Dried-Smoked Lizardfish (*Saurida tumbil*) as An Improvement in Product Quality on An Export Scale

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Abstract. Lizardfish has a high economic value and delicious taste. Lizardfish can be processed into smoked fish. This study aimed to compare the changes in the quality of fresh lizardfish and dried-smoked lizardfish, and to examine protein damage in fresh lizardfish and dried-smoked lizardfish products based on protein functional groups. The study was analyzed using organoleptic quality testing, sensory testing, FTIR, texture (hardness), color, water content, ash content, protein, amino acid profile, and TPC testing. The ash content in fresh lizardfish ranged from 0.94-0.95%, whereas in dried-smoked lizardfish, it increased from 4.25-4.30%. The moisture of smoked lizardfish was 15.67%. The color test results for dried-smoked lizardfish showed a dark color because the L value was close to 0. The a* value of fish meat was higher (12.67). The b* value of the fish meat was higher (41.70). The results of measuring the hardness level of dried smoked lizardfish showed a higher hardness value of 8313 g. The protein content in fresh lizardfish was 18.01-18.21%, increasing sharply from 76.78-76.87% in dried-smoked lizardfish. The application of liquid smoke to dried-smoked lizardfish can improve the product quality.

1 Introduction

The fisheries sector is one of the leading business sectors in Central Java Province, especially the capture fisheries sector. The Central Java Province has a substantial marine area. Sea fish commonly caught by fishermen include tuna, skipjack tuna, catfish, anchovies, and lizardfish. Lizardfish (*Saurida tumbil*) are found in muddy bottom waters at depths between 20 and 60 m and shallower waters. Lizardfish eat shrimp and squid, by-products of shrimp fishing activities [1]. Lizardfish has high economic value and delicious taste. A method of processing is required to raise the economic value of fish and avoid excessive loss of nutritional content because of fluctuation in fish production and the short shelf life of fish meat. Until now, only a few people know the benefits of lizardfish. Lizardfish can be processed into fishery products, such as smoked fish.

Smoked fish is one of the popular fishery products and is liked by the Indonesian people because it has a unique taste sensation that creates an appetite for consumers. Smoked fish is a combination of salting, smoking, and drying processes. Drying aims to remove some water from the fish's body. The drying process affects the texture and durability of the product, and the smoking process aims to preserve it and give it a distinctive color and taste due to the smoke decomposition process in the fish [2]. In Indonesia, smoked fish makes up 62,389 units, or 12.42% of all fish processing facilities (PDSKP, 2021) This indicates that smoked fish plays an important role in meeting nutritional needs in Indonesia. In Indonesia, most

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smoking processes are still performed traditionally with basic equipment, paying little attention to sanitation and hygiene, and is detrimental to environmental health, so the products produced do not meet Indonesian national standards [3]. Using liquid smoke in the fish smoking process can be an alternate way for improving the quality of smoked fish products.

Liquid smoke is a product produced from the condensation of coconut shell smoke through a pyrolysis process. Liquid smoke contains components including phenol, organic acids, and carbonyls which function as antibacterial, antifungal, and coagulant. Applying liquid smoke to food items can be done in a number of methods, such as dipping, soaking, or combining it with boiling water. The purpose of the study was to assess the impact of adding liquid smoke to dried-smoked fish products, focusing on moisture content, texture (hardness), and color.

2 Materials and methods

2.1 Materials

Fresh lizardfish was bought from the traditional market in Semarang. Fish were transported in Styrofoam boxes filled with ice gel to preserve their freshness. Liquid smoke was obtained from PT. Asap Cair Multiguna, Indonesia.

2.2 Methods

2.2.1 Fourier-transform infrared spectrometry (FTIR)

The extent of deacetylation was assessed using FTIR analysis, which identifies functional groups such as NH, OH, C-C, CH, and C=O. The FTIR detection results were represented by peaks corresponding to the functional groups of a compound along with their specific wave numbers. The infrared spectrophotometer used was the Shimadzu IR for liquid samples, with the sample container type ATR-8200H/8200HA.

2.2.2 Proximate test of smoked fish and fresh Fish

The proximate test was a chemical analysis method used to determine the nutritional content of a food product. Proximate analysis comprised several stages, including the assessment of moisture, protein, ash, fat, carbohydrate and fiber content (AOAC, 1970). The tests used in this study only tested protein content, water content, and ash content.

2.2.2.1 Moisture content analysis

Moisture content analysis was done by gravimetric method using an oven at 103℃-104℃ for removed the water. The detail method of moisture content analysis followed AOAC (2000) using analytical number 928.08.

2.2.2.2 Ash content test

The ash content was analyzed using the gravimetric method as followed AOAC (2000) with analytical number 960.39.

2.2.2.3 Protein content test

Protein content was performed by Kjeldahl method. The complete step including destruction, distillation and titration was done according to AOAC (2000) method using analytical number 950.46.

2.2.3 Amino acid profile test

A sample solution of 30 µL was added with a drying solution (sodium hydroxide, sodium acetate, and Sulfuric acid) with a ratio of 2:2:1. The solution was then dried until all the solvents had evaporated. A derivatization solution (a mixture of Sodium hydroxide, sodium

acetate, and Sulfuric acid) of 30 µL was added to the drying results with a ratio of 3:3:1 and then left for 20 minutes.

A ten (10) mL of 1 M sodium acetate buffer was added to do the dilution, and Whatman filter paper was then used for filtering. The stock solution, standard solution, and borate buffer were combined in a 1:1 ratio before the standard solution was injected. Within 30 minutes, 5 µL of this combination was put into the HPLC. The amino acid content was calculated using the formula:

$$\text{Amino Acid (\%)}: \frac{The\ Sample\ area \times 100\%}{The\ standard\ area \times Weight\ sample\ (g)}$$

Description:
Fp : Dilution factor
C : Standard concentration of amino acids (µg/mL)
BM : Molecular weight of some amino acids (g/mol)

2.2.4 Color analysis

The color of smoked fish was evaluated by determining the values of L^* (lightness), a^* (which ranges from (+) red to (-) green), and b^* (which ranges from (+) yellow to (-) blue). The photographs were taken with a camera attached to a PC running camera software. Color testing was done with the smartphone software "Color Grab" (Loomatix). The image was taken with a cubic styrofoam box measuring 30 x 30 x 30 cm. The samples were placed inside a box with a white background and suitable illumination. The taken image was loaded into the app. The chosen image was then locked and designated as a color sample.

2.2.5 Texture (hardness) analysis

Using a texture analyzer (TA-TX2, Stable Micro System, UK), the texture (hardness) of smoked fish was examined. The sample was introduced into the smoked fish sample after being passed underneath a spherical probe at a speed of 1 mm/second and a distance of 15 mm [4].

2.2.6 Sensory Test of Smoked Fish and Fresh Fish

Sensory testing was performed using a scoring method on a scale of 1-9 following the SNI 2725:2013 smoked fish score sheet. Testing conducting sensory on samples with 30 panelists aged 20-25 years. The same as sensory testing on fresh fish, but fresh fish uses the SNI 2729-2021 fresh fish score sheet in the same way.

2.2.7 Total Plate Count (TPC)

The TPC test technique began by sanitizing the equipment in an autoclave at 121°C for 2 hours. Plate Count Agar (PCA) was made by dissolving 8 g of PCA in 400 mL of distilled water and keeping the temperature between 45 and 55°C. A ten (10) mL of KH2PO4 was dissolved in one liter of distilled water or Butterfield's Phosphate Buffered and sterilized at 121°C for 15 minutes. To reach a dilution of 10^{-1}, 10 g of the sample was dissolved in 90 mL of Butterfield's phosphate buffer and then homogenized for two minutes. The sample should then be mixed until it reaches a dilution of 10^{-5}. After that, it should be transferred to a petri dish and incubated for 24 hours at 37°C. Each petri dish's bacterial population was counted.

3 Results and Discussions

3.1 Fourier-Transform Infrared Spectrometry (FTIR)

Based on the test results, there is not a big difference between fresh lizard fish and smoked lizard fish. The results of the FTIR analysis of fresh lizard fish are inversely proportional to the smoked lizard fish presented in Fig. 1, 2 and Table 1.

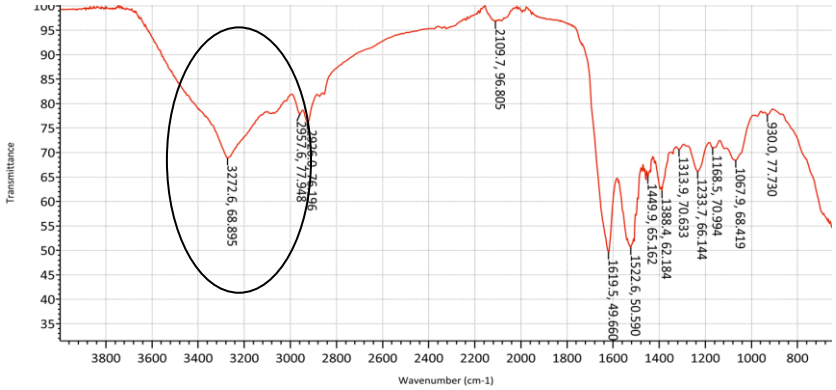

Fig. 1. FTIR spectrum of fresh lizardfish (*S. tumbil*)

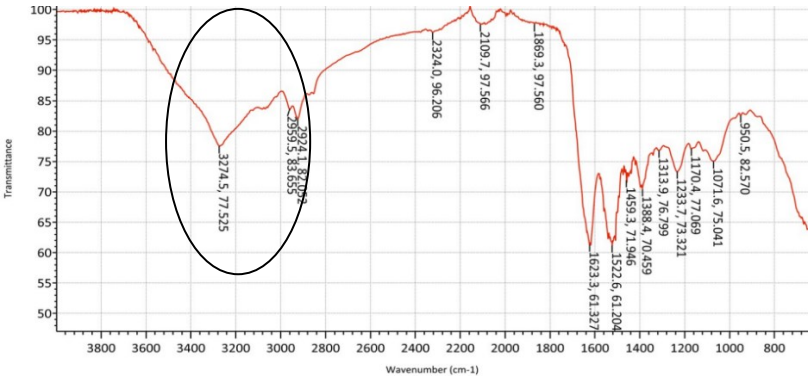

Fig. 2. FTIR spectrum of smoked lizardfish (*S. tumbil*)

Table. 1. FTIR spectrum table of fresh lizardfish (*S. tumbil*)

Sampel	Peak Number	Wavenumber (cm^{-1})	Intensity
Fresh lizardfish	13	3272.6	68.895
Dried-smoked lizardfish	15	3274.5	78.542

The FTIR spectrum showeds no significant difference between fresh and smoked lizardfish. 13 to 14 main peaks indicated the presence of certain functional groups. The structure of the protein compound is characterized by the presence of NH_2 or amine compounds as components. NH_2 compounds are known to have an IR spectrum in the range of 3300cm^{-1} - 3600cm^{-1}. The CT-N structure is identical to CT-C. Thus, in the range of 3249cm^{-1}, it is considered to originate from the stretching of the N-H structure [5].

The results of the infrared spectrophotometer on lizardfish from the spectrum appearing 3272.6cm^{-1} in fresh lizardfish indicates the presence of O-H compound bonds usually appeared in the range of 3300cm^{-1}- 3600cm^{-1} and are much different from the infrared

spectrophotometer on smoked lizardfish which is only 2959 which indicates protein damage. There is a spectrum of N - H = NH_2 because it shows the presence of an amide group in the results. The next spectrum seen is C-N in the range of 2200 cm^{-1} and the last spectrum of CH_3 appears in the range of 1375 cm^{-1}-1950 cm^{-1}. There were no significan differences between fresh and smoked lizardfish. Analysis of functional groups in smoked lizardfish showed the existence of amino acids that make up the protein, indicated by the presence of NH_2. The FTIR spectrum, 3290 cm^{-1} to 3357 cm^{-1} can denoted the existance of N-H, O-H, and NH_2 compounds [6].

Amino acids, that constitute proteins, possess NH_2 groups along their loeng carbon chains. The NH_2 group, known as the amide group, is detected in the infrared spectrum in the range of 3290 cm^{-1} to 3600 cm^{-1}. The presence of a secondary amide structure in the infrared spectrum indicates protein damage, which in turn indicates protein denaturation. Protein damage can be observed following the emergence of secondary structures. It is known that the fresh and smoked lizardfish protein is still in good condition, even though it changes the primary structure of the protein [7].

3.2 Proximate Content

Based on the test, there is a difference between fresh lizardfish and smoked lizardfish. The results of the proximate content of fresh lizardfish were inversely proportional to smoked lizardfish displayed in Table 2.

Table 2. Proximate content of fresh and dried-smoked lizardfish (*S. tumbil*)

Treatment	Ash (%)	Moisture (%)	Protein (%)
Fresh lizardfish	0.945	79.91	18.11
Dried-smoked lizardfish	4.275	15.67	76.825

3.2.1 Protein Content

The protein content in fresh lizardfish ranges from 18.01% to 18.21%, increasing sharply from 76.78% to 76.87% in dried-smoked lizardfish. This increase in protein content shows that the drying and smoking process is very effective in concentrating protein. In addition, the amino acids content including L-Alanine and L-Arginine also showed a significant increase in smoked dried fish compared to fresh fish, reflecting high protein quality (Table 2). Smoking process can increase essential amino acids content in fish products, which are important for various biological functions in the human body [8].

That temperature and cooking time affect the chemical content and physical quality of food ingredients. However, the temperature did not have a significant impact. On the other hand, cooking time affects amino acid hydrolysis [9].

3.2.2 Water Content

Water content of smoked fish is regulated by SNI 2725:2013, which sets a maximum limit of 60%. The average water content of smoked lizardfish is 15.67%. According to these findings, the water content of smoked beloso fish complies with the SNI 2725:2013 standard (60%). Smoked fish products using smoking cabinets and furnaces have a water content that still exceeds the standard limits set by SNI [10].

Water content is a very important quality parameter for a snack product because water content is a liquid that can provide opportunities for reactions that can cause a decrease in quality [11]. The humidity of the surrounding air affects the high and low moisture of smoked fish; therefore, smoking using a stove and oven produces different values. Increasing or decreasing the water content of food ingredients is the impact of the tendency for differences

in the humidity of the surrounding air, in other words, the water content of food ingredients changes according to their environment [12].

3.2.3 Ash Content

The ash content of fresh and smoked lizardfish were 0.945% and 4.275%, respectively. The rise in ash content of fish from traditional smoke to liquid smoke is affected by the heating temperature and duration, and it is inversely referred to the moisture content. The higher the temperature and oven time, the higher is the ash content in the fish, which is inversely proportional to the decrease in moisture content [13, 14].

Laboratory test results showed that the ash content in fresh lizardfish ranged from 0.94% to 0.95%, whereas in smoked dried lizardfish it increased significantly from 4.25% to 4.30%. The drying and smoking processes significantly increased the ash content in fish products. This increase was due to the reduction in water content during the smoking process, which caused the mineral concentration to be higher in the dried fish [15].

3.3 Amino Acids

Based on the test, 15 types of amino acids were found in fresh lizardfish compared to those in smoked lizardfish. The results of the amino acid profile analysis of fresh lizardfish compared to that of smoked lizardfish are presented in Table 3.

Table 3. Amino acid profile test results of fresh and smoked lizardfish

No.	Parameters	Amino Acid Profile Value (mg/g)		ΔT
		Fresh Lizardfish	Dried-smoked Lizardfish	
1	L-Alanine**	1.379	20.273	18.894
2	L-Arginine*	988	11.367	10.379
3	L-Aspartic acid **	0	1.608	1.608
4	Glycine**	344	11.871	11.527
5	L-Glutamic acid**	247	42.843	42.596
6	L-Histidine*	0	2.740	2.740
7	L-Isoleucine*	416	5.704	5.288
8	L-Leucin*	810	15.772	14.962
9	L-Lysine*	336	17.164	16.828
10	L-Valine*	383	13.069	12.686
11	L-Phenylalanine*	7.184	0	7.184
12	L-Proline**	8.382	6.242	2.140
13	L-Serine**	588	149	439
14	L-Threonine*	0	0	0
15	L-Tyrosine**	3.924	0	3.924
Total		11.657	16.3218	151.561

Description: * Essential Amino Acid
** Non-Essential Amino Acid

Based on the test results, the amino acids alanine, arginine, glycine, glutamic acid, leucine, lysine, and valine comprised a large proportion of smoked lizardfish products. The amino acids often found in fish are glutamic acid, aspartate, arginine, lysine, leucine, glycine, and alanine [16].

Glutamic acid showed the highest results in the amino acid profile of smoked lizardfish. Glutamic acid provides a distinctive taste to smoked fish. The savory or umami flavor that is often identified in fish products originates from the glutamic acid contained in smoked fish. The frying cooking method also shows the highest glutamic acid value in smoked lizardfish. That glutamic acid found in protein in free form contributes to providing an umami or savory

taste to food. Among the ways to release glutamate associated with protein into free glutamate is by heating [17].

Aspartic acid in the processing of fresh fish into smoked fish has a difference, namely the appearance of aspartic acid in smoked lizardfish with a value of 1608 mg / g which indicates a change in amino acids that give flavor to smoked lizardfish, aspartic acid is a non-essential amino acid for mammals. Aspartic acid contributes to the production of gluconic acid, urea, and pyrimidine [18]. Furthermore, Aspartic acid is beneficial for treating persistent fatigue. Aspartic acid is produced through the acid hydrolysis of asparagine. Aspartic acid plays an important role in food processing because it can create aroma and taste characteristics in food [19].

3.4 Moisture

The moisture content of dried-smoked and fresh lizardfish is presented in Fig. 3. The result showed that the addition of liquid smoke might influence the moisture levels in the fish. The moisture contents of dried-smoked and fresh lizardfish were 10.28% and 64.30%, respectively. Thus, the dried-smoking process, along with the addition of liquid smoke, can reduce the moisture content of the product. This was due to the presence of acidic compounds in the added liquid smoke, which can expel the free water from the product. Additionally, the liquid smoke permeates the product through osmosis, pushing out the free water contained within it. The addition of liquid smoke to meat leads to remove the free water within the product as a result of osmosis. This process can result in water loss in the product [20].

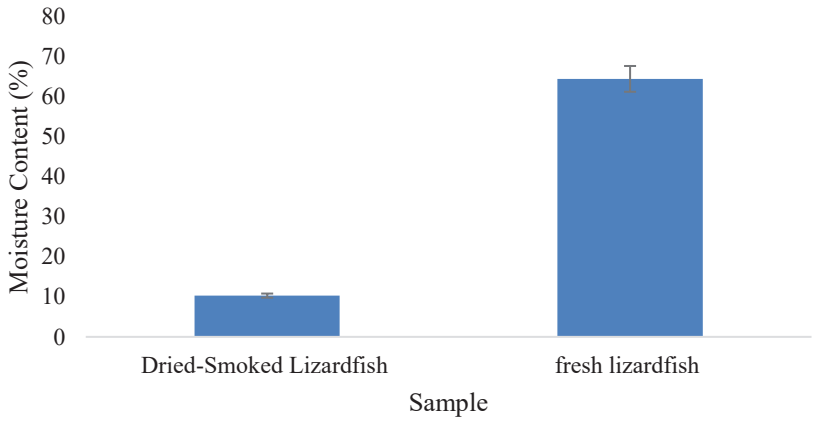

Fig. 3. Moisture content of dried-smoked lizardfish and fresh lizardfish (*S. tumbil*)

The reduced moisture content is inversely related to the concentration of liquid smoke, as liquid smoke has the ability to eliminate moisture in the fish. Acid compounds in liquid smoke lead to protein denaturation, causing proteins to lose their biological properties related to water binding, which allows water to escape more easily from the material. [21].

The salting process also contributes to the decreased water content in smoked barracuda. Salt and acid penetrate the fish muscle, altering the protein properties and reducing the pH level. A low pH value can lead to protein denaturation. The interaction between myofibril proteins and salts can result in protein denaturation, leading to changes in texture and a decreased water holding capacity. [22].

3.5 Color analysis

Table 4 shows the color analysis of the dried lizardfish with the addition of liquid smoke. The value of *L** for a dried-smoked lizardfish aimed to determine the brightness level. The

*L** values ranged from to 0-100. The *L**value of dried-smoked lizardfish (fish flesh and skin) were 43.72 and 22.74, respectively. The skin part has a lower *L**value than fish flesh of dried-smoked lizardfish means the color of the inside part of dried-smoked lizardfish tends to be dark because the *L** value was close to 0. The difference in color in the two samples is thought to be caused by the reaction of smoke components (carbonyl) with proteins (amino acids) contained in the fish flesh and the fish will also influence the color value of the product [23].

Table 4. Color analysis of dried-smoked lizardfish with liquid smoke addition

Color	Samples	
	Fish flesh	Fish skin
*L**	43.72	22.74
*a**	12.67	6.27
*b**	41.70	17.96

L* (lightness), *a** (redness), *b** (yellowness)

The *a** value represents the mixed red-green color in terms of chromaticity. A positive *a** value indicates the presence of red color, ranging from 0 to +80, while a negative *a** value signifies green color, ranging from 0 to -80. Based on the color characteristics displayed in Table 4, it showed that the part of the fish that was analyzed has a different *a** value. The *a** value of fish flesh was higher (12.67) than the fish skin (6.27). The results were positive and near zero, indicating that the color of the dried-smoked lizardfish skin tends to be close to red. Myoglobin content and chemical composition determine meat color [24]. Iodine combines with glycogen in fish, resulting in the red hue. It has been claimed that while cooking, myoglobin is oxidized from ferrous (Fe^{2+}) to ferric (Fe^{3+}), resulting in the creation of metmyoglobin, which gives the meat its reddish hue [25].

The *b** value reflects the mixed blue-yellow color. A positive *b** value, ranging from 0 to +70, indicates the presence of yellow. A negative *b** value, ranging from 0 to -70, denotes the presence of blue. Based on the results, the *b** value of flesh fish was higher than the fish skin, which was 41.70, so the color of flesh fish of dried-smoked lizardfish became closer to yellow. The *b** value in mutton cooked at a higher endpoint temperature result in increased yellowness, causing the *b** value to rise [26]. Fish that have undergone processing have yellow pigmentation because of carotenoid molecules. Colors produced by carotenoid compounds range from brilliant red to yellow and orange. The antioxidants known as carotenoid molecules are unstable at high temperatures and react easily with oxygen. The Maillard reaction, which takes place between amino acid groups and reducing sugars during the heating process, is another factor contributing to the yellow color of processed fish [27] [28].

3.6 Texture (hardness)

The texture (hardness) of the fresh and dried-smoked lizardfish is shown in Fig. 4. The results of the hardness measurement of dried-smoked lizardfish showed that the dried-smoked lizardfish had a higher hardness value of 8040.19 gf. This indicates that more force was needed to break the product, making it harder. The fresh lizardfish had a hardness value of 2404.1 gf. This implies that less force was required to break the product, suggesting that it was not very hard. That boiled carp have lower hardness (7.63) than steamed carp (8.13). This is due to the higher protein content in steamed fish meat, which influences its compact and dense texture. [29].

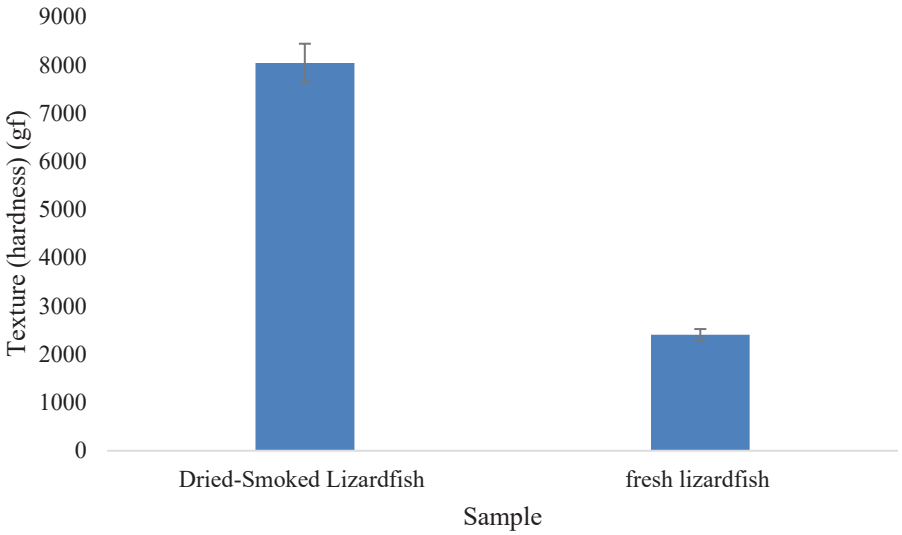

Fig. 4. Texture (hardness) analysis of dried-smoked lizardfish and fresh lizardfish (*Saurida tumbil*)

3.7 Sensory Test

Based on the results of the statistical test of smoked fish sensory testing, the organoleptic test value of fresh lizardfish obtained a confidence interval of 8.04 <μ <8.08 so it can be concluded that the lizardfish is suitable as a raw material for making smoked fish because it has passed the value of 7 stated in SNI No. 2729-2021 concerning fresh fish. This value is different from smoked lizardfish which has an organoleptic test obtained a confidence interval of 8.24 <μ <8.48 so it can be concluded that the lizardfish is suitable for consumption according to SNI No. 2725: 2013 smoked fish, namely 7 so it is suitable for consumption.

The results of the sensory test of smoked lizardfish showed good values because it used liquid smoke as an ingredient to convert fresh lizardfish into smoked lizardfish, liquid smoke is easier to apply because the concentration of liquid smoke is easy to control, providinge the same and uniform flavor and color [30]. The different organoleptic values of traditional smoked fish products obtained were between 7.63-8.13 which are lower than smoked fish processed using liquid smoke, which was obtained at 8.64 - 8.78 [31].

Table 5. Fresh lizardfish and smoked lizardfish sensory test results

Appearance			Meat	Odor	Texture	Xi	$(Xi-\bar{x})^2$
Eyes	Gills	Mucus					
8.07	8.07	8.07	8.00	8.07	8.07	8.06	∑9.57
Appearance	Odor	Flavor	Texture	Mold	Mucus	Xi	$(Xi-\bar{x})^2$
7.87	7.93	8.20	8.13	9.00	9.00	8.36	∑3.76

3.8 Total Plate Count (TPC)

TPC in fresh lizardfish showed the number of bacterial colonies ranging from 3.8×10^5 to 5.8×10^5 colonies while smoked lizardfish has a number of bacterial colonies between 5.2×10^2 to 6.3×10^2 which means there is a decrease in colonies of microbes. The smoking process is generally expected to reduce the number of microbes. Indicates that drying and smoking

significantly reduce microbial activity in fish products, increasing food safety. The smoking process produces natural antimicrobial compounds that help inhibit bacterial growth, thereby increasing product shelf life and safety [32].

The TPC results obtained are by SNI No. 2729-2021 concerning fresh fish with a maximum limit of 5×10^6 and SNI No. 2725:2013 smoked fish with a maximum limit of 5×10^4 and the results of the TPC test of fresh lizardfish are 3.8×10^5 to 5.8×10^5 while smoked lizardfish is 5.2×10^2 to 6.3×10^2. It indicates that liquid smoke possesses antibacterial properties that are more convenient and safer to use than traditional smoke. Additionally, the tar fraction containing aromatic hydrocarbons has been removed, ensuring that liquid smoke products are free from pollutants and carcinogens [33].

4 Conclusion

The FTIR spectrum showed the presence of protein in fresh lizardfish and smoked lizardfish, and there was a slight increase in intensity in smoked lizardfish; thus can be concluded that smoking can maintain amino acid content. Lizardfish have good functional groups, texture (hardness), color, and proximate, as well as good sensory properties, therefore, Applying liquid smoke to dry-smoked lizardfish can enhance the quality of the final product.

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