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Product Quality Evaluation of Smoked Catfish Producer in Pati Regency, Jawa Tengah based on Proximate, Microbiological and Organoleptic Parameters

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ABSTRACT
Smoked catfish is one of the popular fishery products in Indonesian society. Its soft meat and easy cultivation are the reasons why catfish is chosen as the raw material for making smoked fish. This research uses a case study of one of the smoked catfish producers (Producer A) in Prawoto Village, Pati Regency, Central Java. The smoking process still uses traditional smoking. The research contributes to determine the quality level of smoked catfish products from Producer A and compare it to the quality level of benchmark product and the national standards. Quality analysis is carried out by chemical (protein, fat, moisture, and ash content), Total Plate Count (TPC) test, and organoleptic quality (the Rate-All-That-Apply (RATA) and hedonic tests). The results of the quality evaluation of Producer A product: protein content 25.21%, moisture content 55.57%, fat content 8.62%, ash content 1.39%, and for TPC is 3.7×103 CFU/g. Meanwhile, organoleptic tests on untrained consumer panelists showed that only a few parameters did not produce significantly different results. The quality parameters of product from Producer A which have higher values compared to that from Producer B are protein, moisture content, and TPC. When compared to the SNI standards, Producer A, which is the main focus, has quality parameters that meet the requirements. Producer B, as a comparison, also meets the SNI standards. Recommendations to improve product quality include using a closed smoking process, and adding salt and liquid smoke for fresh catfish.

KEYWORDS
Food safety; Proximate; Quality; Rate-all-that-apply; Sensory

1. INTRODUCTION

Product quality is an important factor that can influence consumer assessment in consuming the product. Product quality serves as a determinant for consumer satisfaction both in terms of purchasing and using the product [1]. Consumers often evaluate product quality during the selection process because if a product has better quality compared to others, consumers will choose to purchase that product [2]. For fishery products, quality evaluation is also essential to maintain consumer trust in food safety.

Fresh fishery products are commodities that are highly prone to quality degradation due to their nutritional content and improper handling. The rapid spoilage of these products is caused by the high-water content and the presence of a neutral pH, which provides an ideal environment for microbiological and biochemical spoilage [3]. Therefore, the quality of fishery products must always be evaluated to prevent the impact of quality deterioration on consumers.

The evaluation of smoked fish quality requires comprehensive assessment of multiple parameters that directly impact food safety, nutritional value, and consumer acceptance. Protein content serves as a critical nutritional indicator, as smoking processes can cause protein denaturation that affects the nutritional quality of the final product [4]. The protein level also influences the texture and binding properties of smoked fish, making it essential for quality standardization [4]. Moisture content is also particularly crucial for smoked fish as it directly affects shelf life and microbial stability [5]. Excessive moisture can promote bacterial growth and reduce stability, while insufficient moisture may result in overly dry products with poor texture and palatability [6]. The smoking process aims to achieve optimal moisture levels that balance preservation effectiveness with sensory quality. Fat content significantly influences both the nutritional profile and sensory characteristics of smoked fish. During smoking, fat undergoes oxidation and flavor development reactions that contribute to the characteristic taste and aroma of smoked products [7]. Additionally, fat content affects the absorption of smoke compounds [8] and the overall mouthfeel experienced by consumers [9]. Microbiological parameters, particularly Total Plate Count (TPC), are fundamental food safety indicators that determine the product's safety for consumption and predict shelf life. The smoking process should effectively reduce microbial load while maintaining product quality, making TPC monitoring essential for process validation and consumer protection [10]. Organoleptic parameters encompass the sensory attributes that directly determine consumer acceptance and purchasing decisions. These parameters evaluate the success of the smoking process in developing desirable aroma, taste, texture, and appearance characteristics of smoked fish products. This comprehensive approach to quality evaluation ensures that smoked fish products meet both safety requirements and consumer expectations, providing a complete assessment framework for small-scale producers seeking to improve their product quality.

Figure 1. Open smoking in Producer A.

Producer A is a small-scale smoked catfish business located in Pati Regency, Central Java, utilizing a traditional open-smoking method (Figure 1). The smoking process uses corn cobs as the smoking material. The daily production capacity is 50 kg, with each kilogram containing four catfish. The smoking procedure at Producer A begins with killing the fish, gutting and skewering them with bamboo, followed by smoking for approximately 30 minutes. A significant drawback of the open-smoking method is the production of high levels of Polycyclic Aromatic Hydrocarbons (PAHs), which are carcinogenic [11]. Therefore, a study evaluating product quality needs to be conducted at Producer A to assess the impact of traditional open-smoking methods on the quality characteristics of smoked catfish.

This study was conducted by measuring the product quality of Producer A and comparing it with the quality of smoked catfish from Producer B, which uses a closed-smoking process with a cabinet (Figure 2). Producer B has a larger production capacity and a broader market share, serving as a benchmark. This aims to identify the quality position of Producer A's products compared to those from a larger company and help establish higher quality standards [12]. The differences in Producer B's procedure include soaking fresh

catfish in brine and liquid smoke for 30 minutes before smoking. Additionally, the product quality is compared to the *Standar Nasional Indonesia (SNI)* to determine whether the products are suitable for public consumption. The data obtained from this study will be communicated to Producer A as recommendations for improving product quality and processing methods.

Figure 2. Closed smoking in Producer B

Research on the evaluation of fishery product quality has been conducted extensively. Comprehensive reviews have summarized the full range of freshness assessment methods, including sensory, physical, chemical, and microbiological approaches [13]. Another study discussed quality measurement methods for smoked fish products based on a single quality parameter [14]. Previous research primarily focused on specific aspects of quality evaluation, such as microbiology [15] and comparisons between the quality of products from traditional and modern smoking methods [16]. However, none has comprehensively evaluated all quality parameters of fishery products. Therefore, this study contributes to provide an applied method for improving the quality of fishery products for small-scale producers. The objectives of this study are: (1) To evaluate the quality of smoked catfish produced by Producer A, (2) To compare the quality of Product A with Product B and the *Standar Nasional* Indonesia (SNI).

2. MATERIALS AND METHODS

2.1. Materials

Research materials consisted of smoked catfish samples obtained from two distinct producers with different processing methods. Producer A samples were collected from a small-scale traditional smoking operation located in Prawoto Village, Pati Regency, Central Java. This producer was selected as the main subject of study due to its use of traditional open-smoking methods with corn cobs as smoking material, representing typical small-scale fishery processing in rural Indonesia. Producer B samples were obtained from a larger commercial facility located in Malang City, East Java. Producer B was chosen as the benchmark despite the geographical distance because of the scarcity of properly established smoked catfish producers with halal certification and standardized production processes in the vicinity of Pati Regency. This producer operates with closed-smoking technology, larger production capacity, broader market penetration, established quality standards, and uses modern smoking techniques including brine and liquid smoke pretreatment. Quality testing was conducted at the Integrated Laboratory of Universitas Diponegoro, Semarang City.

2.2. Sampling Methods

The sampling method followed SNI 2326:2010 guidelines for fishery products, utilizing a single-sample type approach where sampling decisions were based on production batch size. For lot sizes of 4,800 units or less, six samples were randomly selected from Producer A's production batches to ensure representative quality assessment. One sample was collected from Producer B to serve as the benchmark comparison. Only one sample was collected from Producer B due to several practical considerations: (1) the standardized production process of Producer B ensures consistent product quality with minimal batch-to-batch variation, making multiple samples less critical for representative analysis; (2) the primary research focus was on evaluating and improving Producer A's quality, with Producer B serving solely as a benchmark reference point; (3) logistical constraints related to the geographical distance between Pati Regency and Malang City made multiple sample collection costly and time-intensive. The random sampling technique was employed to minimize bias and ensure that the samples collected accurately represented the overall product quality from each producer.

2.3. Evaluation Methods

The research implemented a descriptive analysis method supported by laboratory testing, comprising three stages: determining sampling based on SNI 2326:2010, preparing smoked catfish samples from Producer A and a benchmark product, and conducting laboratory tests. Two types of samples were evaluated: six samples from Producer A as the main sample and one sample from Producer B as the benchmark. Producer B was selected as the benchmark because it operates a larger-scale production facility with closed smoking methods, broader market penetration, and established quality standards, making it suitable for comparison with the traditional small-scale Producer A. Quality evaluation adhered to SNI 2725:2013 standards for smoked fish.

2.4. Experimental Design

The research design involved comparative quality analysis between products from two producers with different smoking methods: traditional open smoking (Producer A) and closed cabinet smoking (Producer B).

2.5. Total Plate Count (TPC) Analysis

Microbiological analysis was performed using the TPC method to determine the total bacterial content in the smoked catfish samples. The TPC test was conducted in accordance with SNI 2725:2013 standards for smoked fish, with a maximum allowable limit of 5×10^4 CFU/g.

2.6. Protein Content Analysis

Protein content was determined using the Kjeldahl method. This method involves digesting the sample with sulfuric acid, followed by distillation and titration to quantify the nitrogen content, which is then converted to protein content. The minimum protein content requirement according to SNI 2725:2013 is 15.00%.

2.7. Moisture Content Analysis

Moisture content was measured using the thermogravimetric method in accordance with SNI-01-2354.2-2015. The sample was dried at a specified temperature until a constant weight was achieved, and the moisture content was calculated based on the weight loss. The maximum moisture content permitted by SNI 2725:2013 for smoked fish is 60.00%.

2.8. Fat Content Analysis

Fat content was determined by the Soxhlet extraction method following SNI 01-2354.3-2006. This method involves continuous extraction of fat from the dried sample using an organic solvent. The fat content was calculated from the weight of the extracted fat relative to the sample weight. The maximum fat content allowed by SNI 2725:2013 is 20.0%.

2.9. Ash Content Analysis

Ash content was determined using the dry ash method at 550 °C. The sample was incinerated in a muffle furnace until complete combustion of organic material, and the remaining inorganic residue was weighed to determine the ash content. The maximum ash content permitted by SNI 2725:2013 is 15.53%.

2.10. Rate-All-That-Apply (RATA) Testing

Organoleptic testing using the Rate-All-That-Apply (RATA) method involved untrained panelists (104 participants) consisting of respondents who previously bought smoked catfish products aged from 18-45 years old, with end-point anchors 1 = 'slightly applicable' and 5 = 'very applicable' [17] to evaluate sensory attributes including aroma, taste, texture, and color parameters. This method simplifies sensory attribute evaluation and enhances hedonic discrimination through greater engagement. The RATA process involved focus group discussions, panelist screening, and sample testing.

2.11. Hedonic Testing

Hedonic testing was conducted to assess overall consumer preference for the smoked catfish samples. The test used a 5-point hedonic scale where 1 = dislike very much, 2 = dislike, 3 = neutral, 4 = like, and 5 = like very much. The hedonic test was administered to the same panel of 104 untrained consumer panelists who participated in the RATA evaluation.

2.12. Data Analysis

The chemical and microbiological test results were analyzed descriptively by comparing the values obtained from Producer A and Producer B samples against the SNI 2725:2013 standards. Organoleptic results from the RATA test were analyzed using the Kruskal-Wallis non-parametric test, followed by a Multiple Comparison test to identify significant differences between the two sample groups. A significance level of $\alpha = 0.05$ was used, where asymptotic significance values <0.05 indicated statistically significant differences between samples.

3. RESULTS AND DISCUSSION

The test results will determine the quality position of Producer A's product compared to the sample from Producer B and its compliance with the *Standard Nasional Indonesia (SNI)* guidelines for smoked fish. The chemical and microbiological test results for the samples from Producer A as the main product, Producer B as the benchmark, and the SNI standards are presented in Table 1.

Table 1. The result of quality testing of smoked catfish.

Sample	Parameter				
	Protein (%)	Moisture content (%)	Fat content (%)	Ash content (%)	TPC (CFU/g)
U1	26.134	48.23	6.58	1.61	1×10^3
U2	24.129	48.99	7.48	1.27	2.2×10^3
U3	26.887	46.34	11.21	1.67	1.1×10^3
U4	24.253	59.02	10.45	1.31	1.8×10^3
U5	25.217	63.54	9.57	1.30	2.1×10^3
U6	23.797	67.24	6.44	1.21	1.4×10^4
RU	25.070	55.57	8.62	1.39	3.7×10^3
P1	23.333	44.80	17.57	3.31	2.2×10^3
SNI	Min. 15.00	Max. 60.00	Max. 20.0	Max.15.5	Max. 5×10^4

Note: U1-U6, Samples Producer A; RU, Average value of samples Producer A; P1, Samples Producer B.

3.1. Protein Content

Protein content is one of the key parameters in the proximate analysis of fish products. The protein content was tested using the Kjeldahl method. Based on Table 1, the highest protein content was found in the sample from Producer A, specifically sample U3, with a value of 26.80%. Overall, the results indicate

that the protein content of all samples meets the requirements of SNI 2725:2013. In this test, the lowest protein content was observed in the sample from Producer B, at 23.33%. This difference is attributed to variations in smoking duration, as the samples from Producer B underwent smoking for up to 8 hours, whereas samples from Producer A were smoked for only 30–45 minutes. The variation in protein content among Producer A samples (U1–U6) can be attributed to several factors related to the traditional open smoking method employed. Sample U3 showed the highest protein content (26.887%), followed by U1 (26.134%) and U5 (25.217%), while samples U6 (23.797%), U2 (24.129%), and U4 (24.253%) exhibited lower values. These differences likely result from inconsistent smoking conditions inherent in open smoking systems, including uneven heat distribution, variable exposure times to direct heat, and differences in fish positioning relative to the heat source. The traditional smoking setup at Producer A lacks precise temperature control, leading to varying degrees of protein denaturation across different samples. Additionally, variations in individual fish size and thickness may have contributed to differential heat penetration and protein modification during the smoking process.

Prolonged smoking generally increases measured protein content on a wet-weight basis due to moisture evaporation and the resulting concentration of solids [18]. However, a limitation of this study is the lack of direct comparison of the effects of different smoking methods with controlled variables for raw materials and processes. Some references suggest that differences in fish species also contribute to variations in the protein quality of smoked fish products, primarily due to differences in amino acid composition [19].

The type of smoking method significantly influences protein denaturation patterns in fish products. Open smoking methods expose fish directly to combustion smoke and uncontrolled heat sources, leading to more rapid and extensive protein denaturation compared to closed smoking systems [4]. In closed smoking chambers, controlled temperature and humidity conditions allow for more gradual protein modification, which can better preserve protein quality and nutritional value rather than traditional smoking [20], [21].

3.2. Moisture Content

The moisture content test was conducted according to SNI-01-2354.2-2015 using the thermogravimetric method. The results showed that most samples met the requirements of the *Standar Nasional Indonesia (SNI)*. The moisture content results are presented in Table 1. The sample with the lowest moisture content was P1, a sample from Producer B used as the benchmark. This outcome is likely due to the prolonged smoking process. These findings aligned with previous studies show that longer smoking durations reduce moisture content, as the heat generated during smoking causes water to evaporate, resulting in lower moisture levels in the product [22].

A reduction in moisture content extends the shelf life of smoked fish while improving texture and other quality parameters [23]. However, compared to SNI standards, some samples from Producer A (samples U5 and U6) exceeded the SNI moisture content threshold, one sample was close to the SNI limit, and three samples had moisture levels like those of Producer B's samples. These results indicate inconsistency in the quality of products from Producer A, potentially due to uneven fish sizes. This issue aligns with previous studies [24], [25], which highlighted that small-scale producers often face challenges in standardizing raw materials due to weak bargaining power with suppliers.

The differences in moisture content between open and closed smoking methods are primarily attributed to the level of process control and environmental conditions during smoking. Open smoking systems, such as those used by Producer A, expose fish to uncontrolled ambient conditions including fluctuating humidity levels, variable air circulation, and inconsistent heat distribution [21]. Conversely, closed smoking chambers provide controlled humidity and temperature conditions that enable more uniform and predictable moisture reduction [26]. Additionally, the longer smoking duration in closed systems (8 hours vs. 30–45 minutes) combined with controlled dehydration conditions contributes to the lower and more uniform moisture content observed in Producer B samples.

3.3. Fat Content

The fat content test was conducted using the Soxhlet method in accordance with SNI 01-2354.3-2006. The results, presented in Table 1, show significant differences in fat content between the main samples and the benchmark samples. The highest fat content was observed in the benchmark sample, with a value of 17.57%. The lowest fat content was found in the main sample number 6, at 6.44%, with an average fat content of 8.62% for the main samples. Despite this variation, all samples met the fat content requirements for smoked fish as specified by SNI 2725:2013, which sets a maximum limit of 20%.

The reduced fat content in the main samples is closely related to their higher moisture content. Fat and moisture content are inversely correlated [27]; lower moisture content results in higher fat content, and vice versa. The lower fat content in the main samples may also be influenced by differences in the smoking equipment used. Producer A uses a traditional stove for smoking, which generates higher heat due to the proximity of the heat source, potentially degrading the fat content in the product. In contrast, the benchmark samples were smoked using a smoking cabinet, which provides a more controlled heat source, resulting in higher fat retention [28].

The fat content levels below the SNI maximum standard (20%) indicate good quality rather than nutritional deficiency, as the SNI sets a maximum limit to prevent excessive fat content that could affect product stability and shelf life. Open smoking methods significantly impact fat retention through several mechanisms: direct exposure to high temperatures causes greater fat oxidation and thermal degradation, uncontrolled heat distribution leads to fat dripping and loss, and lack of humidity control accelerates Fat breakdown [26]. Closed smoking systems preserve fat content more effectively through controlled temperature profiles that minimize thermal stress on Fats, regulated airflow that reduces oxidative reactions, and consistent heating that prevents localized overheating and fat loss.

3.4. Ash Content

Ash content refers to the inorganic residue left after the complete combustion or oxidation of organic material in food samples [29]. The ash content test results (Table 1) for smoked catfish show that samples from Producer B had higher ash content than those from Producer A. Overall, the ash content of all product samples was significantly lower than the maximum standard set by SNI 2725:2013, which is 15.53%. This is likely due to the low mineral content in catfish meat.

Ash content correlates with the mineral composition of fish, with freshwater fish generally having lower mineral levels compared to marine fish [30]. From the findings [30], the ash content of various fresh catfish species ranged from 0.9% to 2.3%, significantly lower than some marine fish species, which can reach up to 8.71%. The higher ash content in samples from Producer B compared to Producer A can be attributed to the brine soaking process used by Producer B, which increases the mineral content in the samples [31].

The ash content levels below the SNI maximum standard (15.53%) are normal and expected for freshwater fish species like catfish, as this reflects their natural mineral composition. The SNI standard sets a maximum limit to prevent excessive mineral addition that could affect taste and quality. The significant difference between open and closed smoking methods on ash content is primarily attributed to pre-treatment processes. Producer B has standardized pre-treatment procedures including brining with salt solutions, which increases sodium and other mineral content through osmotic absorption [31]. Open smoking methods, like those used by Producer A, generally employ minimal pre-treatment, resulting in ash content that closely reflects the natural mineral composition of fresh catfish [30]. The use of liquid smoke in Producer B may also contribute additional mineral compounds, further increasing the overall ash content compared to traditional wood smoke used in Producer A [32].

3.5. TPC evaluation

The microbiological test conducted in this study was the Total Plate Count (TPC) to determine the total bacterial content in the food products. The TPC results are presented in Table 1. The findings show that all smoked catfish samples met the requirements of SNI 2725:2013. The highest TPC value was found in the main sample from Producer A, at 1.4×10^4 CFU/gram.

TPC values below the SNI standard maximum limit (5×10^4 CFU/g) indicate good microbiological quality and confirm that the smoked fish products are safe for consumption. Lower TPC values demonstrate effective microbial control during processing and appropriate hygiene practices throughout the production chain. The TPC results are significantly influenced by the smoking process, storage conditions, and the surrounding environment. Open smoking and storage processes were identified as key factors contributing to the inconsistent TPC results in the main samples. Although traditional hot smoking can achieve temperatures sufficient to reduce microbial loads, the microbiological quality of traditionally smoked fish products is often compromised by recontamination during and after processing due to poor hygiene and handling practices, including inadequate protective clothing, unhygienic processing environments, and improper product handling and storage [33]. Additionally, the microbiological content is also affected by the phenol compounds and organic acids present in liquid smoke, which were used in the benchmark samples. The combination of these compounds is highly effective in controlling microbial growth [32].

3.6. Rate-All-That-Apply (RATA)

The Focus Group Discussion (FGD) was the first stage of the RATA method, aimed at identifying sensory attributes of smoked catfish products. The details of the sensory attributes identified during the FGD are listed in Table 2. The RATA test results were analyzed using the Kruskal-Wallis method, followed by a Multiple Comparison test. Several attributes were found to differ significantly between the two samples, as shown in Figure 3.

Table 2. The results of FGD about smoked catfish attributes.

Attributes	Description
Burnt aroma	A burnt smell caused by burning
Smoky aroma	The aroma of wood smoke from a fireplace
Fatty aroma	An aroma resembling fatty food
Fishy aroma	An odor associated with stored fish
Sweet aroma	A sweet aroma in cooked food
Woody aroma	The scent of fresh or wet wood
Sour taste	A taste generally caused by the presence of organic acids
Salty taste	A taste associated with salt or sodium
Umami taste	A taste produced by compounds like MSG in solution
Sweet taste	A taste associated with sugar
Smoky taste	A characteristic taste produced by wood smoke from a fireplace
Watery texture	A slightly wet texture due to water content released from the product
Soft texture	Texture from a structure of soft tissues in a food product
Compact texture	A stiff texture or not easily detached
Sticky texture	A sticky texture from a product that has undergone spoilage
Shiny color	Shiny color in a surface of a food product due to the reflection of light
Typical smoked fish color	The product's golden-brown color

Based on Figure 3, significant differences were observed in several parameters, including: aroma (smoky, sweet), taste (salty, umami, smoky), texture (compact, sticky), and color (shiny, characteristic of smoked fish). These findings align with the previous research [34], which noted that the most prominent sensory attributes of traditionally smoked products are smoky aroma, salty taste, and shiny color. It was also emphasized that the salty taste and smoky aroma intensify with longer smoking durations [34]. Additional studies have demonstrated that smoking method variations significantly affect sensory characteristics, with closed smoking systems producing more consistent and desirable sensory profiles compared to traditional open smoking methods [34]. Research on smoked fish products has shown that controlled smoking environments enhance aroma development while reducing off-flavors associated with uncontrolled combustion [35].

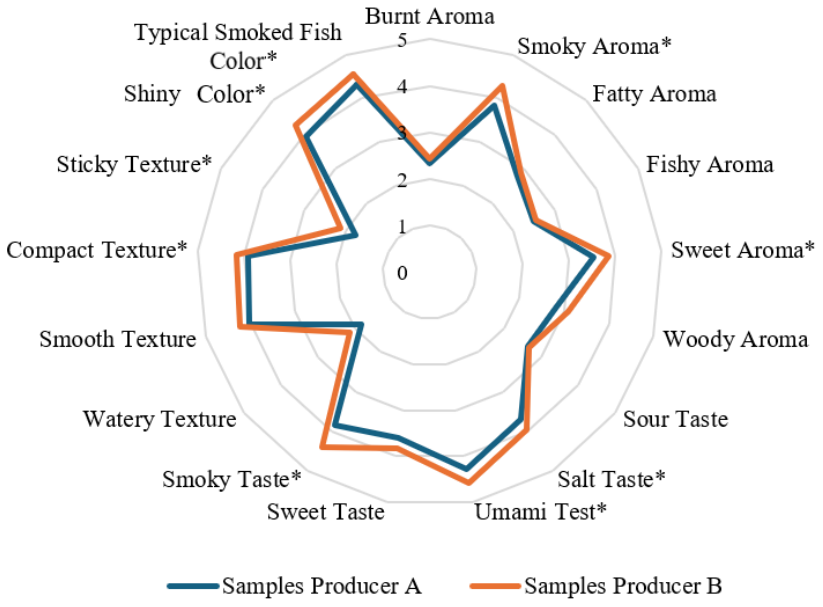

Figure 3. Smoked catfish sensory profile.
* Means significantly different, asymp. sig < 0.05.

3.6.1. Aroma

The aroma parameters identified during the FGD included burnt aroma, smoky aroma, fatty aroma, fishy aroma, sweet aroma, and woody aroma. The test results are shown in Figure 4. Based on the Kruskal-Wallis test results, all aroma parameters differed significantly between the two samples, with asymp. sig values <0.05. The hedonic scores for all aroma parameters were higher in the benchmark sample compared to the main sample (Producer A). This difference is attributed to the addition of liquid smoke in the benchmark sample, whereas no liquid smoke was added to the main sample. Previous research has shown that the aroma of smoked fish is significantly influenced by the concentration of liquid smoke applied [36]. The addition of liquid smoke enhances the aroma profile of smoked fish products, resulting in a more pronounced and appealing aroma.

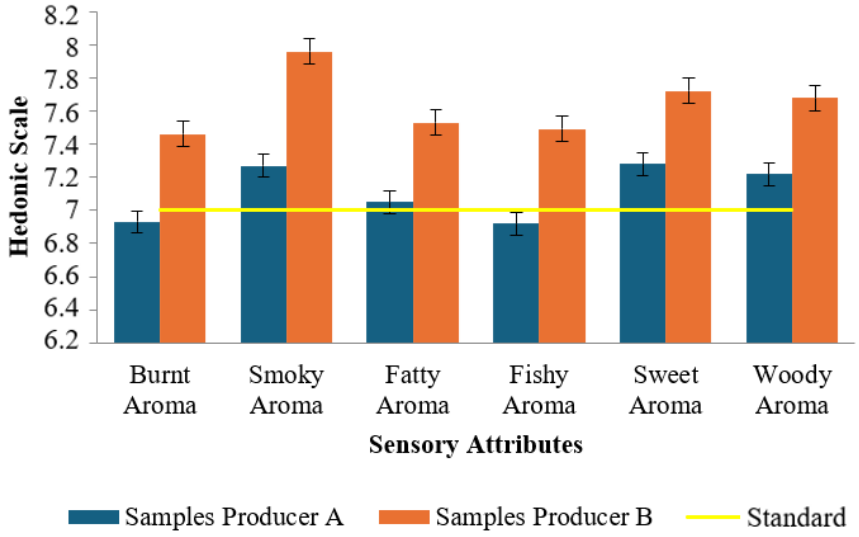

Figure 4. The results of aroma hedonic test from sample Producer A and B.

3.6.2. Taste

The taste parameters used in this study included sour, salty, umami, sweet, and smoky flavor. The test results (Figure 5) showed that all taste parameters differed significantly between the two samples. The taste scores for the main sample were consistently lower compared to the benchmark sample. The absence of added ingredients in the processing of the main sample was the primary factor influencing its lower taste scores. In contrast, the benchmark sample, which incorporated liquid smoke and salt, exhibited distinctive flavor. Similar to previous research, liquid smoke is known to act as a flavor enhancer in processed animal products [37], contributing to the unique taste profile observed in the benchmark sample.

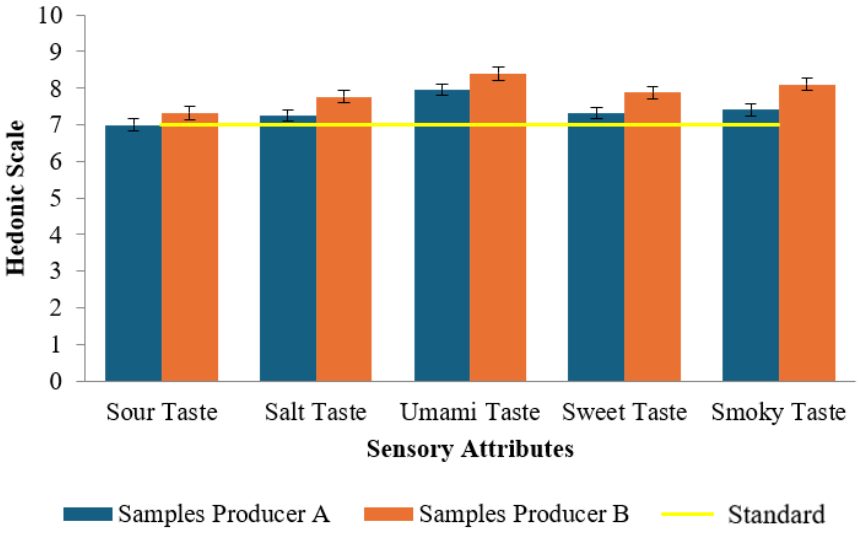

Figure 5. The results of taste hedonic test from sample Producer A and B.

3.6.3. Texture

The texture parameters used in this study of smoked catfish included watery texture, soft texture, compact texture, and sticky texture. The hedonic testing results for texture parameters showed that most parameters differed significantly between the two samples, except for sticky texture, which showed no significant difference. Overall, the results (Figure 6) indicate that the texture scores for the benchmark samples were higher than those for the main samples. Differences in the texture of smoked fish can be attributed to variations in the smoking process. Closed-chamber smoking produces a more uniform texture that is preferred by consumers compared to traditional smoking methods [35]. Additionally, the use of liquid smoke can influence the texture of smoked catfish, as it enhances texture characteristics compared to fish smoked without liquid smoke [38].

3.6.4. Color

The hedonic color test included two predetermined parameters, glossy appearance and the characteristic color of smoked fish. The results of the color test are shown in Figure 7. Statistical analysis using the Kruskal-Wallis test indicated that the two sample groups differed significantly. The smoking method played a crucial role in the hedonic color values of smoked fish. The main samples scored lower because the open-smoking method, with its closer proximity to the heat source, often resulted in a blackened appearance.

The overall quality evaluation of smoked catfish products from Producer A served as the basis for recommending improvements to the production process. This aligns with [39], who emphasized that quality improvements can be achieved by identifying process parameters, analyzing consumer responses to sensory attributes [40], and comparing products with competitors. One critical area for improvement is the moisture content. The high moisture levels in Producer A's products were attributed to the short smoking duration

[41]. Additionally, microbiological testing showed higher TPC values in the main samples compared to the benchmark, which is significantly influenced by the open-smoking process. Open smoking allows for greater contamination of the product [16]. To address this, it is recommended that Producer A adopt closed-smoking methods using a smoking cabinet, which can protect the product from external contaminants.

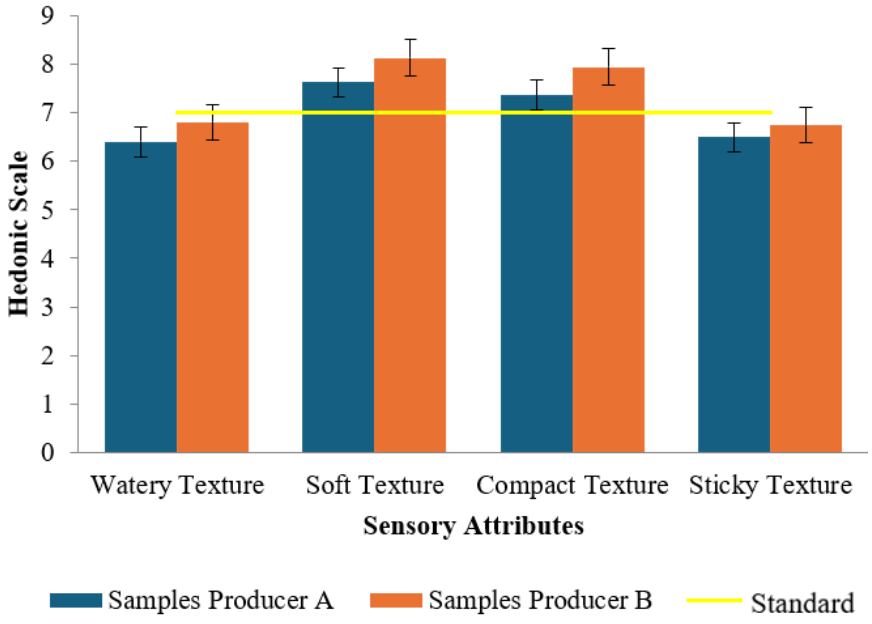

Figure 6. The results of texture hedonic test from sample Producer A and B.

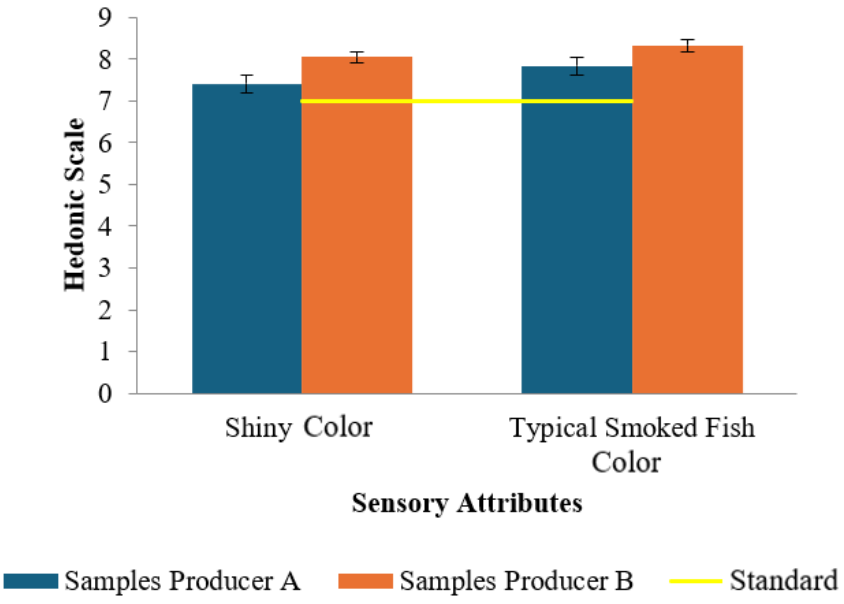

Figure 7. The results of colour hedonic test from sample Producer A and B.

Sensory testing revealed that most parameters for Producer A's samples scored lower than the benchmark samples. These findings are consistent with studies on smoked roa fish, where sensory values of products smoked using open and closed systems were compared [42]. The absence of additives, such as

salt or spices, in the smoking process contributed to the lower sensory scores. Based on these results, it is recommended that salt and spices be added to enhance sensory attributes. Furthermore, the benchmark samples showed that adding liquid smoke and salt significantly increased consumer preference, suggesting that Producer A should consider incorporating liquid smoke into their process to improve product quality and consumer appeal.

4. CONCLUSION

The comparative quality evaluation between open smoking (Producer A) and closed smoking (Producer B) methods revealed significant differences in smoked catfish quality parameters. Producer A's samples resulted in higher protein content (25.070% vs. 23.333%) and moisture content (55.57% vs. 44.80%), while Producer B's sample produced higher fat content (17.57% vs. 8.62%) and ash content (3.31% vs. 1.39%). Microbiological testing showed that Producer A had a higher average TPC of 3.7×10^3 CFU/g compared to Producer B's 2.2×10^3 CFU/g, indicating that open smoking methods may allow greater microbial contamination due to uncontrolled environmental exposure. Organoleptic evaluation revealed that closed smoking methods significantly outperformed open smoking in most sensory parameters, with only sticky texture showing no significant difference between samples. The controlled environment of closed smoking, combined with pre-treatment processes such as brining and liquid smoke application, resulted in enhanced consumer acceptability and more consistent product quality. The findings of this study are beneficial for business operators, as they can evaluate their product quality based on the tested parameters and their compliance with government standards. Additionally, producers can use the quality test results to implement recommendations for improving their production processes, thereby enhancing product quality and aligning it with consumer preferences.

AUTHOR CONTRIBUTION

All authors contributed equally to the main contributor to this paper. All authors read and approved the final paper. **Tian Nur Ma'rifat**: Conceptualization, writing (original draft), and funding acquisition. **Erik Musafi'in**: Investigation and field observation. **Hefti Salis Yufidasari**: Writing (review & editing) and formal analysis. **Bayu Kusuma**: Writing (review & editing), and formal analysis. **Angga Wira Perdana**: Investigation and data curation. **Ahmad Syihab Fahmi Q.R.M**.: Investigation and data curation. **Arief Rahmawan**: Validation. **Savaminee Teerawut**: Supervision.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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