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Chemical and hedonic characteristics of smoked *Katsuwonus pelamis* (fufu fish) from Sorong, West Papua, Indonesia

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Abstract. *Sayuti M, Salampessy RBS, Asriani, Nurbani SZ, Saidin. 2022. Chemical and hedonic characteristics of smoked* Katsuwonus pelamis *(fufu fish) from Sorong, West Papua, Indonesia. Biodiversitas 23: 1707-1713.* Fufu fish is one of the smoked fish products from eastern Indonesia, especially the North Sulawesi and Papua region, with raw materials derived from skipjack tuna or yellow-fin tuna. Samples were obtained from fish-smoking entrepreneurs in Sorong City. Proximate analysis was carried out using the association of official analytical chemist (AOAC) standard, amino acid analysis was carried out using liquid chromatography-mass spectrometry (LC-MS), fatty acid analysis was carried out using gas chromatography-mass spectrometry (GC-MS), and hedonic analysis was carried out using the SNI 2346:2015 standard with 120 panelists. The results showed that fufu fish had a water content of 64.52%, ash content of 0.82%, total fat of 1.97%, protein of 27.75%, carbohydrates of 4.37%, and crude fiber of 2.69%. The main essential amino acids of fufu fish were L-Lycine by 5.59%, L-Histidine by 3.25%, and L-Leucine by 2.61%. On the other hand, the main non-essential amino acids were L-Glutamic acid by 3.83%, L-Aspartic acid by 2.60%, and L-Arginine by 2.43%. The main fatty acids of fufu fish were C15:1 (cis-10) by 47.43%, C14:0 by 16.75%, C16:0 by 12.20%, and C18:0 by 10.97%. On the fufu fish hedonic test results, the panelists generally gave a like score. Based on these findings, it can be concluded that fufu fish had good nutritional content for the community.

Keywords: Amino acid, fatty acid, hedonic test, proximate, smoked fish

INTRODUCTION

More than 80% of the world's fish production is for human consumption. By 2020, fish demand was predicted to grow to 17.9 kg per capita (Bainy et al. 2015). However, data in 2017 shows the need for fish consumption has reached 20.3 kg per capita (FAO 2020). This increase in demand occurred in line with the rise in public awareness on the importance of health and food nutrition for body intake. Fish is considered an essential component of a good and healthy source of nutrition, for example fish has low-fat content compared to animal meat. Its fatty acid content has a positive effect on humans, for instance, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (EFSA and NDA 2014). One form of fishery product that is popular in the community is smoked fish. Fish smoking is one of the oldest preservation methods and is still widely used today (Theobald et al. 2012; Ledesma et al. 2015). Today, fish smoking is used to get the desired color, taste, aroma, and appearance of smoked products (Fasano et al. 2016).

Traditional fish smoking is generally done by forming smoke from wood (Visciano et al. 2008; Duedahl-Olesen et al. 2010). Wood smoke contains a combination of antioxidant and antimicrobial chemicals (e.g., phenols, carboxylic acids, aldehydes, and acetic acid). However, wood smoke also contains some harmful compounds, such as PAH (Essumang et al. 2013; Lingbeck et al. 2014). Smoke results from the thermal pyrolysis of wood when access to oxygen is limited (Purcaro et al. 2013). Types of wood smoking material produce different complex chemical components, a mixture of various volatile and non-volatile structures with various sensory characteristics, such as phenol, syringol, guaiacol, and their derivatives (Gómez-Guillén et al. 2009). The chemical compounds of wood smoke are generally phenols (functions as antioxidants), organic acids, alcohols, carbonyls, hydrocarbons, and nitrogen compounds, such as nitrous oxide (Sumartini et al. 2014), aldehydes, ketones, esters, and ethers, which stick to the surface and penetrate the fish flesh (Bower et al. 2009).

The fish smoking method is different in each country or region. This difference could be due to different fish species and different end product destinations. Some phenolic compounds, formaldehyde, and others from smoke remain in fish flesh and function as preservatives to extend the shelf life of the final product and provide a savory taste with a distinctive aroma resulting from the fish smoking process (Ahmed et al. 2010; Daramola et al. 2013). Skipjack tuna is a fishery commodity export (Leke et al. 2015). Skipjack tuna (*Katsuwonus pelamis* (Linnaeus, 1758)) is one of the most popular fish ingredients preserved using traditional fish smoking methods in Sorong City, West Papua. One of the skipjack tuna (*K. pelamis*) smoked products is fufu fish. The shape of the fufu fish product is different from Asar fish even though the raw materials are both derived from skipjack tuna. Asar fish product is a whole fish, while fufu fish product is a fillet (Figure 1).

Figure 1. Fufu fish (smoked *Katsuwonus pelamis*)

Several factors that can affect the characteristics of smoked fish include fish smoking materials (Ahmed et al. 2010; Oduor-Odote et al. 2010; Abolagba and Melle 2008), smoked fish shape (Birkeland and Skåra 2008), fish sampling locations, sampling seasons, and fish smoking methods (Vasiliadou et al. 2005). Information on the organoleptic characteristics of fufu fish is not yet available. Therefore, this research aimed to provide information about the chemical characteristics (proximate, acid profile, and amino acid) and hedonic tests on fufu fish.

MATERIALS AND METHODS

Sample handling

Fresh skipjack tuna was sliced or filleted into two halves, the middle bone and tail were separated, and the eyes were also removed. Each piece was cut in the middle for about 20 cm, right along the lateral line, but the head and tail were kept separate. After that, the fish were cleaned until there was no remaining dirt and blood. The fish flesh was then pierced with small bamboo skewers (four to six pieces) that had been prepared, and the fish flesh was then pulled to the side so that the fish formed an ellipse. Next, the fish were clamped with a 50 cm bamboo and tied. The fish were arranged on a baking sheet, with the flesh facing the fire (bottom) tilted at about 70-80°C. Next, wood was burned around the fish, but the fire didn't directly touch the fish. The fire was pushed evenly to the center little by little. Fish smoking was done for 2-3 h, depending on the size of the fish. The burning temperature was between 120-150°C, and the temperature in the middle of the fish reached 80-100°C. After the fish was slightly cooked, the heating was continued, with the fire getting smaller until it extinguished. The cooked fufu fish was silver-golden to golden-yellow in color. Next, the fufu fish was cooled for 1-2 h. The fufu fish samples were frozen for further processing, namely the analysis of physicochemical properties, fatty acid, amino acid profiles, and organoleptic tests.

Proximate analysis

The moisture, protein, fat, and ash content were analyzed according to the association of official analytical chemist (AOAC 2005) method conducted at the Integrated Research and Testing Laboratory (*Laboratorium Penelitian dan Pengujian Terpadu* - LPPT) of Universitas Gadjah Mada.

Amino acid analysis

Sample preparation: The sample was weighed of ± 2.5 g; put in a 50 mL reaction tube with screw cap; added 20 mL of 6N HCl; hydrolyzed in an autoclave at 110°C for 12 h; neutralized with 6N of NaOH; added up to 50 mL; filtered with a 0.22 µM filter; diluted 10 times; then injected into LCMSMS 2 µL (Sayuti et al. 2021). Mobile phase-A: 0,1% pentadecafluorooctanoic acid (PDFOA) 99.5%:0.5% water/CH_3CN with 0.1% formic acid; B: 0.1% PDFOA, 10%:90% water/CH_3CN with 0.1% Formic acid; Flow: 0.6 mL/min.

Analysis of saturated and unsaturated fatty acid hydrolysis

About 1-5 mL of samples were taken and added with 5 mL of concentrated HCl, heated in a water bath at 80ºC, and continued to boil for 3 h. Then the sample was cooled. Extraction was conducted with 15 mL of diethyl ether and petroleum ether (1:1), then Vortexed and left until precipitated. The top layer was taken as oil and evaporated in a water bath with the help of N_2 gas (Sayuti et al. 2021).

Methylation

One thousand and five hundred milliliter of methanolic sodium solution was added to the sample, then closed and heated at 60°C for 5-10 min while shaken, then it was cooled. Then, it was added with 2 mL of boron trifluoride methane, heated at 60°C for 5-10 min, and cooled. Extraction was conducted with 1 mL heptane and 1 mL saturated NaCl. Next, the top layer was taken and put into Eppendorf, injected into the GC, then 1µL of the sample was injected into the 2010 Shimadzu GC (Sayuti et al. 2021). GC conditions: Detector: FID, temperature: 260ºC; Method: Methylester 37 New 3032017 Cal,gcm; Column : HP-88, Length: 100 m.

Organoleptic test

The organoleptic test was conducted by hedonic test (Scale with 1 for extremely dislike the product and 9 for extremely like the product) based on the Indonesian National Standard (Standar Nasional Indonesia - SNI 2346:2015) related to Sensory Testing (BSN 2015). The hedonic test panelists consisted of 120 people from Java, Sulawesi, Maluku, North Maluku, Papua, and West Papua.

RESULTS AND DISCUSSIONS

Proximate analysis

Fish smoking has the effect of decreasing 2.3% water content, in the other hand increasing 1.96% protein content (Table 2). Smoking causes evaporation of the water content of the fish. The duration of smoking, the humidity of the smoking chamber, and the interaction of smoke with the water content of the material can affect the final product a_w (Kostyra and Baryłko-Pikielna 2006). The smoking process can remove water content in fish flesh to a certain extent to stop microbial activity (Fuentes et al. 2010). The longer the fish is smoked, the more water content is released (Kumolu-Johnson et al. 2010). Ten percent reduction in water content occurred on the grilled fish burger at 76°C (Bainy et al. 2015). The decrease in water content is about 65% in salmon and 75% in mackerel due to the thermal effects of processing (Bastías et al. 2017). The increase of 1.92% protein content and 1.63% total fat also observed (Table 2). The longer the fish is smoked, the higher the protein content and the lower the water content (Huda et al. 2010). The average protein level of skipjack smoked with wood materials ranges from 15.4% to 31.5% (Gehring et al. 2011). Asar fish (Smoked *K. pelamis*) has water content 67.8%, ash content 1.92%, total fat 1.74%, protein 26.98%, carbohydrate 0.79%, crude fiber 2.44% (Sayuti et al. 2021).

Amino acid analysis

Fufu fish and fresh skipjack tuna have nine essential amino acids and nine non-essential amino acids (Table 3). The essential amino acids of fufu fish and fresh skipjack tuna are lycine, histidine, leucine, valine, isoleucine, phenylalanine, threonine, methionine, and tryptophan, while non-essential amino acids include glutamic, aspartic, arginine, alanine, glycine, proline, serine, tyrosine and cysteine.

Table 1. Hedonic test score scale (SNI 2346:2015)

Specifications	Scores
Like Extremely	9
Like Very Much	8
Like Moderately	7
Like Slightly	6
Neither Like nor Dislike	5
Dislike Slightly	4
Dislike Moderately	3
Dislike Very Much	2
Dislike Extremely	1

Table 2. The proximate test results of fufu fish and fresh skipjack tuna

Parameters	Fufu Fish	Fresh Skipjack Tuna
Water content	64.52 ± 0.16	66.87 ± 0.16
Ash content	0.82 ± 0.04	1.34 ± 0.10
Total fat	1.97 ± 0.07	0.29 ± 0.04
Protein	27.75 ± 0.17	25.79 ± 0.09
Carbohydrates	4.37 ± 0.17	5.21 ± 0.10
Crude fiber	2.69 ± 0.15	4.36 ± 0.11

NB: The score was derived from the average of ± standard deviation of three times expressed in the wet weight basis.

Table 3. Results of analysis of amino acid content on fufu fish and fresh skipjack tuna

Test parameters	Results test	
	Fufu fish	Fresh Skipjack tuna
Essential amino acids		
L-Histidine	3,25	1,76
L-Lycine	5,59	3,98
L-Phenylalanine	1,41	1,05
L-Isoleucine	1,63	1,24
L-Leucine	2,61	2,08
L-Methionine	0,99	0,74
L-Valine	1,82	1,37
L-Threonine	1,35	1,03
L-Tryptofan	0,07	0,04
Non-essential amino acids		
L-Arginine	2,43	1,75
L-Tyrosine	1,12	0,83
L-Proline	1,18	0,93
L-Glutamic acid	3,83	3,02
L-Aspartic acid	2,6	1,96
L-Cysteine	0,15	0,14
L-Serine	1,13	0,85
L-Alanine	1,7	1,36
L-Glycine	1,31	0,99

The smoking process of freshwater fish (carp, rainbow trout, and northern pike) causes an increase in almost all amino acids, with the highest amount from the essential amino acid (EAA) group (Cieślik et al. 2018). Essential amino acids asar fish contains L-lysine 5.25%, L-histidine 3.42% and L-leucine 2.45%. Non-essential amino acids Smoked *K. pelamis* contain 3.51% L-glutamic acid, 2.44% L-aspartic acid and 2.22% L-arginine (Sayuti et al. 2021). During fish smoking, there is an increase in protein content at 5.5% and raw ash of ~14%, and a decrease in fat content by 27% (Alaba et al. 2017). In contrast, the mineral content of fish does not show a significant difference (Katola and Kapute 2017). The essential amino acids for adults consist of lysine, leucine, isoleucine, threonine, methionine, valine, phenylalanine, and tryptophan, while the essential amino acids for children are arginine and histidine (Erkan et al. 2010). The human body cannot produce essential amino acids, so external intake is needed (Nadiah et al. 2014). Lysine deficiency in vegetable proteins such as cereals can be supplemented by consuming fish (Abdulkarim et al. 2017). Lysine is the basic ingredient of blood antibodies, strengthens the circulatory system, and maintains normal cell growth. On the other hand, leucine and valine have the same function to repair damaged organs and normal function of all tissues (Purwaningsih 2012). Histidine functions in the growth and repair of body tissues and produces red blood cells (Erkan et al. 2010). L-Arginine is effective in repairing the glomerular endothelium (Sulistyowati et al. 2017). Arginine has beneficial effects for critically ill patients to stimulate immune function, heal a wound, increase nitrogen balance in the body, increase blood flow, and decrease clinical infection (Zhou and Martindale 2007). Arginine affects hepatocyte cell damage in mice (*Mus musculus*) (Nekso 2017). On the other hand, glutamic acid and aspartic acid are important because they create unique aroma characteristics and taste in food (Thariq et al. 2014; Pratama et al. 2018). Glutamic acid is a natural constituent in almost all foods that contain high protein, such as meat, fish, milk, and vegetables (Jacoeb et al. 2012). Glutamic acid also acts as the cause of the umami (savory) taste found in almost all foodstuffs (Suryaningrum et al. 2010).

Analysis of saturated and unsaturated fatty acid

Fufu fish contains 7 main components of fatty acids, namely tridecanoic acid, methyl ester (C14:0) by 16.75%, cis 10-pentadecenoic acid methyl ester (C15:1 (cis-10) by 47.43%, hexadecanoic acid, methyl ester (C16:0) by 12.20%, cis 10-heptadecenoic acid methyl ester (C17:1 (cis-10) methyl ester by 3.31%, octadecanoic acid, methyl ester (C18:0) by 10.97%, linolelaidic acid methyl ester (C18:2 (all trans-9,12) by 5.12%, and eicosanoic acid, methyl ester (C20:0) by 4.21% (Table 4). Fresh skipjack tuna contains 10 main components of fatty acids, namely tridecanoic acid, methyl ester (C14:0) by 3.22%, cis-9-tetradecenoic acid, methyl ester (C14:1) by 1.18 %, cis 10-pentadecenoic acid methyl ester (C15:1 (cis-10)) by 61.23%, hexadecanoic acid, methyl ester (C16:0) by 14.11%, cis-9-hexadecenoic acid, methyl ester (C16:1 (cis-9)) by 1.47%, heptadecanoic acid, methyl ester (C17:0 methyl ester) by 0.84%, cis 10-heptadecenoic acid methyl ester (C17:1 (cis-10) methyl ester by 3.83%, octadecanoic acid, methyl ester (C18:0) by 10.19%, linolelaidic acid methyl ester (C18:2 (all trans-9,12) by 2.63%, and eicosanoic acid, methyl ester (C20:0) by 1.29%. Fish smoking has an effect on the fatty acid composition from fresh to smoked products. The duration of smoking and different smoking methods can affect the chemical characteristics of smoked fish products (Yusnaini et al. 2012). The main fatty acids of asar fish were 37.44% C15:1 (cis-10), 19.6% C18:0, 11.12% C14:0, 10.85% C18:2 (all-trans-9,12) and 9.55% C20 :0 (Sayuti et al. 2021). The total monounsaturated fatty acids (MUFA) for some smoked marine fish ranges from 26.0% to 39.8%, while the total polyunsaturated fatty acids (PUFA) for smoked marine fish ranges from 31.9% to 45.4% (Ilow et al. 2013). These fatty acids are known to have antimicrobial and antifungal activities (Abubakar and Majinda 2016). Palmitic acid or hexadecanoic acid (C16:0) is also known to have anti-inflammatory effects. Hexadecanoic acid acts as an inhibitor of the action of phospholipase, an inflammatory mediator, to reduce the risk of diseases such as ulcerative colitis, Crohn's disease, and rheumatoid arthritis (Aparna et al. 2012). Pentadecanoic acid (C15:1 (cis-10) is a saturated fatty acid that is quite rare in nature. In cow's milk, the content of pentadecanoic fatty acids is about 1.2%. Pentadecanoic is known to have antimicrobial and antifungal activities (Nisha and Rao 2018). Myristic acid (C14:0) acts as a lipid anchor in the biomembrane (Nelson and Cox 2005). Various human epidemiological research has shown that myristic acid and lauric acid are the saturated fatty acids most strongly associated with average serum cholesterol concentrations in humans (German and Dillard 2010). Omega-3 supplements have anti-inflammatory effects (Goldberg and Katz 2007) and significantly reduce metabolic syndrome risk factors (Panchal 2012).

Organoleptic test

In general, the 70 panelists gave a Like score with an average value above 7 for fufu fish products (Figure 4). The highest value was found in the odor aspect, appearance, taste, and texture aspect. Fufu fish has a distinctive aroma due to the smoking process. Carbonyl and phenol compounds and their derivatives in smoke cause changes in the taste and aroma of smoked fish (Kostyra and Baryłko-Pikielna 2006). The duration of fish smoking affects the color acceptance of smoked fish (Mardiana and Fatmawati 2014). Good quality smoked fish will have a golden yellow color (Sulistijowati et al. 2011).

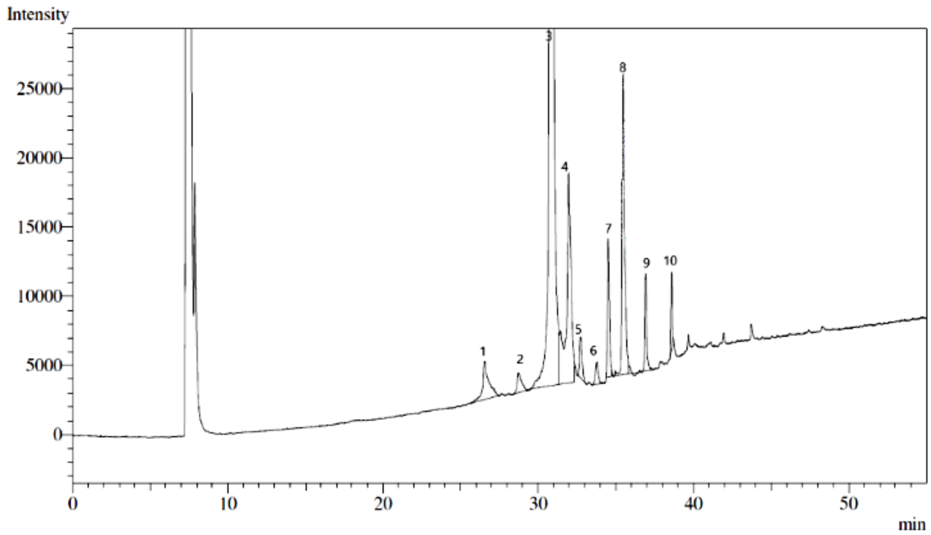

Figure 2. Fatty acid content of fresh skipjack tuna

Table 4. Analysis results of fatty acid content of Fufu Fish and Skipjack Tuna Fufu

Compound name	Molecular formula	Fufu fish		Fresh Skipjack Tuna	
		Peak	Concentration (% relative area)	Peak	Concentration (% relative area)
C14:0	$C_{15}H_{30}O_2$	1	16,75	1	3,22
C14:1	$C_{15}H_{28}O_2$	-	-	2	1,18
C15:1 (cis-10)	$C_{16}H_{30}O_2$	2	47,43	3	61,23
C16:0	$C_{17}H_{34}O_2$	3	12,20	4	14,11
C16:1 (cis-9)	$C_{17}H_{32}O_2$	-	-	5	1,47
C17:0 Methyl ester	$C_{18}H_{36}O_2$	-	-	6	0,84
C17:1 (cis-10) Methyl ester	$C_{18}H_{34}O_2$	4	3,31	7	3,83
C18:0	$C_{19}H_{38}O_2$	5	10,97	8	10,19
C18:2 (all trans-9,12)	$C_{19}H_{34}O_2$	6	5,12	9	2,63
C20:0	$C_{21}H_{42}O_2$	7	4,21	10	1,29
Total			100		100

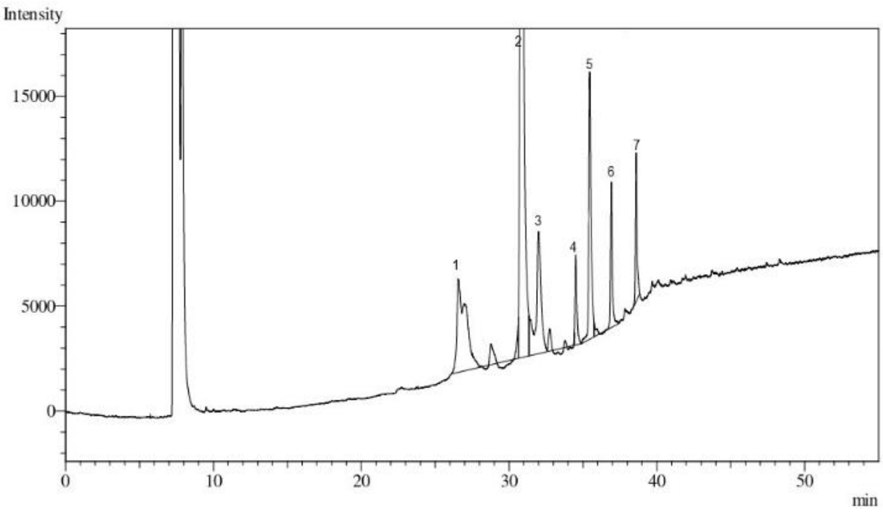

Figure 3. Fatty acid content of Fufu fish

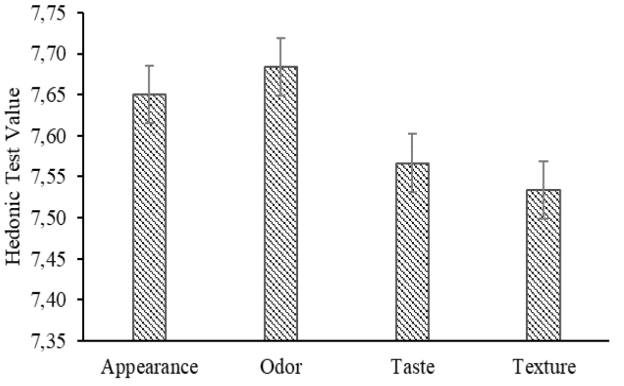

Figure 4. Fufu fish preferences based on sensory profiles determined by semi-trained panelists

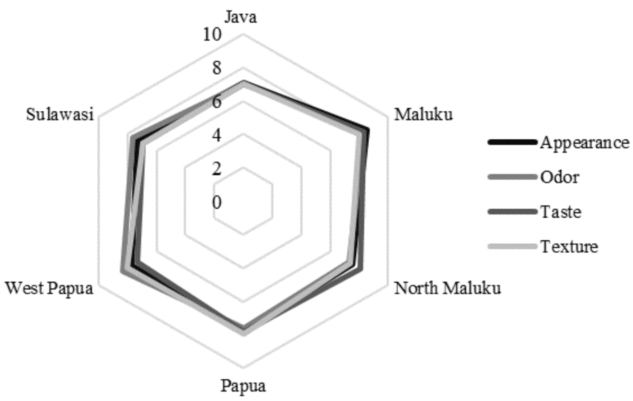

Figure 5. Hedonic analysis results on fufu fish based on panelists' areas of origin

The panelists' preference for fufu fish based on areas of origin from the highest to the lowest is Maluku, West Papua, Papua, North Maluku, Sulawesi, and Java (Figure 5). The organoleptic characteristics of this sample were not significantly different ($P > 0.05$) between the panelists' areas of origin. The majority of the panelists gave a score of 7, which means they liked the product. Panelists from Maluku gave a score of really like the product (8) on all aspects (odor, appearance, taste, and texture). Phenol and carbonyl compounds play an important role in the taste of smoked fish, such as guaiacol and syringol as phenolic compounds that provide specific organoleptic characteristics (Kjällstrand and Petersson 2001; Cardinal et al. 2006; Martinez et al. 2007; Jónsdóttir et al. 2008; Oduor-Odote et al. 2010). Smoked fish in a closed smoking house produces a high aroma; this is because heat and smoke are more concentrated through the fish being smoked compared to an open smoking room, where the heat and smoke spreads and does not maximally pass through the fish being smoked because the wind blows it (Dotulong and Montolalu 2018). The duration of fish smoking causes differences in the texture of smoked fish—the longer the fish undergoes the smoking process, the resulting texture will be tougher and harder so that the texture is less favored by panelists (Sumartini et al. 2014). The more smoke absorbed by the fish's body will affect the taste of the smoked fish (Lombongadil et al. 2013). The different amount of smoke attached to the fish due to the duration of the smoking process and the amount of smoking material used will cause an increase in the smoke component of the fish so that the color, taste, and aroma produced will also differ from each fish smoking producer (Isamu et al. 2012). Phenol and carbonyl compounds give flavor to smoked fish (Martinez et al. 2007). The smoke component can extend the shelf life because it has antibacterial activities (Abolagba and Igbinevbo 2010) in addition, it can also produce products with a specific taste and aroma (Bower et al. 2009).

In conclusion, fresh skipjack tuna and fufu fish are good sources of protein. Fish smoking increases protein and fat content, but it decreases water, ash, carbohydrates, and crude fiber content. Fufu fish contains essential and non-essential amino acids very useful for nutritional intake. Fufu fish also contains fatty acids with many benefits. Based on the results of the hedonic test, the panelists gave a like response. Fufu fish is a product potential for future development.

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