruddin. (2014). Effectiveness of the use of *Hypostomus plecostomus* to improve the quality of fish processing wastewater (based on BOD, COD, TOM) (Efektivitas Penggunaan ikan sapu-sapu (*Hypostomus plecostomus*) untuk meningkatkan kualitas air limbah pengolahan ikan (berdasarkan nilai BOD, COD, TOM)). Journal Management of Aquatic Resources, 3(4): 15-23.

Panase, P.; Uppapong, S.; Tuncharoen, S.; Tanitsion, J.; Soontornprasit, K. and Intawicha, P. (2018). Partial replacement of commercial fish meal with Amazon sailfin catfish *Pterygoplichthys pardalis* meal in diets for juvenile Mekong giant catfish *Pangasianodon gigas*. Aquaculture Report, 12: 25-29. http://doi.org/10.1016/j.aqrep.2018.08.005

Poernomo, D.; Suseno, S.H. and Subekti, B.P. (2013). Physicochemical characteristics of fishballs from mashed Istiophorus orientalis. Indonesian Fisheries Processing Journal (Karakteristik fisika kimia bakso dari daging lumat ikan layaran (*Istiophorus orientalis*). Jurnal Pengolahan Hasil Perikanan Indonesia), 16(1): 58-68.

Prasaja, T.; Kusuma, T.S.; Wijayanto, R.M. and Rusdan I.H. (2019). Macronutrient content of the African catfish fishball formula (*Clarias gariepinus*) with jackfruit seed flour (*Artocapus heterophyllus*). Al-Azhar Indonesian Journal, Science and Technology (Kandungan makronutrien formula bakso ikan lele dumbo (*Clarias gariepinus*) dengan tepung biji nangka (*Artocapus heterophyllus*). Jurnal Al-Azhar Indonesia Seri Sains dan Teknologi), 5(2): 79. http://doi.org/10.36722/sst.v5i2.354

Rao, K.R. and Sunchu, V. (2017). A report on *Pterygoplichthys pardalis* Amazon sailfin suckermounth catfishes in freshwater tanks at Telangan State, India. International Journal of Fisheries and Aquatic Studies, 5(2): 249-254.

Restu. (2012). Production of toman fishballs *Channa micropeltes*. Journal of Tropical Animal Science (Pembuatan bakso ikan Toman (*Channa micropeltes*). Jurnal Ilmu Hewan Tropika), 1(1): 15-19.

Riyadi, N.H. and Atmaka, W. (2010). Diversification and characterization flavor of "tenggiri fish (*Scomberomus commerson*) fishball" on adding the liquid smoke of coconut shell. Journal of Agriculture Product Technology (Diversifikasi dan karakterisasi citarasa bakso ikan tenggiri (*Scomberomorus commerson*) dengan penambahan asap cair tempurung kelapa. Jurnal Teknologi Hasil Pertanian), 3(1): 1-12. http://doi.org/10.20961/jthp.v0i0.13612

Rurukan, O.P.M.; Mamuaja, C.F.; Mandey, L.C. and Lexie, P. (2019). Effect of adding carrot pulp (Daucus carrota) and tapioca flour on the physicochemical and sensory properties of snakehead fish meatball (Ophiocephalus striatus). Journal of Agricultural Technology (Pengaruh penambahan bubur wortel (*Daucus carrota*) dan tapioca flour terhadap sifat fisikokimia dan sensoris bakso ikan gabus (*Ophiocephalus striatus*). Jurnal Jurusan Teknologi Pertanian), 2(4):1-10. http://doi.org/https://doi.org/10.35791/cocos.v2i4.1823

Serdiati, N.; Arfiati, D.; Widodo, M.S.; Lelono, T.D.; Ndobe, S.; Mansyur, K. and Moore, A.M. (2020). Perspectives on sustainable management of the Poso Lake (Indonesia) endemic ricefish, *Oryzias nigrimas* (Actinopterygii:

Adrianichthyidae). Revista de Biología Tropical, 69 (1): 139–152. https://doi.org/10.15517/rbt.v69i1.42404.

Simonović, P.; Nikolić, V. and Grujić, S. (2010). Amazon sailfin catfish *Pterygoplichthys pardalis* (Castellnau, 1855) (Loricariidae, Siluriformes), a new fish species recorded in the Serbian section of the Danube River. Biotechnology and Biotechnological Equipment, 24: 655–660. https://doi.org/10.1080/13102818.2010.10817916.

Sinambella, T.A.; Putri, M.S. and Apiandi, A. (2020). Utilization of trimmed meat and belly of swordfish (*Tylosurus crocodillus*) in the production of shredded fish. Journal of Agricultural Technology (Pemanfaatan daging trimmed dan belly ikan todak (*Tylosurus crocodillus*) pada pembuatan abon ikan. Jurnal Teknologi Pertanian), 9(1): 30-42.

Srinual, O.; Punyatong, M.; Moonmanee, T.; Intawicha, P.; Yachai, M. and Tapingkae, W. (2020). Replacement of fish meal with suckermouth armored catfish and its effect on performance and intestinal morphology of indigenous Thai chicken. Journal of Animal & Plant Sciences, 30(4): 803-810.

Sugiyono. (2010). Quantitative, qualitative and R&D educational research methods (Metode penelitian pendidikan kuantitatif, kualitatif dan R&D). Alfabeta, Bandung, 456pp.

Trisnawati, R. (2007). Utilization of sailfin fish surimi (*Hyposarcus pardalis*) in making empek-empek (Pemanfaatan surimi ikan sapu-sapu (*Hyposarcus pardalis*) dalam pembuatan empek-empek). http://repository.ipb.ac.id/handle/123456789/48416

Yanuarita, D.; Inaku, D.F.; Nurdin, N.; Rahim, S.W.; Kudsiah, H.; Parawansa, B.S.; Rukminasari, N.; Irmawati and Moka, W. (2020). Aquatic invasive species distribution within Wallace Region: a preliminary review. IOP Conference Series: Earth and Environmental Science, 564 (1): 012038. https://doi.org/10.1088/1755-1315/564/1/012038.