Characteristics of chikuwa with the addition of liquid smoke as an antibacterial agent

1,*Swastawati, F., 1Agustini, T.W., 1Riyadi, P.H., 1Purnamayati, L., 2Prasetyo, D.Y.B., 3Setiaputri, A.A. and 4Sholehah, D.F.

1Department of Fish Product Technology, Faculty of Fisheries and Marine Sciences, Universitas Diponegoro, Jl. Prof. H. Soedarto, SH, Semarang 50275, Central Java, Indonesia
2 Department of Fisheries Science, Universitas Nahdlatul Ulama Purwokerto, Banyumas 53145, Central Java, Indonesia
3Master’s Student of Department of Aquatic Product Technology, IPB University, Bogor 16680, West Java, Indonesia
4Master’s Student of Department of Aquatic Resources Management, Universitas Diponegoro, Semarang 50275, Central Java, Indonesia

Abstract

Chikuwa is a surimi-based product that quickly deteriorates due to bacterial growth. Chikuwa has a high nutrient content from fish as its main ingredient. The high nutritional content leads to quality degradation and a shortened shelf life. The addition of liquid smoke to chikuwa can inhibit the growth of microorganisms, such as bacteria. This research aimed to investigate the effect of adding liquid smoke as an antibacterial agent to catfish and snapper surimi-based chikuwa. The results showed that the application of liquid smoke significantly affected the pH, total volatile base nitrogen, and total plate count of chikuwa compared to chikuwa without the addition of liquid smoke. However, the addition of liquid smoke did not affect the aw value. The use of different types of fish significantly affected the results. This is due to the different nutrient contents in each fish. Chikuwa with and without the addition of liquid smoke resulted in good quality and consumable products as indicated by TVBN and TPC values has met the standards of 35 mg-N/100 g and 1×10^5 CFU/g, respectively.

1. Introduction

Chikuwa is a surimi-based product with seasoning shaped using bamboo rods and roasted at 130-180°C until its inner temperature reaches 75°C (Jia et al., 2018; Leviyani et al., 2019). Chikuwa belongs to a gel-based fishery product, where texture is an important parameter to determine the quality. Low-quality chikuwa is easily broken when chewed. As a result, fish meat used as raw materials affects the quality of chikuwa. The texture of catfish varies depending on the species (Cheng et al., 2014).

Catfish (Clarias sp.) and red Snapper (Lutjanus sp.) are Indonesian fishery commodities whose production is expected to increase annually. They come from the broader Indonesian ocean that reaches 104,000 km (Tran et al., 2017; Colon, 2018). In Indonesia, catfish are easily cultured freshwater fish (Hastuti and Subandiyono, 2014). Catfish is mainly consumed by frying or grilling, and it can be processed into Kamaboko (Suryaningrum et al., 2015) and Abon (meat floss) (Sundari et al., 2017). Red Snapper is an export commodity and is mainly processed into fillets (Rucitra, 2019). Since there has been no research on catfish and red snapper processing into Chikuwa, the fish can be used as raw materials.

Catfish and red snapper have a high nutrient content. Catfish contains 52.45% moisture, 4.05% ash, 20.83% protein, 3.85% carbohydrate, and 13.86% lipids (Adeniyi et al., 2012). Red snapper contains 78.00% moisture, 1.46% ash, 20.45% protein, and 1.37% lipids (Nurnadia et al., 2011). High nutrient content can affect the shelf life of chikuwa. The deterioration is mainly caused by enzymatic activity and the growth of gram-negative microorganisms that leads to shorter shelf-life and a decrease in consumer acceptance (Masniyom, 2011). Therefore, it is necessary to have a food additive that can serve as an antibacterial agent to extend its shelf-life.

Liquid smoke results from condensed steam distillation products and contains chemical components that serve as antimicrobial properties and natural

*Corresponding author.
Email: fronthea_thp@yahoo.co.id; fronthea.swastawati@live.undip.ac.id

DOI: https://doi.org/10.26656/fr.2017.6(5).544
preservatives. Liquid smoke could be used as a food preservative because of the antimicrobial and antioxidant compounds such as aldehydes, carboxylic acids, and phenols. Liquid smoke is able to maintain the quality of food with its antioxidant and antimicrobial properties and gives the desired colour, flavour, and aroma (0; Lingbeck et al., 2014). Liquid smoke has been added to many foodstuffs, including pork sausages (Bhuyan et al., 2018), yellowfin tuna (Nithin et al., 2015), and bacon (Soares et al., 2016). The novelty of this research is the application of liquid smoke in chikuwa. Therefore, this study investigated the effect of liquid smoke as an antibacterial agent on catfish and snapper surimi-based Chikuwa.

2. Materials and methods

2.1 Materials

Catfish (Clarias sp.) and Snapper (Lutjanus sp.) were purchased from a local market in Semarang, Central Java, Indonesia. The distance between the local market and the laboratory is approximately 45 minutes. Both fish were brought to the laboratory in a Styrofoam icebox to maintain cold temperatures. After that, both fish were cleaned, filed, and the meat was separated from the gills, skin, and stomach. Then, the fish meat was ground, and the prepared seasoning was added. Coconut shell liquid smoke was purchased from PT. Asap Cair Multiguna in Semarang, Central Java, Indonesia, and chemical reagents were purchased from PT. Bratachem, Semarang, Central Java, Indonesia.

2.2 Chikuwa preparation

The chikuwa was made according to Bhatkar et al. (2002). Fish fillets were washed and cleaned with running water and then crushed with a meat grinder. Minced fish were then put into a food processor to be mixed with seasonings, such as sugar, salt, potato starch, and ice cubes. Liquid smoke was added with 3% catfish (CLA) and snapper (CKA) weight. Homogeneous dough was kneaded until homogeneity was achieved. The dough and 1 to 2 tablespoons of water were added. It was kneaded until homogeneity was achieved. The dough was moulded using a cutting board or placemat that had a flat surface. Then, the mixture was neatly rolled on the bamboo. The dough was flattened using bamboo, and its edges were trimmed until it was neat. The chikuwa roasting process was carried out using an electric stove for 20 mins by rotating the bamboo several times. The roasting could be evenly distributed and produced an even brown colour. Ripe chikuwa was released from bamboo. Chikuwa was then packed airtight using polypropylene plastic and stored at -18°C for 24 hrs. The sample was then analyzed in the laboratory. The processing time from sample preparation to chikuwa fish product preparation was approximately 6 hrs. This study was divided into 4 groups: CL: chikuwa from Catfish (Clarias sp.), CK: chikuwa from Snapper (Lutjanus sp.), CLA: chikuwa from Catfish (Clarias sp.) with liquid smoke, and CKA: chikuwa from Snapper (Lutjanus sp.) with liquid smoke.

2.3 a_w assay

The a_w content was tested by putting the sample in a specialized tube and inserting it into an aw metre (Benchtop Water Activity Metre, Aqualab 4TE). The aw metre was calibrated by adding BaCl_2-H_2O to the sample container. The a_w meter was closed and left for 3 mins until the aw scale was recorded at 0.9. Then, the a_w metre was opened, and the sample area was cleaned. After cleaning, the sample was inserted and recorded again after 5 mins. The scale was read by checking the temperature scale for the correction factor (Bhuyan et al., 2018).

2.4 pH assay

The pH measurement was done by weighing a sample that was cut into pieces as small as 10 g, smoothed on a mortar, and homogenized with 20 mL of distilled water for 1 min. The solvent was poured in a 10 mL beaker glass, and the pH was measured using a pH metre. The device was first calibrated with a pH buffer solvent 7 before use (Bhuyan et al., 2018).

2.5 Total volatile base nitrogen assay

The total volatile base nitrogen (TVBN) analysis was performed following the methods reported by National Standardization Agency for Indonesia number 2354.8: 2009. TVBN testing was carried out by weighing a sample as heavy as 10±0.1 g. Then, 90 mL of 6% perchloric acid was added. Samples were homogenized for 2 mins. The sample was filtered using coarse filter paper, and the extract (filtrate) was obtained. Up to 50 mL of extract was inserted into the distillation tube. Then, a few drops of the phenolphthalein indicator and a few drops of antifoaming silicon were added. The distillation tube was attached to a steam distillation apparatus, and 10 mL of 20% NaOH was added. An Erlenmeyer container containing 100 mL H_2BO_3 3% and 3–5 drops of the Tashiro indicator was prepared. Then, steamed distillation was carried out for approximately 10 min to obtain 100 mL of distillate. Therefore, the final volume was less than 200 mL of a green solvent. The blank solvent was distilled by replacing the sample extract with 50 mL of 6% PCA, further processing the sample. The sample distillates and blanks were titrated using 0.02 N HCl solvents. A purple reformation marked the endpoint of the titration. The TVBN content could be calculated using the formula (National Standardization
3. Results and discussion

3.1 $a_w$ content

The $a_w$ indicates the amount of free water in food that microbes can use for growth. If the water content of the material is reduced, microbial growth slows. Park (2008) reported that water in food is found in various forms, such as free water and bound water. Free water can help the damage to foodstuffs, such as chemical, enzymatic, and microbiological elements.

The $a_w$ value between the chikuwa in the treatment and control groups ranged from 0.899 to 0.900 and was not significantly different (P>0.05) (Figure 1). This result indicated that liquid smoke did not affect the $a_w$. Several studies have suggested that $a_w$ in common carp surimi ranges between 0.96–0.98, piramutaba surimi 0.98, and anchovy kamaboko 0.92 (Galvao et al., 2012; Ramos et al., 2012; Liu et al., 2014). A food product with an $a_w$ of 0.9–1 is a water-rich food that allows for bacterial growth (Ramos et al., 2012).

The $a_w$ content of foodstuffs is closely related to bacterial growth. The results of $a_w$ measurements were used to develop products, control product quality, and as essential criteria for evaluating product safety. Higher $a_w$ content in foodstuffs is caused by several factors, such as the type and quality of raw materials and the processing. Bacteria have the minimum, optimum, and maximum $a_w$ conditions for growth (Abbas et al., 2009). Foodstuffs with an $a_w$ content of 0.85 could be safe to reduce the growth rate of pathogenic bacteria. As a moist food, Chikuwa had an $a_w$ level greater than 0.85 and was categorized as a high $a_w$ product, but it was safe if other chemical factors, such as pH, were adequately considered.

![Figure 1. The water activity of chikuwa from a different group. Values are expressed as mean ± standard deviation. Values with different superscript are significantly different (P<0.05). CL: chikuwa from Catfish (Clarias sp.), CK: chikuwa from Snapper (Lutjanus sp.), CLA: chikuwa from Catfish (Clarias sp.) with liquid smoke, and CKA: chikuwa from Snapper (Lutjanus sp.) with liquid smoke.](image-url)

### 3.2 pH

pH is a vital parameter in determining the quality of a product because a decrease in the quality of fresh fish can affect the pH content (Susanto et al., 2011). A pH test was performed to determine the acidity or basicity of a sample. Based on the data (Figure 2), the pH of chikuwa CL and CK was neutral. This result indicated the freshness of the raw materials and corresponded to the $a_w$ value. The addition of liquid smoke decreased the pH, as shown by the pH values of CLA and CKA of 5.67 and 5.47, respectively. The addition of liquid smoke gave a sour attribute to the sample. Prasetyo et al. (2015) reported that adding rice husk liquid smoke to milkfish decreased the pH to approximately 5.5-5.6. The fish meat absorbed the acid compound from the liquid smoke and led to a decrease in pH. High and low pH contents are influenced by the smoking duration, prolonged smoking, and smoking elements and acids are more absorbed and attached to the product (Tnuwo et al., 2019).

The organic acid in liquid smoke is dominated by acetic acid (Montazeri et al., 2013; Budaraga et al., 2017). Kailaku et al. (2017) reported that the pH of coconut shell liquid smoke is 2.79. The decreased pH in chikuwa is also caused by water loss due to the reaction of polyphenols and carbonyl in liquid smoke with protein content in fish meat (Swastawati et al., 2013). The pH of
the CLA was higher than the CKA. This was due to protein content differences in both fish.

Processed fish meat with a high pH was commonly caused by essential compounds such as ammonia, trimethylamine, and other volatile compounds, which can reduce the organoleptic content of the product. An increase in pH is caused by spoilage bacteria that produce proteolytic enzymes. This enzyme can break down proteins into ammonia (NH$_3$), trimethylamine, and volatile components, thus increasing the pH content (Goulas and Kontominas, 2005). According to Montazeri et al. (2013), preservation with liquid smoke results in a pH of approximately 2.3-5.7 or even lower or acid, which may inhibit the growth of microorganisms. Some commercial liquid smoke has a pH of 3–4, where pH ≤ 4 can inhibit the growth of bacteria and fungi (Chemie, 2003; Swastawati et al., 2014).

3.3 Total volatile base nitrogen

A TVBN test was one of the testing parameters to determine the level of freshness of fish. The TVBN test was carried out by measuring the number of nitrogenous bases formed in fish due to the bacterial metabolism of protein. According to Chudasama et al. (2018), high protein content can cause protein degradation or contamination of proteins, peptides, and amino acids found in fish bodies. This degradation process was caused by the activity of bacteria, which can convert proteins into volatile bases such as ammonia, diethylamine, and trimethylamine.

The results indicated that the addition of liquid smoke decreased the TVBN value in both treatment samples (CLA and CKA) compared to the control sample (CL and CK) (Figure 3). The results were similar to Achjadi et al. (2013), who applied liquid smoke to pomfret fish, resulting in a lower TVBN than the control sample. Hadanu and Apituley (2013) reported that liquid smoke contains phenols, organic acids, aldehydes, and ketones that work as antibacterial agents. The main chemical compounds in the smoke include formic acid, acetic acid, butyric acid, caprylate, vanillate, syringic acid, methoxyphenyl, furfural glyoxal metals, methanol, ethanol, octanol, acetalddehyde, diacetyl, acetone, and 3.4 benzopyrenes. These chemical compounds can play a bacteriostatic, bactericidal role and inhibit fat oxidation. These compounds also stick to meat and provide a preservative effect (Budaraga et al., 2017; Janairo and Amalin, 2018). Therefore, the application of liquid smoke inhibited the growth of bacteria in chikuwa and produced a lower TVBN value than the control sample.

The use of liquid smoke in tuna can inhibit bacterial growth due to phenol and acid contents in liquid smoke, which damage the bacterial cell membrane. A lower value of TVBN indicates this compared to tuna without liquid smoke (Lasindrang, 2017). Furthermore, the chemical components of liquid smoke, including organic acids, carboxylic acids and some ingredients, cause acidic conditions. Acidic conditions inhibit bacterial and fungal growth.

A static test showed a significant difference (p <0.05) in the TVBN values for CLA and CKA. The TVBN values in CLA were lower than those in CKA, amounting to 8.29 mg-N/100 g and 13.62 mg-N/100 g, respectively. This difference was due to the different protein contents in the fish. The protein content in catfish was 15.86% (Mahboob et al., 2019), whereas, for snapper, it was 21.46%. The production of TVBN in catfish was 15.86% (Mahboob et al., 2019), whereas, for snapper, it was 21.46%. The production of TVBN is due to protein breakdown by microbes (Kumar et al., 2014). Additionally, both chikuwa with the treatment and control had TVBN values below the standard for consumption (35 mg-N/100 g). TVBN values in fishery
products is 35 mg-N/100 g (European Commission, 2008).

3.4 Antibacterial activity

Foodstuffs that contain protein, such as chikuwa made from fish, are easily damaged by bacteria from the environment. The growth of microorganisms in this product can be caused by unwanted physical and chemical changes that are inappropriate for consumption because they cause health problems. Therefore, it was essential to determine the number of bacteria in foodstuffs to check their feasibility for consumption (Mailoa et al., 2017).

The application of liquid smoke in chikuwa decreased the TPC value compared to the control chikuwa (Figure 4). TPC values in CLA and CKA were lower than those of CL and CK. This indicated that liquid smoke acted as an antibacterial agent. The TPC value was below the maximum consumption level of $5 \times 10^5$ CFU/g. This result was better than that of Handayani et al. (2019) added sugarcane liquid smoke to tilapia dumplings, resulting in a TPC value of $5 \times 10^3$ CFU/g. The use of liquid smoke encapsulated with maltodextrin showed a small difference in the TPC value of Nile tilapia that received 0, 1 and 1.5% of liquid smoke during cold preservation. The TPC value was 2.867, 2.700, and 2.307, respectively. It was indicated that a higher liquid smoke concentration exhibited a higher antimicrobial level. The phenol content and pH contribute to antimicrobial effects in this product (Ariestya et al., 2016).

Liquid smoke is a potent antibacterial agent that can inhibit the growth of pathogenic bacteria such as Escherichia coli and Salmonella enterica serovar Typhi (Dien et al., 2019). Coconut shell liquid smoke effectively inhibits the growth of Staphylococcus aureus and Pseudomonas aeruginosa in fish meatballs. The addition of coconut shell liquid smoke on fish meatballs can increase the shelf life of fish meatballs from 16 to 32 hrs (Zuraida et al., 2011).

The TPC value was correlated with TVBN, and the addition of liquid smoke produced lower TPC and TVBN values in CLA and CKA than in CL and CK. TVBN was a product of bacterial spoilage metabolism, while TPC showed the number of bacteria. Based on the data, the addition of liquid smoke can inhibit the activity of bacteria in chikuwa. Liquid smoke has various functional properties, such as producing the desired flavour. Another function is preservation because of the content of phenol and acid compounds that act as antioxidants and antimicrobials (Toledo, 2008; Riyadi, 2019).

4. Conclusion

The application of liquid smoke can inhibit the growth of bacteria in chikuwa. This result was indicated by a decrease in pH, TVBN, and TPC in chikuwa based on catfish and snapper compared to the control chikuwa. However, the addition of liquid smoke did not affect the value of $a_w$. The nutritional content of each fish caused the difference in results between catfish and snapper chikuwa. The results of this study indicate that liquid smoke can act as an antibacterial agent in chikuwa products.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgement

The authors would like to thank Diponegoro University for facilitating this research. This research was funded by the Ministry of Research, Technology, and Higher Education of Indonesia with Grant Number 101-99/UN7.P4.3/PP/2019.

References

Abbas, K.A., Saleh, A.M., Mohamed, A. and Lasekan, O. (2009). The relationship between water activity and fish spoilage during cold storage: A review. Journal of Food Agriculture and Environment, 7(3), 86–90.

Achmadi, S.S., Mubarik, N.R., Nursyamsi, R. and Septiaji, P. (2013). Characterization of redistilled liquid smoke of oil-palm shells and its application as fish preservatives. Journal of Applied Sciences, 13 (3), 401–408. https://doi.org/10.3923/jas.2013.401.408
Adeniyi, S.A., Orjielwe, C.L., Ehigbonare, J.E. and Josiah, S.J. (2012). Nutritional composition of three different fishes (Clarias gariepinus, Malapterurus electricus and Tilapia guineensis). Pakistan Journal of Nutrition, 11(9), 793–797. https://doi.org/10.3923/pjn.2012.891.895

Ariestya, D.I., Swastawati, F. and Susanto, E. (2016). Antimicrobial activity of microencapsulation liquid smoke on Tilapia [Oreochromis niloticus (Linnaeus, 17580] meat for preservatives in cold storage (+5°C). Aquatic Procedia, 7, 19–27. https://doi.org/10.1016/j.aqpro.2016.07.003

Bhatkar, M.A., Joshi, V.R. and Balam, M.B. (2002). Effect of Microwave Pasteurisation on the Quality of Fish Chikuwa. Journal of the Indian Fisheries Association, 29, 93–101.

Bhuyan, D., Das, A., Laskar, S.K., Bora, D.P., Tamuli, S. and Hazarika, M. (2018). Effect of different smoking methods on the quality of pork sausages. Veterinary World, 11(12), 1712–1719. https://doi.org/10.14202/vetworld.2018.1712-1719

Budaraga, I.K., Armim, A., Marilda, Y. and Bulanin, U. (2017). Chemical Components Analysis of Cinnamon Liquid Smoke with GC MS from Various Production of different Purification Method. International Journal of ChemTech Research, 10(1), 12–26.

Chemie, G. (2003). Tari smoke. Tari Service International. Germany: Posatfach Ludwigshafen amRhein.

Cheng, J.H., Sun, D.W., Han, Z. and Zeng, X.A. (2014). Texture and structure measurements and analyses for evaluation of fish and fillet freshness quality: A review. Comprehensive Reviews in Food Science and Food Safety, 13(1), 52–61. https://doi.org/10.1111/1541-4337.12043

Chudasama, B.G., Dave, T.H. and Bholia, D.V. (2018). Comparative study of quality changes in physicochemical and sensory characteristics of iced and refrigerated chilled store Indian Mackerel (Rastrelliger kanagurta). Journal of Entomology and Zoology Studies, 6(4), 533–537.

Colon, P.I. (2018). Snapper Fishing in Indonesia: The Prerequisites for a Sustainable Management Approach. Costa Rica: University for Peace.

Dien, H.A., Montolalu, R.I. and Berhimpon, S. (2019). Liquid smoke inhibits growth of pathogenic and histamine forming bacteria on skipjack fillets. IOP Conference Series: Earth and Environmental Science, 278, 012018. https://doi.org/10.1088/1755-1315/278/1/012018

Swastawati, F., Darmanto, Y.S., Sya’rani, L., Kuswanto, L.K. and Taylor, K.D.A. (2014). Quality characteristics of smoked skipjack (Katsuwonus pelamis) using different liquid smoke. International Journal of Bioscience Biochemistry and Bioinformatics, 4(2), 94–99. https://doi.org/10.7763/IJBBB.2014.V4.318

Galvao, G.C.S., Lourenco, L.F.H., Ribeiro, S.C.A., Ribeiro, C.F.A., Park, K.J. and Araujo, E.A.F. (2012). Microbiological and physicochemical characterization of surimi obtained from waste of piramutaba fillet. Food Science and Technology, 32(2), 302-307. https://doi.org/10.1590/S0101-20612012005000058

Goulas, A.E. and Kontominas, M.G. (2005). Effect of salting and smoking-method on the keeping quality of chub mackerel (Scomber japonicus): Biochemical and sensory attributes. Food Chemistry, 93(3), 511–520. https://doi.org/10.1016/j.foodchem.2004.09.040

European Commission. (2008). Commission regulation (EC) No 1022/2008 of 17 October 2008 amending regulation (EC) No 2074/2005 as regards the total volatile basic nitrogen (TVB-N) limits. Retrieved from European Commission website: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008R1022&from=EN

Handayani, E., Swastawati, F. and Rianingsih, L. (2019). Shelf life of tilapia (Oreochromis niloticus) dumplings with addition of bagasse liquid smoke during storage at chilling temperature (+5°C). Jurnal Perikanan Universitas Gadjah Mada, 21(2), 111–118. https://doi.org/10.22146/jfs.42017

Hastuti, S. and Subandiyono, S. (2014). Production Performance of African Catfish (Clarias gariepinus, Burch) were Rearing with Biofloc Technology. Indonesian Journal of Fisheries Science and Technology, 10(1), 37–42.

Janairo, J.I.B. and Amalin, D.M. (2018). Volatile chemical profile of cacao liquid smoke. International Food Research Journal, 25(1), 213–216.

Jia, R., Eguche, M., Ding, W., Nakazawa, N., Osako, K. and Okazaki, E. (2018). Quality Changes of Commercial Surimi-based Products after Frozen Storage. Transactions of the Japan Society of Refrigerating and Air Conditioning Engineers, 35(3), 205-210. https://doi.org/10.11322/tjsrae.18-15FB_OA

Lasindrang, M. (2017). Potential of liquid smoke from
palm kernel shell as biopreservative to tuna (Thunnus sp.) fish protein. Indonesian Food and Nutrition Progress, 14(1), 59-67. https://doi.org/10.22146/ifnp.24281

Leviyani, R.A., Kurniasih, R.A. and Swastawati, F. (2019). Application of Liquid Smoke for Chikuwa tilapia. IOP Conference Series: Earth and Environmental Science, 246, 012084. https://doi.org/10.1088/1755-1315/246/1/012084

Lingbeck, J.M., Cordero, P., O’Bryan, C.A., Johnson, M.G., Ricke, S.C. and Crandall, P.G. (2014). Functionality of liquid smoke as an all-natural antimicrobial in food preservation. Meat Science, 97(2), 197–206. https://doi.org/10.1016/j.meatsci.2014.02.003

Liu, Q., Kong, B., Han, J., Chen, Q. and He, X. (2014). Effects of superchilling and cryoprotectants on the quality of common carp (Cyprinus carpio) surimi: Microbial growth, oxidation, and physiochemical properties. LWT - Food Science and Technology, 57(1), 165-171. https://doi.org/10.1016/j.lwt.2014.01.008

Kailaku, S.I., Syakir, M., Mulyawanti, I. and Syah, A.N.A. (2017). Antimicrobial activity of coconut shell liquid smoke. IOP Conference Series: Materials Science and Engineering, 206, 012050. https://doi.org/10.1088/1757-899X/206/1/012050

Kumar, P.M., Annathai, R.A., Shakila, J.R. and Shanmugam, S.A. (2014). Proximate and major mineral composition of 23 medium sized marine fin fishes landed in the Thoothukudi Coast of India. Journal of Nutrition and Food Sciences, 4(1), 1000259. https://doi.org/10.4172/2155-9600.1000259

Mahboob, S., Al-Ghanim, K.A., Al-Balawi, H.F.A., Al-Misned, F. and Ahmed, Z. (2019). Study on assessment of proximate composition and meat quality of fresh and stored Clarias gariepinus and Cyprinus carpio. Brazilian Journal of Biology, 79(4), 651–658. https://doi.org/10.1590/1519-6984.187647

Mailoa, M.N., Tapotubun, A.M. and Matrutty, T.E.A.A. (2017). Analysis Total Plate Count (TPC) on Fresh Steak Tuna Applications Edible Coating Caulerpa sp. during Stored at Chilling Temperature. IOP Conference Series Earth and Environmental Science, 89, 012014. https://doi.org/10.1088/1755-1315/89/1/012014

Masiyom, P. (2011). Deterioration and shelf-life extension of fish and fishery products by modified atmosphere packaging. Songklanakarin Journal of Science and Technology, 33(2), 181–192.

Montazeri, N., Oliveira, A.C.M., Himelbloom, B.H., Leigh, M.B. and Crapo, C.A. (2013). Chemical characterization of commercial liquid smoke products. Food Science and Nutrition, 1(1), 102–115. https://doi.org/10.1002/fsn3.9

National Standardization Agency for Indonesia. (2009). Chemical Assay-Part 8: Determination of Total Volatile Base Nitrogen (TVB-N) and Trimetil Amin Nitrogen (TMA-N) on Fisheries Products. Jakarta, Indonesia: National Standardization Agency for Indonesia.

National Standardization Agency for Indonesia. (2015). Determination of Total Plate Count on Fisheries Product. SNI 2332.3:2015 - Indonesian National Standard of Microbiological Determination. Jakarta, Indonesia: National Standardization Agency for Indonesia.

Nithin, C.T., Ananthanarayanan, T.R., Yathavamoorthi, R., Bindu, J., Joshy, C.G. and Gopal T.K.S. (2015). Physico-chemical Changes in Liquid Smoke Flavoured Yellowfin Tuna (Thunnus albacares) Sausage During Chilled Storage. Agricultural Research, 4(4), 420–427. https://doi.org/10.1007/s40003-015-0189-z

Nurmadia, A.A., Azrini, A. and Amin, I. (2011). Proximate composition and energetic value of selected marine fish and shellfish from the West Coast of Peninsular Malaysia. International Food Research Journal, 18(1), 137–148.

Park, Y.W. (2008). Moisture and Water Activity. In Nollet, L.M.L. and Tolda, F. (Eds). Handbook of Processed Meats and Poultry Analysis, p. 35–67. Boca Raton, USA: CRC Press. https://doi.org/10.1201/9781420045338.ch3

Prasetyo, D.Y.B., Darmanto, Y.S. and Swastawati, F. (2015). The effect of different temperature and the longer of smoking to the quality of smoke milkfish (Chanos chanos Forsk) boneless. Jurnal Aplikasi Teknologi Pangan, 4(3), 94–98.

Ramos, L.R.O., Choi, N.D. and Ryu, H.S. (2012). Effect of processing conditions on the protein quality of fried anchovy kamaboko Engraulis japonica. Fisheries and Aquatic Science, 15(4), 265-273. https://doi.org/10.5657/FAS.2012.0265

Riyadi, P.H. (2019). Screening of Chemical Components in The Protein Hydrolyzate Extract from Viscera of Tilapia (Oreochromis niloticus) With Color Assay. Russian Journal of Agricultural and Socio-Economic Sciences, 6(90), 339-345. https://doi.org/10.18551/rjoes.2019-06.42

Rucitra, A.L. (2019). The application of material handling in fish fillet production process of red

© 2022 The Authors. Published by Rynnye Lyam Resources
Snapper in PT X. *IOP Conference Series Earth and Environmental Science*, 230, 012061. https://doi.org/10.1088/1755-1315/230/1/012061

Soares, J.M., da Silva, P.F., Puton, B.M.S., Brustolin, A.P., Cansian, R.L., Dallago, R.M. and Valduga, E. (2016). Antimicrobial and antioxidant activity of liquid smoke and its potential application to bacon. *Innovative Food Science and Emerging Technologies*, 38(Part A), 189–197. https://doi.org/10.1016/j.ifset.2016.10.007

Sundari, R.S., Kusmayadi, A. and Umbara, D.S. (2017). The Added Value of Shredded Lele and Patin Catfish. *Jurnal Pertanian Agros*, 19(1), 45–54.

Susanto, E., Agustini, T.W., Ritanto, E.P., Dewi, E.N. and Swastawati, F. (2011). Changes in oxidation and reduction potential (Eh) and pH of tropical fish during storage. *Journal of Coastal Development*, 14(3), 223–234.

Suryaningrum, T.D., Irianto, H.E. and Ikasari, D. (2015). Characteristics of Kamaboko from Catfish (*Clarias gariepinus*) Surimi Processed with Carrot and Beet Root as Filler and Natural Food Colorants. *Squalen Bulletin of Marine & Fisheries Postharvest and Biotechnology*, 10(3), 99–108. https://doi.org/10.15578/squalen.v10i3.169

Swastawati, F., Susanto, E., Cahyono, B. and Trilaksono, W.A. (2012). Sensory Evaluation and Chemical Characteristics of Smoked Stingray (*Dasyatis bleekereyi*) Processed by Using Two Different Liquid Smoke. *International Journal of Bioscience Biochemistry and Bioinformatics*, 2(3), 212–216. https://doi.org/10.7763/IJBBB.2012.V2.103

Swastawati, F., Surti, T., Agustini, T.W. and Riyadi, P.H. (2013). Quality characteristics of smoke fish processed by different methods and types of fish. *Jurnal Aplikasi Teknologi Pangan*, 2, 126–132.

Tnuwo, G., Berhimpon, S., Taher, N., Sanger, G., Mongi, E., Mentang, F. and Dotulong, V. (2019). Water Sorption Isotherm of Wooden Fish (Katsuabushi) Made from Different Liquid Smoke Concentration and Soaking Duration. *Media Teknologi Hasil Perikanan*, 7, 36–40. https://doi.org/10.35800/mthp.7.2.2019.23614

Toledo, R.T. (2008). Wood smoke components and functional properties. In Kramer, D.E. and Brown, L. (Eds.) International Smoked Seafood Conference Proceedings, p. 55–61. Alaska, USA: Sea Grant. https://doi.org/10.4027/isscp.2008.12

Tran, N., Rodriguez, U.P., Chan, C.Y., Phillips, M.J., Mohan, C.V., Henriksson, P.J.G., Koeshendrajana, S., Suri, S. and Hall, S. (2017). Indonesian aquaculture futures: An analysis of fish supply and demand in Indonesia to 2030 and role of aquaculture using the AsiaFish model. *Marine Policy*, 79, 25–32. https://doi.org/10.1016/j.marpol.2017.02.002

Zuraida, I., Sukarno, S. and Budijanto, S. (2011). Antibacterial activity of coconut shell liquid smoke (CS-LS) and its application on fish ball preservation. *International Food Research Journal*, 18(1), 405-410.