Estimation of Shelf Life of Sambal Payangka Fish (*Ophiocara porocephala*) Using Different Types of Packaging with Accelerated Shelf-Life Testing (ASLT) Method

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ABSTRACT

Payangka fish sambal, made from payangka fish, the one endemic fish from Gorontalo. This research aims to use the Accelerated Shelf-Life Test (ASLT) method with the Arrhenius model to measure shelf life of sambal. This method includes treating several types of packaging: plastic bottles (A1), glass bottles (A2), and standing pouches with aluminum foil (A3). The quality assessment was carried out using peroxide and organoleptic levels, as well as aroma. During three days of storage, a decrease in the quality was observed at temperatures of 35 °C, 45 °C, and 55 °C, with observations made every twenty-four hours. The results showed that the peroxide levels increased during storage, ranging from 2.53-4.12 $mEqO_2$/kg for plastic packaging, 2.33-3.18 $mEqO_2$/kg, for glass bottles, and 2.40-3.86 $mEqO_2$/kg for standing pouches with aluminum foil. Additionally, the organoleptic test for payangka fish aroma showed a decrease in panelist ratings, ranging from better to worse. The Arrhenius model calculations showed that peroxide levels are important in determining shelf life of payangka fish sambal. When tested at room temperature (25 °C - 30 °C), payanga fish sambal stored in glass bottles exhibited a relatively longer shelf life. Specifically, at a temperature of 25 °C, shelf life ranged from 68 days to 48 days at 30 °C.

Keywords: Arrhenius; payangka fish; sauce; shelf life

INTRODUCTION

Payangka is the most dominant fish in Lake Limboto, Gorontalo, which has two scientific names, including *Ophieleotris aporos* (Haryono, 2004) and *Ophiocara porocephala* (Suryandari & Krismono, 2006) During storage, payangka fish containing fish often experience a decline in microbiological quality, and this is shown through the proliferation of bacteria. Additionally, chemical damage, such as acidification, and sensory alterations, including changes in aroma or odor contribute to quality degradation. Diminished quality leads to customer dissatisfaction and reduces shelf life of payangka fish sambal, underscoring its implications for food safety (Afandi, et al. 2020).

Due to the short shelf life of payangka fish, it is used for making different products, such as payangka sambal. Payangka sambal is usually produced in MSME. In MSME, the method is used to determine shelf life entails storing the product in these plastic bottles at room temperature until signs of spoilages occurs. The spoilage of payangka fish sambal becomes visible through the development of a rancid odor, serving as the indicator for determining its shelf life, although this

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method is less accurate and time-consuming. During storage, food products undergo physical and chemical changes, leading to degradation in quality and taste. Therefore, it is important to know the expiration date of food products to ensure they are safe for consumption. This is related to the safety of a product, which must be showed by the manufacturer on the product label as stipulated in Law No. 18 of 2012 concerning food and Government Regulation No. 69 of 1999 concerning Labels and Advertising.

Various methods can be used to estimate shelf life, and for sambal products, the Accelerated Shelf Life Test (ASLT) method using the Arrhenius Model is often used. This approach accelerates shelf life by subjecting the product to elevated temperature. In the ASLT method, products are stored under normal conditions at extreme temperatures to elevate the rate of product deterioration. The Arrhenius method is commonly applied to perishable products exposed to extreme temperatures, such as food products prone to rancidity, protein denaturation, and non-enzymatic browning (Maillard reaction) (Asiah et al., 2018). Research on shelf life estimation of various products has been extensively conducted, including fruit nori (Hasany, et al. 2017), stingray sambal (Afandi, et al. 2020), wedang uwuh (a traditional Javanese herbal drink originating from Indonesia) powder (Ijayanti, 2020), and virgin coconut oil (Calligaris et al. 2022). Since different food composition affect the shelf life of the product, therefore the shelf life of payangka sambal is importance to be determined as one representative of food high in protein and fat. In addition the type of packaging also affect the shelflife due to the difference in oxygen transmission rate, moisture barrier properties, and barrier of light. Therefore, this research was aimed to determine the optimal storage and packaging lifespan for payangka fish sambal using plastic and glass bottles, as well as standing pouches with aluminum foil packaging through the ASLT method with the Arrhenius model.

METHODS

Materials

The materials used are payangka fish, purchased from fishermen, the main ingredient used in the production of payangka fish sambal. Other ingredients include shallots, bird's eye chilies, tomatoes, coconut oil (Bimoli), salt (Refina), and powdered broth (Royco). Meanwhile, packaging materials include glass bottles, standing pouches (a combination of aluminum foil and plastic), and PET plastic bottles. The materials used in the peroxide number analysis include glacial acetic acid, chloroform, saturated KI solution, distilled water, starch, iodine, and standard sodium thiosulfate solution ($Na_2S_2O_3$) 0.01 N, all the materials purchased from Sigma Aldrich.

The equipment used in the preparation of payangka fish sambal includes a baking tray, a chopper (Phillips), a tablespoon, a stove, a frying pan, a spatula, and a knife. The equipment used in the peroxide number analysis includes measuring cups, Erlenmeyer flasks, burettes, analytical balances, spatulas, micropipettes, magnetic stirrers, and hotplate stirrers.

Method

Payangka fish sambal products are packaged in plastic bottles, glass bottles, and standing pouches with aluminum foil. The ASLT method was implemented by storing the products in the incubators with three different temperatures: 35°C±2; 45°C±2; and 55°C±2. Shelf life determination was performed using the Arrhenius equation, which was then processed using Microsoft Excel software. Subsequently, the data resulting from the Arrhenius equation was plotted on a graph showing the relationship between time (x-axis) and the average of each parameter at different storage temperature (y-axis) (Affandi et al., 2020). Additionally, peroxide number analysis and organoleptic (aroma) analysis were conducted daily for three consecutive days.

Nutritional Content of Fresh Payangka Fish

In two different locations, the nutritional content of fresh Payangka fish was examined. The ash and protein content were tested at the Gorontalo Fisheries Product Testing and Quality Application Center (BPMHP), while the moisture and fat content were tested at the Chemistry Laboratory of the Department of Food Science and Technology, Gorontalo State University. The dry ashing method, gravimetric method, carbohydrate analysis by difference method, protein analysis by Micro-Kjedahl method, and fat analysis by Soxhlet method were used to measure the content.

Organoleptic Test (Kadir, 2021)

The organoleptic test was conducted three times, on the first, second, and third days. The quality assessment of payangka fish sambal included sensory organoleptic observations of aroma for each treatment, with subjective observations of sambal using a hedonic scale ranging from 1 to 7. The scoring criteria were: 1 = very poor, 2 = poor, 3 = somewhat poor, 4 = neutral, 5 = somewhat good, 6 = good, 7 = very good, and this was assessed using evaluation sheets. The assessment was carried out by a group of 15 trained panelists. Moreover, critical quality parameters were established through the evaluation conducted by these trained panelists. The selection, training, and focus group discussions (FGD) of these panelists were meticulously conducted to ensure reliability and accuracy in the assessment process.

Measurement of Initial Quality Indicators and Critical Damage Limits of Payangka Fish Sambal (Kadir, 2021)

To determine the initial quality indicators of payangka fish sambal, subjective observations on the first day were used to establish the panelists assessment scores of the product. Meanwhile, the critical quality of payangka fish sambal was determined by considering factors that experience rapid deterioration and have the most significant effect on consumer acceptance. To simulate the deterioration of payangka fish sambal, it was stored at an extreme temperature of 55°C until it reached a point where it was no longer organoleptically acceptable. Following this, FGD was conducted to establish important quality parameters. The critical limit, the point at which the product is no longer sensorially acceptable, was determined. Important limits for organoleptic sensory parameters were established by examining how panelists scored the product.

Peroxide Number (Jemaa, et al. 2017)

The peroxide number was analyzed using iodometry. In an Erlenmeyer flask, 5 g of sample was added and mixed with 30 mL of a solvent mixture of glacial acetic acid: chloroform (3:2 v/v). After the sample completely dissolved, 0.5 mL of saturated KI solution was added and homogenized by shaking for 1 minute, and then, 30 mL of distilled water was added. A standard solution of sodium thiosulfate (Na2S2O3) 0.01 N with starch indicator was titrated until the blue color disappeared. The formula for calculating the peroxide number is as follows (Equation 1).

$$\text{Peroxide Number} = \frac{(\text{S}-\text{B}) \text{ x N x } 1000}{\text{Sample weight (g)}} \quad (1)$$

where: S = sample titration (mL), B = blank titration (mL), and N = normality of $Na_2S_2O_3$.

Shelf Life Estimation (Liviawaty, et al. 2021)

The rate of quality deterioration at zero and first orders forms the basis for calculating expiration dates or estimating shelf life. The Arrhenius equations used are as follows (Equations 2 and 3).

$$\text{Zero order: } t = \frac{(Qt-Q0)}{K} \quad (2)$$

$$\text{First order: } t = \frac{\ln(\frac{Qt}{Q0})}{K} \quad (3)$$

where: t = shelf life, Q0 = initial quality value, Qt = Critical limit/final quality limit, and K = reaction rate constant.

RESULTS AND DISCUSSION

Nutritional Content of Payangka Fish (Preliminary Data)

Preliminary research was conducted to determine the nutritional content of payangka fish, and this was carried out due to the lack of research data on its nutritional content. Based on the results of nutritional content testing conducted on payangka fish, the data is presented in Table 1.

The Table 1 shows that in the nutritional content testing of 100 g of fresh payangka fish, the contents of moisture are 45.39% (w.b.), fat is 14.72% (w.b.), protein is 21.16% (w.b.), ash is 1.61% (w.b.), and carbohydrate is 16.82% (w.b.).

Decrease in Aroma Quality of Payangka Fish Sambal

This research aimed to identify the deterioration of payangka fish sambal products, with a specific focus on the aroma attribute, which is considered one of the primary factors contributing to product deterioration. During storage, the aroma attribute of payangka fish sambal decreased, shifting towards a more rotten smell. According to Affandi et al. (2020), the rotten smell in payangka fish sambal products is caused by microbial activity, and there is also a rancid aroma caused by oil oxidation in sambal. The aroma parameter holds significant importance in evaluating payangka fish sambal products. The aroma values for this product during storage are presented in Figure 1.

The aroma quality scores of payangka fish sambal during storage are presented in Figure 1, showing that the average scores for each packaging experienced a decrease in aroma quality during storage. In plastic bottle packaging (A1), the scores ranged from 6.5 to 2.2, showing a decline from good to poor. Similarly, in glass bottle packaging (A2), there was a decrease in aroma quality ranging from 6.3 to 3.9, showing a decline from good to somewhat poor. The standing pouch with aluminum foil packaging also experienced a decrease in aroma quality ranging from 6.4 to 2.5, showing a decline from good to poor.

The decline in panelists ratings observed with prolonged storage of payangka fish sambal in each packaging can be primarily attributed to the development of an unpleasant aroma. The unpleasant smell that arised during storage is suspected to be

Table 1. Proximate content per 100 g of payangka fish

Proximate content	Fresh payangka fish
Moisture content (% w.b.)	45.39
Fat content (% w.b.)	14.72
Protein content (% w.b.)	21.46
Ash content (% w.b.)	1.61
Carbohydrate content (% w.b.)	16.82

Source: Primary data (2022).

caused by microbial activity and oxidation reactions in the oil and fat, leading to rancidity in the product. The degradation of fats and oils due to oxidation is characterized by the emergence of flavors, flatness, or oiliness, followed by changes in taste and aroma that occur naturally. Undesirable odors and musty smells develop. In the final stage, a rancid odor arises, and the taste becomes bitter due to the formation of peroxide compounds from secondary reactions of oxidation processes (Hasibuan & Meilano, 2018). This research is in line with the results of Affandi et al. (2020), which reported a decrease in aroma quality in glass-packaged stingray fish sambal, with a foul odor attributed to microbial activity and oxidation reactions. Furthermore, Afdillah et al. (2018) reported a decrease in the quality of shredded mackerel fish caused by microbial growth, which increased during storage and with rising storage temperatures. Fardiaz (1992) also stated that factors influencing microbial growth include temperature, pressure, air, and processing factors.

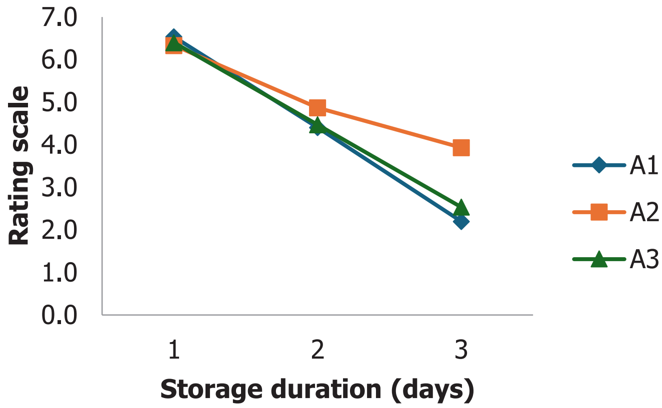

Figure 1. Aroma quality of payangka fish sambal packed in plastic bottle (A1), glass bottle (A2), and standing pouch (A3) and storage at 55 °C.

Peroxide Number

Peroxide formation is one of the primary factors contributing to the deterioration of payangka fish sambal. The formation of short-chain compounds such as aldehydes, lactones, and acrolein, resulting from the breakdown of unsaturated fatty acids, leads to unpleasant odors, flavors, and rancidity in the oil (Yeniza & Asmara, 2019). The changes in peroxide number values of payangka fish sambal during storage are presented in Table 2.

Kinetics of The Degradation Rate of Payangka Fish Sambal Quality Concerning Peroxide Number Parameter

The kinetics of quality degradation can be observed through the increase in peroxide number. The selection

Table 2. Changes in peroxide number values ($mEqO_2/kg$) of payangka fish sambal in each packaging during storage

Treatment	Temperature	Day 1	Day 2	Day 3
A1	35	1.67±0.31	1.73±0.23	2.07±0.31
	45	2.40±0.20	2.8±0.21	3.26±0.11
	55	2.53±0.11	3.26±0.12	4.12±0.12
A2	35	1.53±0.11	1.60±0.20	1.66±0.12
	45	2.26±0.23	2.46±0.12	2.73±0.12
	55	2.33±0.31	2.66±0.12	3.18±0.12
A3	35	1.60±0.20	1.66±0.12	2.00±0.20
	45	2.33±0.12	2.66±0.12	2.99±0.20
	55	2.4±0.20	3.06±0.12	3.86±0.11

Note:
*This data is the average result of 3 repetitions.
*A1 = plastic bottle packaging, A2 = glass bottle packaging, and A3 = standing pouch aluminum foil packaging.

of reaction order was conducted by comparing R^2 in the linear regression of zero-order and first-order reactions at each storage temperature (Affandi et al., 2020). The reaction order (R^2)closer to 1 was selected, hence the first-order reaction was selected. Subsequently, the data was further processed with the Arrhenius plot to determine the product's shelf life.

The reaction order of peroxide number increased as an indicator of quality decline in each packaging. This was projected by plotting time (x) versus peroxide score (y) into zero-order and first-order graphs, resulting in linear regression equations and R^2 in Table 3. The k value or slope of the first-order reaction was used to determine the Arrhenius equation because it has a high R^2 or close to 1. Peroxides were formed due to the oxidation of fats, both contained in payangka fish and the oil used in payangka fish sambal product. This is in line with Labuza (1982) cited in Sucipta et al (2017) where examples of degradation types classified under first-order reactions include: vitamins, rancidity (in salad and vegetable oils), microbial-induced spoilage, flavor deviation by microbes (in poultry, meat, and fish), protein content reduction, and more.

The Arrhenius equation is obtained by using the slope value of the first-order linear regression equation, which represents the rate constant (k). This can be achieved by plotting the value of 1/T for the x-axis and ln k for the y-axis, where T is the storage temperature used in Kelvin units. The degradation of quality based on the peroxide number of payangka fish sambal in plastic bottle packaging, glass bottle packaging, and standing pouch aluminum foil packaging is presented in the Arrhenius equation graph (Figure 2).

Shelf Life Estimation Of Payangka Fish Sambal

The ASLT Arrhenius model requires initial quality and critical limit data as well as the rate constant (K). The initial quality is known to be 2 $mEqO_2$/kg showing that the peroxide quality of the product has not exceeded the standard of 10 $mEqO_2$/kg. The rate constant (K) data are obtained from each extreme temperature. namely 35 °C. 45°C. and 55 °C. The Arrhenius model equation used to estimate shelf life of payangka fish sambal is as follows: Table 5 shows the rate constant (K) required to estimate shelf life of payangka fish sambal at room temperature 30 °C and 25 °C (Equation 4).

$$\text{First order: } t = \frac{\ln(\frac{Qt}{Q0})}{K} \quad (4)$$

where:
t = shelf life; Q0 = initial quality value; Qt = final critical limit value; and K= ate constant.

Based on the analysis of shelf life of payangka fish sambal based on peroxide values using the Arrhenius method, payangka fish sambal shelf life using glass bottle packaging at room temperature (30 °C and 25 °C) ranges from 48 days to 68 days, while with plastic bottle packaging at room temperature (30°C and 25°C) ranges from 19 days to 25 days. This research shows a longer shelf life of payangka fish sambal compared to Afandi et al. (2020), which reported shelf life of stingray sambal for

Table 3. Linear regression equations of the degradation of peroxide number quality of payangka fish sambal and their coefficients of determination (R^2)

Packaging	Temperature	Slope		R^2	
		zero order	first order	zero order	first order
	35 °C	y = 0.066x	y = 0.0416x	0.9976	0.9962
A1	45 °C	y = 0.228x	y = 0.0925x	0.9912	0.9958
	55 °C	y = 0.406x	y = 0.1509x	0.9803	0.9913
A2	35 °C	y = 0.172x	y = 0.0966x	0.8315	0.8438
	45 °C	y = 0.33x	y = 0.1263x	1	0.9985
	55 °C	y = 0.716x	y = 0.2387x	0.9963	0.9998
A3	35 °C	y = 0.172x	y= 0.0929x	0.8315	0.8433
	45 °C	y = 0.424x	y = 0.1533x	0.9981	1
	55 °C	y = 0.782x	y = 0.2458x	0.9973	0.9994

Note:
*A1 = plastic bottle packaging, A2 = glass bottle packaging, and A3 = standing pouch aluminum foil packaging.

only 197.96 hours (7 days) with glass bottle packaging. In another research, Hasibuan (2020), investigation into the protective properties and migration tendencies of packaging materials in vegetable oil packaging showed notable differences. Specifically, compared to glass bottles, plastic bottles containing olive oil, sunflower oil, and palm oil exhibited significant peroxide values (PV) and thiobarbituric acid (TBA) levels. According to Rosmawati dkk. (2020), glass bottle packaging exhibits inert properties, indicating that it reacts slowly to chemicals and

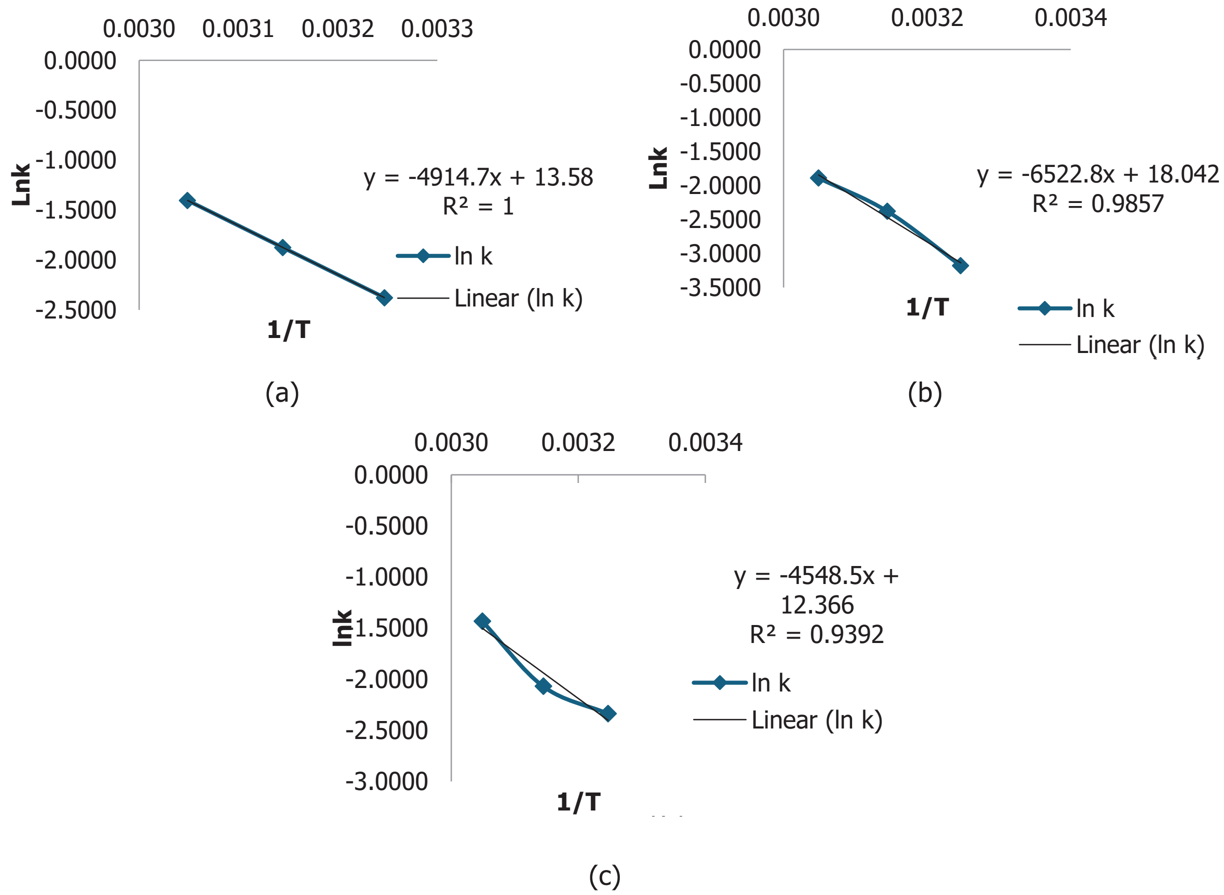

Figure 2. The Arrhenius equation graph of peroxide number quality degradation in each packaging (a) plastic bottle, (b) glass bottle, (c) standing pouch aluminum foil

Table 4. The Arrhenius equations and activation energy (Ea) for the peroxide number parameter of payangka fish sambal in each packaging

Packaging	Parameter	Equation	R^2	Slope	Ea (J/g mol.K)
A1	Peroxide	y = -6522.8x + 18.042	0.9857	6522.8	54230.56
A2	Peroxide	y = -4548.5x + 12.366	0.9392	4548.5	37816.23
Peroxide	Peroxide	y = -4914.7x + 13.58	1	4914.7	40860.82

A1 = plastic bottle. A2 = glass bottle. and A3 = standing pouch aluminum foil.

does not cause contamination to the packaged product. Meanwhile, based on the research, shelf life in plastic and standing pouch packaging is not significantly different. In the context of standing pouch aluminum foil packaging with room temperature application (30 °C and 25 °C), shelf life ranges from 20 days to 26 days. However, plastic bottle packaging presents a significantly different shelf life, withstanding pouch aluminum foil packaging

Table 5. Estimation of shelf life of payangka fish sambal in packed in plastic bottle (A1), glass bottle (A2), and standing pouch (A3)

Packaging	Value of K for 30 °C	Value of K for 25 °C	Shelf life for 30 °C	Shelf life for 25 °C
A1	0.0306	0.0214	48 days	68 days
A2	0.0710	0.0552	20 days	26 days
A3	0.0714	0.0544	19 days	25 days

at room temperature (30 °C and 25 °C) ranging from 19 days to 25 days. This is because aluminum foil and plastic bottles have pores or cavities on the surface that allow water vapor absorption. In other words, glass bottles and plastic bottle packaging are more water vapor-resistant than aluminum standing pouch packaging. These results are consistent with Sunoto (2006) that packaging system greatly determines shelf life due to the different barrier and permeability characteristics of each packaging.

When comparing payangka fish products with bonito fish floss products at 30 °C based on the Arrhenius model calculations at order one, shelf life of sambal stored in aluminum foil packaging is estimated to be 116 days based on TBA analysis, and 194 days in glass bottle packaging. Based on research, shelf life of payangka fish sambal products at 30°C, according to the Arrhenius model calculations (order one), is 20 days in aluminum foil packaging and 48 days in glass bottle packaging. Shelf life of bonito fish floss products in each packaging is longer compared to payangka fish sambal products, presumably due to the high-fat content in fresh payangka fish (14.72%), which contributes to quality deterioration based on peroxide parameters, resulting in a decreased shelf life. This is consistent with Silvana (2012), who stated that fish have easily oxidizable lipids because they predominantly consist of long-chain unsaturated fatty acids such as EPA, and DHA, commonly known as omega-6 and omega-3. Vulnerable fatty acids undergo oxidation, resulting in hydroperoxides and other breakdown products such as aldehydes, ketones, and alcohols, leading to quality deterioration in fish.

CONCLUSION

In conclusion, this research showed that payangka fish sambal stored in glass bottle packaging had the best aroma quality and peroxide number quality on the same day and at temperature during storage. The glass bottle packaging arised as the best packaging for storing payangka fish sambal, with shelf life at room temperature of 30 °C for 48 days and 25 °C for 68 days.

CONFLICT OF INTEREST

The authors declare no conflicts of interest related to the results of this study.

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